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Criteria for choice in Research and Development Evaluation in Sri Lanka

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Criteria for choice in R & D Evaluation in Sri Lanka

The evolution of the concept of choice has taken many years. In the early years the choice of a subject for research was an individual's own intellectual curiosity. The reputation of the scientist depending on the merit of his research work soon became the consideration for financial support from academic and scientific societies. Later it became necessary to seek government funds for science and technology research. With the increasing demand for such funds the concept of choice became necessary with emphasis on the systematic use of scientific knowledge to attain definite economic and social goals.

The criteria for choice then became necessary. The criteria must be defined, understood, and whenever possible, readily applicable to the selection of research proposals.

Choices have to be made to ensure a fair and equitable distribution of limited R & D funds between the various (1) fields of science, (2) institutions.

Within the field of science we accept two categories (1) Basic science, (2) Applied science. Although in many areas the distinction between the two is not always clear it is a useful guide in the selection process.

In the developing countries, it is imperative to distribute limited resources to areas of scientific research which help in the development process. Hence — science for development - becomes the most important criterion for choice. Basic science will therefore take a second place. As it is often academic, research in this field will be more or less confined to the universities.

The next criterion will be the necessity for research training for scientists. The shortage of scientific manpower hampers the research effort and the development of the country. Therefore, a research proposal should aim at training one or more assistants in research methodology leading to a masters or doctorate degree. In Sri Lanka, we have adopted a policy where science for development and research training are the important criteria in the selection process.

The Natural Resources, Energy and Science Authority attempts to achieve this by establishing a "peer review" mechanism to evaluate project proposals and to monitor and assess the research work done on the grants awarded from time to time.

Working Committees — There are ten working Committees to cover the fields — Natural Resources, Energy, Physical and Engineering Sciences, Chemical Sciences, Biological Sciences, Medical and Veterinary Sciences, Agriculture and Animal Husbandry, Science Education, Science Information, Social Sciences.

The members of these Committees are senior experts in their fields of research. In addition, one or two members from a related field are included. This ensures the elimination of a narrow parochial viewpoint so that a research proposal may be judged from a larger perspective of its relevance to the rest of science.

Research Grants Scheme — Research proposals are invited through the national newspapers about the middle of each year and the awards are made by December so that work may commence in January of each year.

The major beneficiaries of this scheme are the Universities. Since research in the Universities is not related to any specific national programme, but is largely the outcome of self-motivation, rather flexible criteria have been set out for selection of projects.

Evaluation of projects — The criteria may be summarized as follows:

1. Relevance to short-term national development;
2. Contribution to the stimulation of university teaching as a means of achieving broad based, long-term, national development;
3. Multidisciplinary nature, particularly in respect of important national problems requiring scientific collaboration of several public sector institutions;
4. Uniqueness arising out of conditions special to Sri Lanka;
5. The availability of a suitable supervisor in the case of young applicants with little or no research experience.
6. Possibility of obtaining a research degree (M.Sc., Ph.D., M.D.) as the basis of research carried out in Sri Lanka;
7. Re-orientation of scientists who have returned after protracted stays abroad;
8. Previous research carried out locally, and the performance with research grants awarded by the former National Science Council or Natural Resources, Energy & Science Authority (NARESA).

Monitoring of research projects — Monitoring of programmes of research in all research organizations and sponsoring agencies, is through periodic progress reports. NARESA requests half-yearly and final reports.

Criteria for assessment of progress reports are again flexible. The Working Committees generally look for evidence in respect of quantity and quality of work performed within the period under review in relation to the total volume of work expected to be carried out within a programmed time scale.

Majority of the projects supported by NARESA are exploratory in nature, and not specifically problem-oriented. Hence each project in effect is only a phase in the study of a bigger field of investigation. Although research sponsorship has to be considered an investment in projects of this nature (the research output) could hardly be quantified in clear monetary terms. Therefore unlike problem-oriented research programmes, or projects which carry an element of commercial or national profitability, these research activities are not amenable to evaluation procedures such as the social cost-benefit analysis.

When scientific research in any form is financed and carried out by a research institution, the net benefits can sometimes be evaluated as the "Net Added Value" to the institution. However, when a sponsoring agency such as NARESA or any other research council funds a programme of research, the net gains are not fully enjoyed by the sponsoring agency. In such cases the gains are distributed among the principal investigator, his research assistants, and the institution in which such research work was carried out. However, if the sponsoring agency is a state institution, then the total value added is a national gain, and hence may be assessed in the context of national profitability.

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Crop Response to Methods of Surface Water Distribution

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Abstract: Comparative studies of irrigation methods in relation to crop response was carried out in 1973-1974. Of the two methods of irrigation evaluated, zig-zag furrow method gave well marked yield responses compared to standard furrows. The yields obtained under this method of irrigation was well marked in high moisture response crops. Another feature observed in zig-zag furrows was that the yields in different sections of the furrows are more uniform compared to standard furrows.

1. Introduction

The irrigation methods can be broadly classified into three types:- viz. Surface irrigation, Sub-surface irrigation and Overhead irrigation. Surface irrigation may be either flood irrigation or furrow irrigation. The latter in turn is of the following sub-types:

i. **Standard furrows:** Where the water front advances along the direction of the grade.

ii. **Zig-zag furrows:** Where the water front advances alternately along and against the grade and where the exact geometry of the furrow zig-zags usually tends to depend on the slope, gradient and the spacing of the crop.

iii. **Corrugations:** Where the water front advances down the natural slope in furrows which are invariably less than 200 ft in length.

iv. **Improved corrugations:** Where the water front advances down the natural slope in carefully shaped up furrows along the complete length of the field (even if the field is several miles long) with the use of gated pipes.

The present study is concerned with the standard furrow method and the zig-zag furrow method and is an attempt to evaluate certain aspects of the relative irrigation efficiency of the two methods.

The standard furrow method, which in fact is widespread in Sri Lanka, involves comparative disadvantages such as high labour requirements and low efficiency of water use. It could also contribute to excessive soil erosion and loss

of irrigation water through run-off. The zig-zag furrow method, on the other hand, which is less frequent in occurrence in Sri Lanka and, where it occurs, is largely confined to irrigating perennial crops, possesses the advantages of low labour inputs and greater efficiency in water use. The lack of popularity of the zig-zag method in the country is probably due to the fact that it is alien to conventional practices of surface irrigation.

In Sri Lanka, emphasis on irrigated highland cultivation originated with the irrigation projects, developed in the recent past. Uda Walawe, one of such projects, where 63,000 acres of rolling land with natural slopes of 2.5 - 3.5 percent is developed to a grade of 0.5 percent. In this project with the limited availability of water, irrigation was carried out in rotational basis using standard furrows widely. The above combination always results in considerable reduction of crop yield due to improper irrigation and high labour requirements. Therefore the feasibility of adopting zig-zag method, to suit the cultivation of annual crops under the existing "Land System" was examined because of its low labour requirements. This method also facilitates increased water application per unit area of land.

It is the author's contention that the principal significance of the present study lies in the fact that increasing attention is being paid to the production of subsidiary field crops (ie. crops other than paddy) under irrigated conditions in the Dry Zone of Sri Lanka and the consequent need to determine the effects of the different types of irrigation possible upon crop yields. The crops selected for the experiment—Cotton, Chillies and Soyabeans—are among the major crops currently recommended in the programmes of diversification of irrigated agriculture in Sri Lanka.

2. Materials and Methods

The experiments upon which this paper is based, were conducted at the Research Centre, Eraminiyaya, Angunukolapellessa, and were commenced in the Maha season of 1972/73 and were continued in the Yala season of 1973 and 1974.

Results of the study of Maha 1972/73, confined to chilli and cotton provided preliminary evidence that the zig-zag furrow method is superior, in both yield and crop performance, to the standard furrow method. They also indicated that, in the former method, 20 ft furrow segments were superior to longer furrow segments.

Based on this preliminary findings, a more comprehensive comparative study of the two methods was undertaken, once again with chillies and cotton, during the Yala season of 1973, in an experiment laid out in a split-plot design in sub plots of 400 sq ft, replicated three times having methods of irrigation as the main treatment and the three stream sizes, 10 g.p.m., 15 g.p.m. and 20 g.p.m. as the sub treatments (see Figure 7). During the Yala season of 1974, the experiment was repeated

with soyabeans. This was also conducted in split-plot design and was replicated 5 times, with variation in the method of irrigation as the main treatment and variation in stream size as the sub-treatment.

In the experiments of 1973 and 1974, the total length of furrow was fixed at 200 ft. The ridges were spaced 2 ft apart with an average height of 8 inches. The furrow segments were 20 ft in length. The crop spacings were 2′ × 1′ for cotton and chilli and 2′ × 3′ for soyabeans.

Soil conditions at the location of the experiments were as follows:

Soil series	:	Ranna Series of Reddish Brown Earths.
Soil structure	:	Sub-angular blocky.
Soil texture	:	Sandy clay loam.
Drainage condition	:	Well drained.
Organic matter	:	Low.
Steady state infiltration rate	:	1.5″ per hour.
Water holding capacity	:	1.5″ per foot.
Grade in feet	:	0.5 percent
Natural slope in feet	:	2.5 percent

The crop management and plant care were carried out in accordance with the standard recommendations of the Department of Agriculture. The irrigation frequencies were fixed at once in four days, five days, and seven days for soyabeans, chillies, and cotton respectively. The irrigation was carried out as per treatment throughout the crop season and the time to irrigate each treatment was recorded. At harvest, the yield data were taken, dividing the full length of the furrow into four sections of 50′ each. This was for the purpose of comparing yields along the different sections of the furrow.

3. Results

The results of the experiments are presented in Tables 1, 2 and 3 and are illustrated graphically in Figures 1 to 5. In overall terms, the results make it clear that the significant variations in the crop responses correlate only with variations of the main treatment (zig-zag method vs standard furrow method) and not with differences in the sub-treatment (ie. stream size).

The data tabulated in Table 1 show that, under the zig-zag furrow method while overall yield levels were significantly higher than under the standard furrow

TABLE 1. Mean yields in pounds per acre and deviation of yields from the mean value in different sections of furrow

Method of Irrigation	*Crop*	*Stream Size*	*Mean Yield*	*SECTION OF FURROW* 1'-50'	50'-100'	100'-150'	150'-200'	*Total Deviation*
Zig-zag Furrows	Cotton	10 g.p.m	2624.84	+270.09	—83.85	+42.80	—299.04	±312.89
		15 g.p.m.	2763.92	+348.86	—147.98	—123.16	—77.72	±348.86
		20 g.p.m	2684.09	+274.36	—52.41	—24.39	—197.56	±274.36
Standard Furrows		10 g.p.m	2284.58	—52.20	—106.72	—333.45	+492.37	±492.37
		15 g.p.m	2359.46	+217.03	+299.51	+18.84	—535.38	±535.38
		20 g.p.m	2347.94	+11.34	+20.64	+241.14	—273.12	±273.12
Zig-zag Furrows	Chilli	10 g.p.m	2205.77	—2.81	+56.19	—25.59	—27.79	±56.19
		15 g.p.m	2113.90	+202.46	+141.24	—60.68	—283.02	±343.70
		20 g.p.m	2023.15	—160.53	+63.93	+184.52	—87.92	±248.45
Standard Furrows		10 g.p.m	1537.60	+84.56	+309.76	—65.24	—328.08	±393.32
		15 g.p.m	1505.72	+454.02	—186.51	—285.05	—17.54	±471.56
		20 g.p.m	1199.70	—342.11	+7.27	+262.99	+71.85	±342.11
Zig-zag Furrows	Soyabean	10 g.p.m	2161.24	+224.60	—156.54	+20.42	—47.64	±224.60
		15 g.p.m	2654.44	—122.51	—68.06	+176.96	+13.61	±190.57
		20 g.p.m	2314.13	—	—108.88	—81.68	+190.56	±190.56
Standard Furrows		10 g.p.m	1817.27	—183.70	+6.80	+306.22	—129.32	±313.02
		15 g.p.m	1892.14	+40.84	—204.19	—258.64	+421.99	±462.83
		20 g.p.m	2123.55	+27.22	+27.14	—272.25	—217.89	±272.25

L.S.D. for irrigation means i) Cotton 240.8 lbs/acre
ii) Chilli 496.2 lbs/acre
iii) Soyabean 157.9 lbs/acre

Coefficient of Variation i) Cotton 9.46%
ii) Chilli 27.7%
iii) Soyabean 22.85%

TABLE 2. Showing the yield under zig-zag method as a percentage of yield under standard method

Method of Irrigation	*Stream Size*	*Crop*	*Mean Yield/Acre in lbs*	*Yield under zig-zag method as % of Yield under standard method*
Standard Furrows	10 g.p.m	Cotton	2284.58	
Zig-zag Furrows	10 g.p.m	Cotton	2624.84	114.90
Standard Furrows	15 g.p.m	Cotton	2359.46	
Zig-zag Furrows	15. g.p.m	Cotton	2763.92	117.10
Standard Furrows	20 g.p.m	Cotton	2347.94	
Zig-zag Furrows	20 g.p.m	Cotton	2684.09	114.30
Standard Furrows	10 g.p.m	Chilli	1537.60	
Zig-zag Furrows	10 g.p.m	Chilli	2205.77	143.40
Standard Furrows	15 g.p.m	Chilli	1505.72	
Zig-zag Furrows	15 g.p.m	Chilli	2113.90	140.30
Standard Furrows	20 g.p.m.	Chilli	1199.70	
Zig-zag Furrows	20 g.p.m	Chilli	2023.15	168.60
Standard Furrows	10 g.p.m	Soyabean	1817.27	
Zig-zag Furrows	10 g.p.m	Soyabean	2661.24	146.20
Standard Furrows	15 g.p.m	Soyabean	1892.14	
Zig-zag Furrows	15 g.p.m	Soyabean	2654.44	140.30
Standard Furrows	20 g.p.m	Soyabean	2123.55	
Zig-zag Furrows	20 g.p.m	Soyabean	2314.18	109.00

TABLE 3. The time of irrigation, total quantity of irrigation water received and the yield/per acre foot of applied water under different treatments

Method of irrigation	*Crop*	*Stream size*	*Time taken to reach the end of furrow in minutes*	*Quantity of water/irrigation/acre in inches*	*Total No. of irrigations*	*Rain fall*	*Total qty. of water received in inches*	*Yield/acre foot or water in lbs.*
Zig-zag furrow	Chilli	10 g.p.m	21	1.01	13	9.36	22.49	98.07
		15 g.p.m	16	1.16	13	9.36	24.44	86.49
		20 g.p.m	15	1.45	13	9.36	28.21	71.70
Standard furrow		10 g.p.m	17.5	0.85	13	9.36	20.41	75.37
		15 g.p.m	13.5	0.98	13	9.36	22.10	68.12
		20 g.p.m	12.5	1.21	13	9.36	25.09	47.79
Zig-zag furrow	Cotton	10 g.p.m	42	2.03	7	9.36	23.57	111.36
		15 g.p.m	31	2.28	7	9.36	25.11	110.07
		20 g.p.m	22	2.13	7	9.36	24.27	110.59
Standard furrow		10 g.p.m	29.5	1.43	7	9.36	19.37	117.94
		15 g.p.m	23.0	1.66	7	9.36	20.98	112.35
		20 g.p.m	16.0	1.54	7	9.36	20.14	116.63
Zig-zag furrow	Soyabean	10 g.p.m	31	1.50	13	5.75	25.25	105.39
		15 g.p.m	29	2.10	13	5.75	33.05	80.19
		20 g.p.m	25	2.42	13	5.75	37.21	62.19
Standard furrow		10 g.p.m	26	1.26	13	5.75	28.37	64.05
		15 g.p.m	19	1.38	13	5.75	23.69	79.87
		20 g.p.m	16	1.54	13	5.75	25.77	82.40

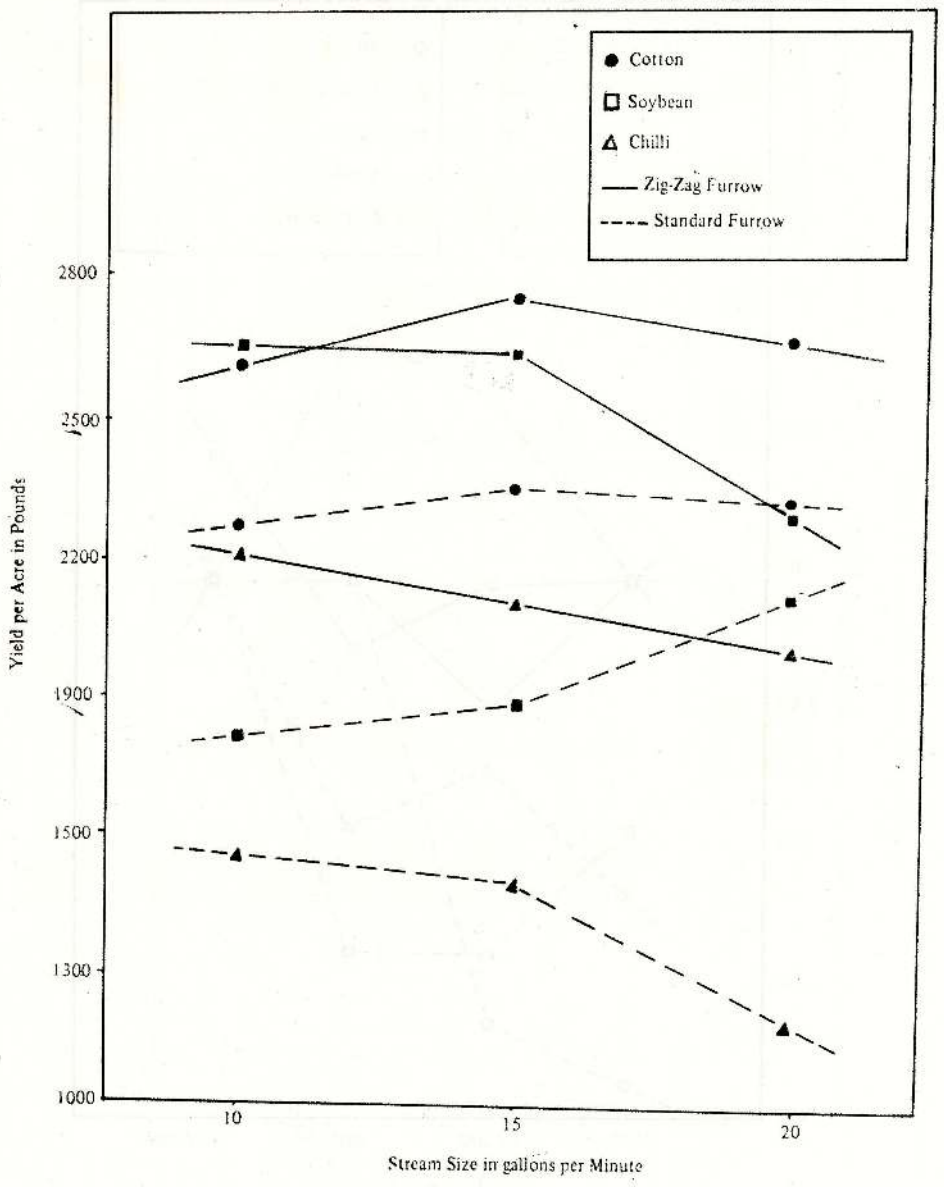

Figure 1. Mean per acre crop yields.

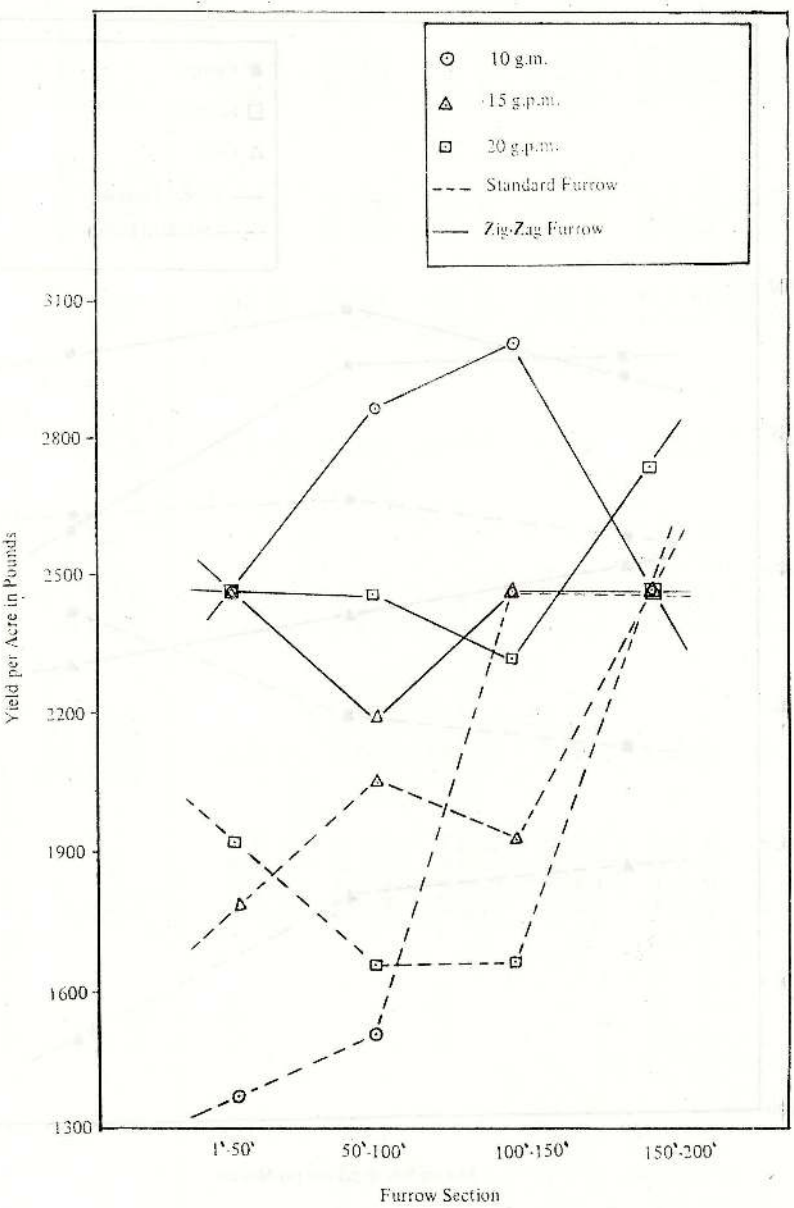

Figure 2. Yield variation in different sections of furrow - Soybean.

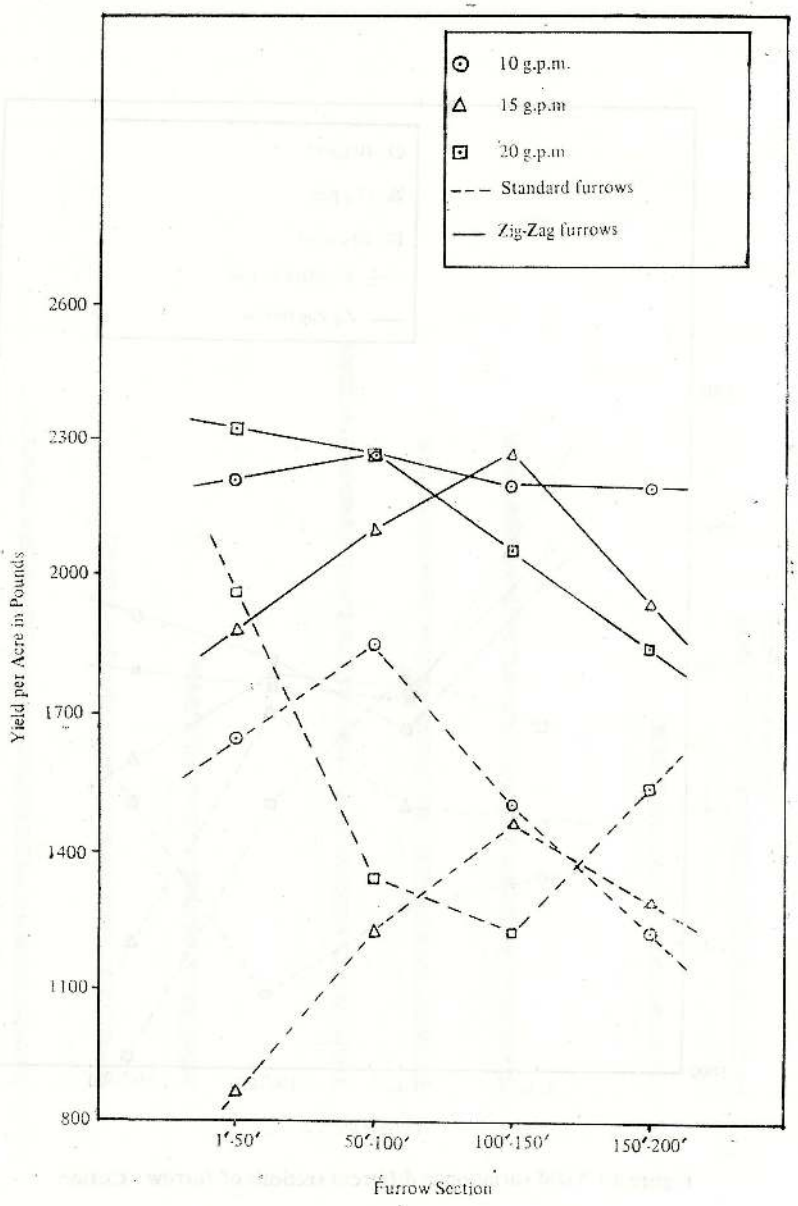

Figure 3 - Yield variation in different sections of furrow Chilli

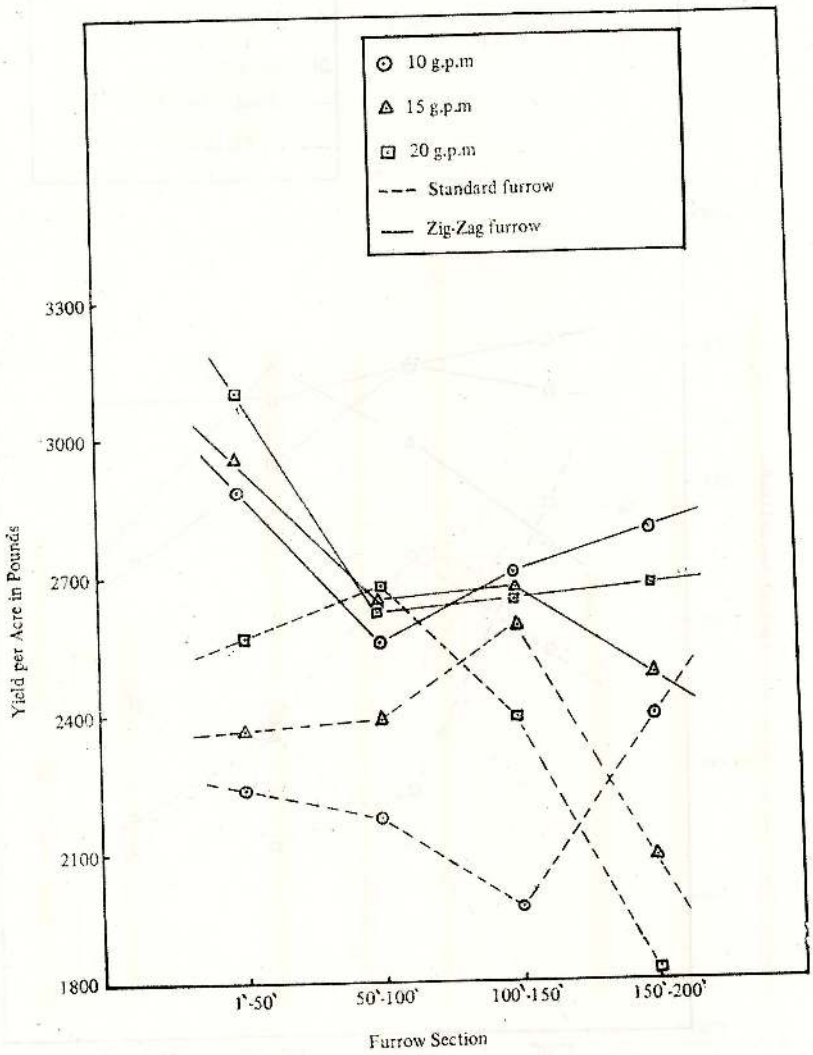

Figure 4 - Yield variation in different sections of furrow - Cotton

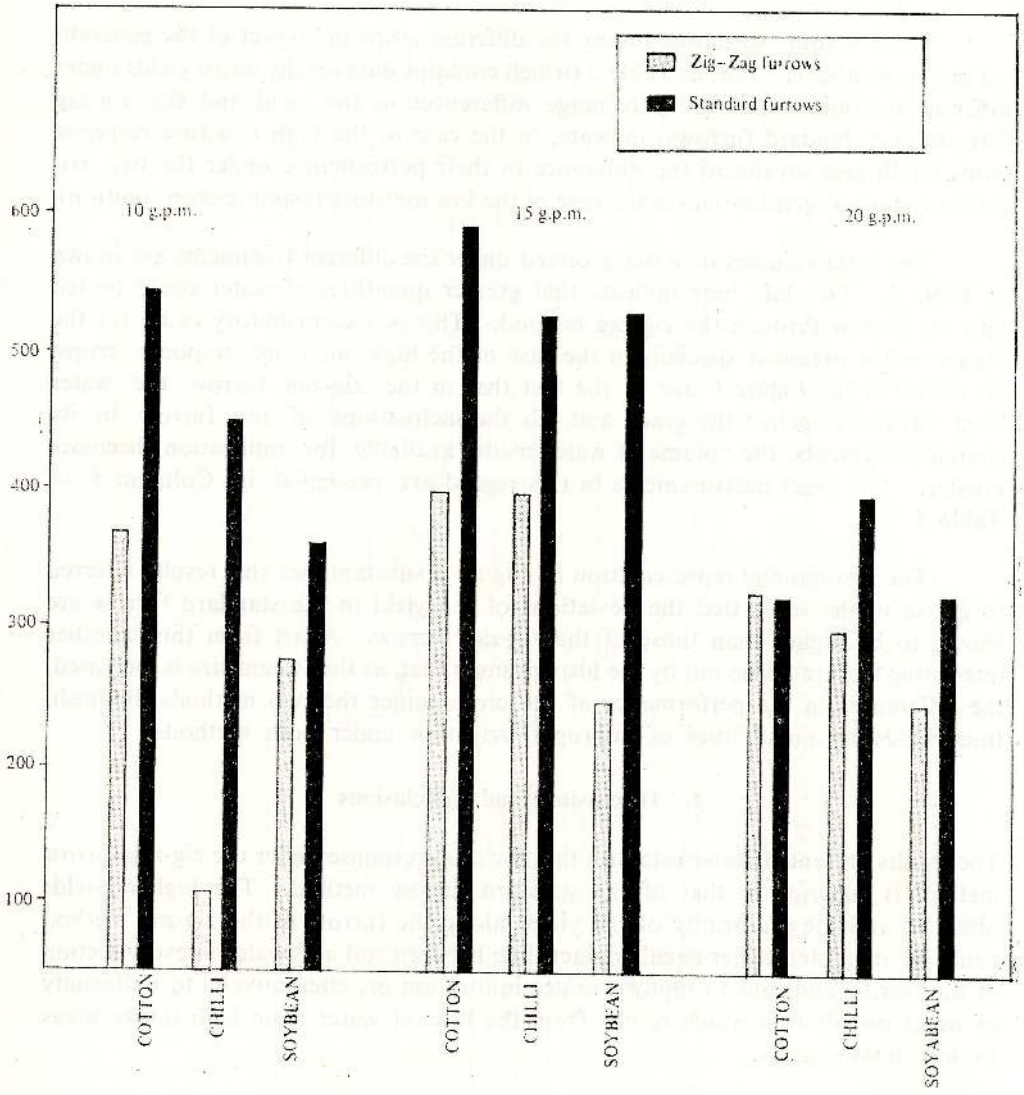

Figure. 5 Total deviations from mean in different treatments

method, the yields obtained in different sections of the furrow were also more uniform (see Figure I). It should further be noted (Columns 5 - 8, Table 1) that the deviations of yield in different segments of the furrow from the mean yield are greater in the standard furrow method than in the zig-zag method.

There is some variation among the different crops in respect of the generalizations made above. For, as Table 2 (which contains data on the mean yields under different treatments and the percentage differences in the yield and the zig-zag furrows and standard furrows) indicate, in the case of the high moisture response crops (chilli and soyabean) the difference in their performance under the two irrigation systems is greater than in the case of the low moisture response crop (cotton).

The total volumes of water received under the different treatments are shown in Table 3. The data here indicate that greater quantities of water could be fed into the furrow through the zig-zag method. This is a contributory cause for the higher yields obtained specially in the case of the high moisture response crops. As shown in the Figure 6 due to the fact that in the zig-zag furrow the water front advances against the grade and fills the inclinations of the furrow in its alternate segments, the volume of water made available for infiltration becomes greater. The exact measurements in this regard are presented in Column 5 of Table 3.

The histogramic representation of Figure 5 substantiates the results referred to above in the sense that the deviations of the yield in the standard furrow are shown to be higher than those of the zig-zag furrow. Apart from this, another interesting feature borne out by the histograms is that, as the stream size is increased, the differences in the performance of the crops under the two methods diminish, thus indicating possibilities of improper irrigation under both methods.

4. Discussions and Conclusions

The results presented above establish that the crop response under the zig-zag furrow method is superior to that of the standard furrow method. The higher yields obtained and the uniformity of the yields along the furrow of the zig-zag method could be attributed either equal contact time between soil and water in every section of the furrow and thus to uniform water infiltration or, alternatively, to uniformity of water distribution which results from the flow of water from high intake areas to low intake areas.

The cause of water front advancement in zig-zag furrows is shown in Figure 6. As stated earlier, in this method the water has to advance against the grade in alternate furrow segments, filling the inclination of the furrow. This process obviously permits a longer contact time and facilitates the infiltration of a greater

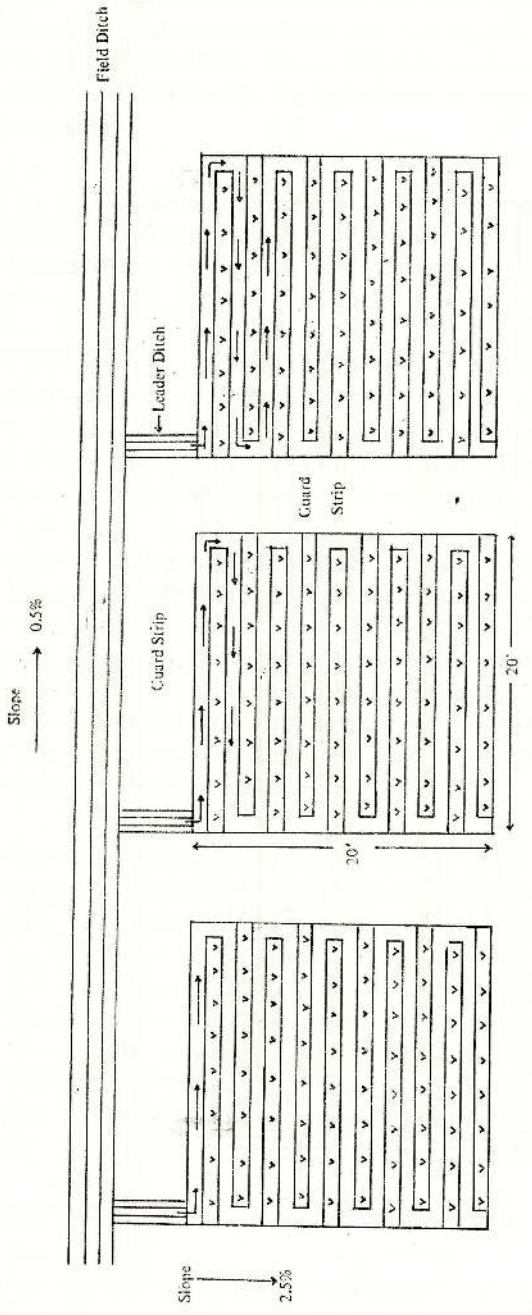

PLATE 1. - Diagrametic representation of water front advancement in Zig-Zag Furrows.

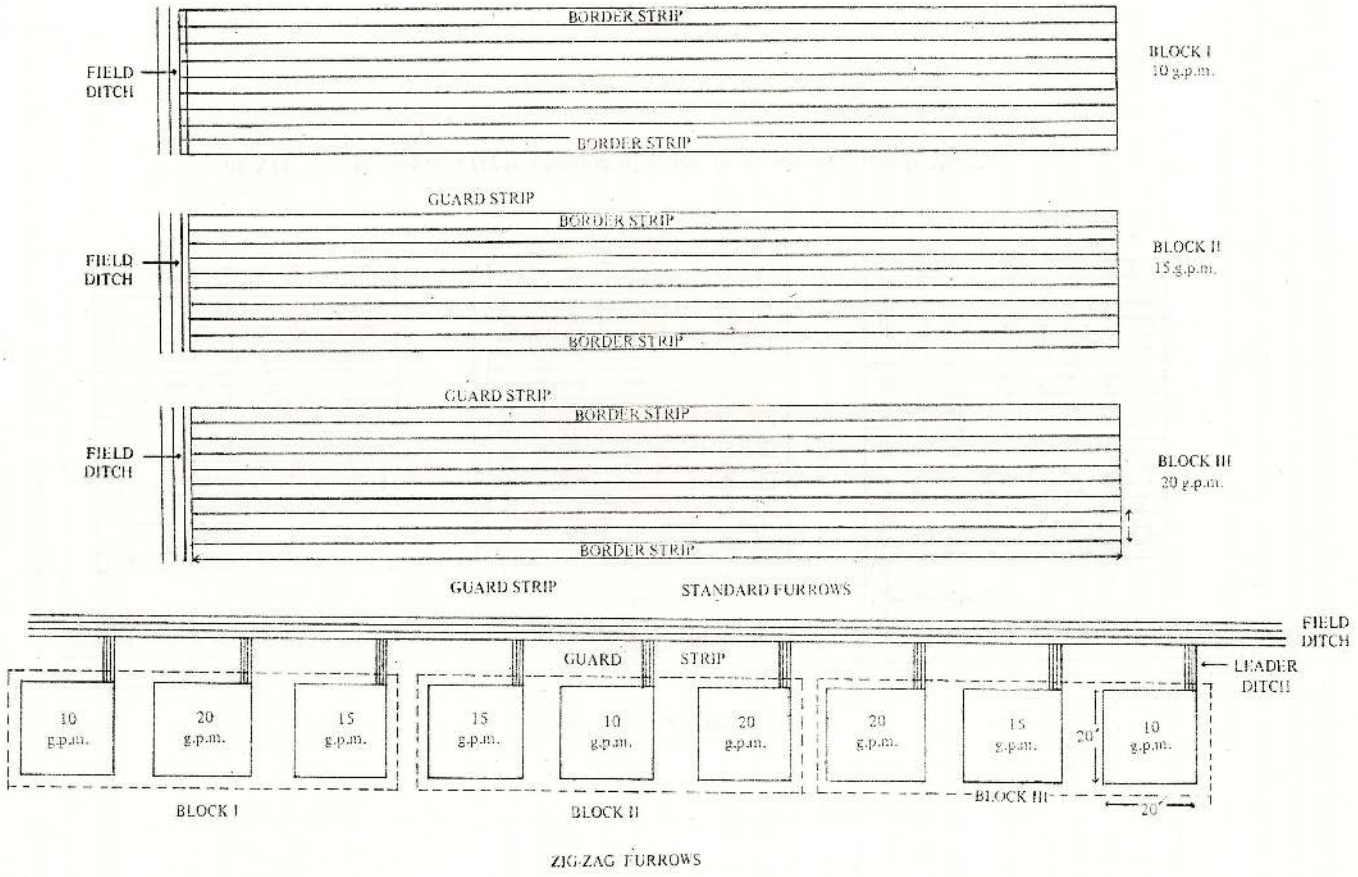

PLATE II. Diagrametic Representation of Field layout of Experiment - Cotton

volume of water. In standard furrows, on the other hand, the water front does not change direction once the water is let into the furrow. Furthermore, here the total quantity of water fed into the furrow depends on stream size, length of furrow and grade of the furrow. Normally, the water tends to gush down the grade lowering the infiltration time.

One of the economic implications of adopting the practice of zig-zag furrow method, as mentioned before, is the low labour input inherent to its large scale application. Provided the availability of water is not a limiting factor, irrigation under this method could be carried out simultaneously in a number of zig-zag furrows, either by siphoning from field ditches or by supplying water through buried pipes. The time required for irrigating all zig-zag furrows is the time needed to irrigate one zig-zag furrow, depending, of course, on variables such as stream size and soil conditions. In contrast, under the standard furrow method, water supply to each furrow has to be carried out consecutively, which process obviously requires more labour and more time.

Yet another advantage of the zig-zag furrow method of irrigation is that it facilitates a substantial reduction of uneven irrigation, which in fact, is an error factor even in experimental plots. Water supply in the furrows, either through buried pipes or by siphoning enables uniform irrigation, provided the land preparation is done uniformly. Furthermore, since the zig-zag furrow method permits greater contact time between soil and water, it overcomes the problems of the "sealing effect" (ie. the formation of an impermeable soil crust on the furrow bed) which characteristically inhibits infiltration of water.

The foregoing discussion leads us to the conclusion that in respect of the principal criteria which should be considered in the choice of irrigation technique, the zig-zag furrow is superior to the standard furrow method. The latter is, of course, the more widespread in the cultivation of highland crops, at present, even though it entails a series of problems such as over-irrigation and/or under-irrigation, higher labour inputs and lower infiltration of water to the soil. In practical application by the farmers, the standard furrow method also involves other problems that relate to difficulties of estimating the optimum length of the furrow and the size of the stream. The overall beneficial effect of the zig-zag furrow method of irrigation appears more pronounced in the case of high moisture response crops.

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Variations in some Nutritional Status Indicators among Students in the University of Colombo

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Abstract: Data related to socio-economic status and some indicators of nutritional status were obtained from 769 students who gained admission to the four faculties in the University of Colombo in 1981. The nutritional status indicators studied were height, weight, weight for height, haemoglobin concentration and age at menarche. Students from different faculties differed markedly in their socio-economic background, as well as in their nutritional status. The students from the Faculty of Medicine, a larger proportion of whom were from higher socio-economic groupings had better anthropometric parameters, lower prevalence of anaemia and a lower mean age at menarche compared to the students from the other faculties, the worse affected being students from the Faculty of Arts. The high prevalence of anaemia observed among this apparently healthy young adults was of special significance.

1. Introduction

In Sri Lanka, students from varied socio-economic backgrounds gain entry to the University, due to the free education policy adopted by successive governments. University students occupy an important position in a society, being the group from which the future intelligentsia of the country emerge.

The earliest information on the health and nutritional status of the university students is available from the study by Bibile *et al* [2], according to which tropical parasitic disorders (48%) and malnutrition (17%) dominated the clinical picture. Wickramanayake[10] in his study on university students who were resident in the hostels, observed that the calorie intake among the male students were below the 'recommended allowance' whereas for the females, the intake was higher.

Recent surveys on nutritional status carried out in Sri Lanka have identified the prevalence of protein calorie malnutrition among pre-school children and school children to be considerably high.[7,8]

Information related to some nutritional status indicators among an important young adult population such as university students would be most useful. This study was planned to obtain such data with a view to identifying the socio-economic characteristics influencing these indicators.

2. Methodology

The study population were the students who entered the University of Colombo in 1981 (769). They entered the four Faculties of Medicine (189), Science (141) Law (66) and Arts (373). The nutritional status indicators that were identified for purposes of this study had to be limited to those that are practicable with minimum resources i.e. measurements of height and weight, assessment of haemoglobin level. Assessment of the age at menarche was also carried out, as this is considered as a population indicator of nutritional status.[1]

Personal and socio-economic information related to each student was obtained by using an interviewer administeree questionnaire which was pre-coded. Two nursing sisters at the Health Centre, University of Colombo were trained in administering the questionnaire. Reliability checks were done by one of the authors (RGXP). Age at menarche was also obtained during the interview.

Anthropometric measurements carried out were height and weight. Height was measured in centimetres using a sliding scale calibrated vertically and recordings were made to the nearest 0.1 cm. All students were weighed wearing light clothing without shoes, using a platform beam balance. Weight was recorded to the nearest 0.1 kg. Two trained investigators were responsible for making all the measurements. Instruments were standardised at regular intervals. One of the authors (RGXP) was responsible for repeating the measurements on a random sample of the study population.

Haemoglobin estimation was done by the oxyhaemoglobin method using a photoelectric colorimeter, for which blood samples were obtained from the students.

3. Results

All 769 students who entered the four faculties in the University of Colombo were included in the study. There were no refusals. The study population comprised of 50.8% males and 40.2% females and their mean ages were 22.6 years and 22.06 years respectively. The subjects were divided according to the 'faculty' to which they gained entry. This sub-division into 4 groups has been used for comparison of the identified indicators as it has been observed that the socio-economic backgrounds of students differ among the faculties.

Two criteria were adopted to assess the socio-economic status of the study population, i.e. monthly income of the family and occupation of head of the family. Distribution of family income per month among students showed well marked inter-faculty differences (Table 1).

TABLE 1. Distribution of study population by family income

Faculty	*Family income in Rs. per month*					
	300	*301-500*	*501-1000*	*1001-1500*	*1500*	*Total*
Medicine	10	15	34	60	70	189
Science	9	16	34	24	57	140
Law	27	11	7	4	17	66
Arts	228	72	52	16	5	373
All Faculties	274	114	127	104	149	768

No information — 1

Two income categories 'high' and 'low' were identified. Low income was defined as a total family income of Rs 1000 and less per month and 'high' income as more than Rs. 1001 per month. On considering the total study population, 67% belonged to the 'low' income group. It is observed that the proportion of students belonging to the 'low' income group was as high as 94% among the students from the Faculty of Arts compared to 31.2% among those in the Faculty of Medicine (Table 2).

TABLE 2. Income distribution by faculty

Faculty	*% within the income group*		
	Low	*High*	*Total*
Medicine	31.2	68.8	100 %
Science	42.1	57.8	99.9 %
Law	68.2	31.8	100 %
Arts	94.4	5.6	100 %
All Faculties	67%	33%	100%

On application of significance tests, highly significant differences (18 standard deviations) from the media were obtained when tested against the alternative that income decreases as one proceeds in the order of faculties - Medicine, Science,

Law and Arts. The level of significance is too high and leads to the suspicion that the lowest incomes were underestimates, perhaps to qualify for student loans and bursaries.

Social class was determined according to the occupation of the head of the family, which was classified into one of the following five categories:-

i. Professional

ii. Executives, Managers, etc.

iii. Skilled employment

iv. Semi-skilled workers

v. Unemployed.

In order to make a clearer distinction among "social classes" thus identified, categories I and II were combined to form Group I and categories III, IV & V were combined to form Group II. A marked inter-faculty difference is observed as shown in Table 3.

TABLE 3. Social class distribution by faculty

Faculty	*Social Class*				*Total*	
	Group I		*Group II*			
	No.	*%*	*No.*	*%*	*No.*	*%*
Medicine	143	75.6%	46	24.3%	189	100%
Science	34	24.1%	107	75.8%	141	100%
Law	13	19.1%	53	80.3%	66	100%
Arts	12	3.2%	361	96.8%	373	100%
All Faculties	202	26.3%	567	73.7%	769	100%

75.6% of medical students belonged to Group I, the comparable figure for arts students being 3.2%. The difference observed was highly significant showing that the proportion of professionals and executives as head of the family decreased as one proceeds in the order of faculties - Medicine, Science, Law and Arts.

Average weight and height values of the study population are given in Table 4, according to the faculties and for the sexes separately.

TABLE 4. Mean height and weight of the study population according to faculties (Sexes separate)

Faculty	*Sex*	*Number*	*Height in cms.* Mean %	S.D.	*Weight in Kg.* Mean %	S.D.
Medicine	M	98	168.4	6.6	51.8	6.9
	F	91	157.8	5.3	44.03	5.6
Science	M	87	166.9	5.0	50.69	7.1
	F	54	154.5	5.8	42.9	5.8
Law	M	36	164.4	5.2	42.9	5.4
	F	30	155.4	6.2	44.4	4.7
Arts	M	170	163.8	5.8	49.01	6.0
	F	203	152.7	5.4	42.8	5.5

For males, there was a significant difference for mean height and for mean weight between medical and arts students using tests for multiple comparisons ($p < 0.01$) by both the Tukey and the Bonferroni methods (medical greater than arts). Among females, the difference was significant in respect of height ($p < 0.01$) but not for weight.

In an adult population, assessment of nutritional status based on height or weight alone may not be adequate and indices based on weight/height ratios have been used.[5] Weight as a percentage of standard weight for his/her height was calculated for each student and comparisons were made with the weight for height data given in the ICNND tables of USA.[4] (There are no reference tables for anthropometric data for adults in Sri Lanka).

The study population was divided into 5 groups according to their percentage deviation from the weight/height standard, i.e. ICNND tables. In these tables 100% was the "ideal" weight for a given height for American adults and it was observed that very high proportion of the study population were shorter and lighter than the Americans, hence it was decided to adopt the following classification—

Group I— Students below 70% of the weight for height

" II— Students below 70-74% of the weight for height

" III— Students below 75-79% of the weight for height

" IV— Students below 80-84% of the weight for height

" V— Students below more than 84% of the weight for height

Tables 5 and 6 shows the distribution of the study population by the 'nutritional group' (sexes separately).

TABLE 5. Distribution of Male Population by weight as a Percentage of the Standard Weight for a given Height*

Nutritional Groups	*155*	*—158*	*—161*	*—164*	*—167*	*—170*	*—173*	*—176*	*—179*	*179*	*Total*	*%*
						Height in cms.						
I 70%	4	6	5	5	10	10	3	2	2	1	48	12.3%
II 70-74%	1	7	11	18	20	14	14	9	4	1	99	25.4%
III 75-79%	3	7	10	23	20	16	10	8	3	2	102	26.2%
IV 80-84%	0	3	7	13	11	15	9	4	3	1	66	17.0%
V 85%	2	3	8	9	11	13	12	9	3	2	71	18.4%
Total No.	10	26	41	68	72	68	48	32	15	7	388	100%

TABLE 6. Distribution of the Female Population by Weight as a Percentage of the Standard Weight for a given Height*

Nutritional Groups	Height in cms. 145	—148	—157	—154	—157	—160	—163	—166	—169	169	Total	%
I 70%	0	4	7	3	7	3	5	0	1	0	30	8.0%
II 70-74%	0	4	5	11	16	7	8	8	4	0	63	17.0%
III 75-80%	2	8	12	13	10	9	5	6	2	0	67	18.0%
IV 80-84%	5	8	8	15	12	16	6	3	1	2	76	20.0%
V 85%	8	8	18	26	31	24	13	5	1	1	135	36.3%
Total No.	15	32	50	68	76	59	37	22	9	3	371	100%

*Derived from the ICNND tables as a standard of reference

Number of students not included 7
Number of students with a height < 140 cms. 5
Number of students with a height > 169 cms. 2

The pattern observed was different for the two sexes. The proportion of male students in Group V (18.4%) is lower than that of females (36.3%). Among the females, there was a shift of the table to the left and downwards compared to the males. The shift to the left imply that the Sri Lankan females studied are shorter than the American female by a larger amount than the male. The shift downwards implies that even though the females are 'short' in stature, for a majority of them their weight in relation to their height was 84% or more when compared with the reference values. It was also observed that the proportion of males who were of 'short stature' and belonged to Group V were lower, compared to the females.

Tables 7 and 8 show that there was no significant inter-faculty difference observed in the proportion of students belonging to the different nutritional groups, (using Chi-square based on ordered groups, Lehman,[6]).

TABLE 7. Number of Students in each Nutritional Group by Faculty — (Males)

Nutritional Group	*Faculty* *Medicine*		*Science*		*Law*		*Arts*		*All Faculties*
1	13	13.3%	13	14.9%	5	13.9%	17	10.0%	48
2	18	18.4%	24	27.6%	10	27.7%	46	27.0%	98
3	28	28.6%	21	24.1%	5	13.9%	49	28.8%	103
4	20	20.4%	8	9.2%	10	27.7%	28	16.5%	66
5	19	14.4%	21	24.1%	6	16.6%	30	17.6%	76
Total	98	100%	87	100%	36	100%	170	100%	391

$x^2 = 2.669$ on 4 df $\quad p < 0.5$

TABLE 8. Number of Students in each Nutritional Group by Faculty — (Females)

Nutritional Group	*Faculty* *Medicine*		*Science*		*Law*		*Arts*		*All Faculties*
1	8	8.7%	6	11.0%	2	6.6%	15	7.4%	31
2	20	22.0%	9	16.6%	2	6.6%	32	15.7%	63
3	16	17.6%	13	24.0%	7	23.3%	33	16.3%	68
4	23	25.3%	7	12.9%	6	20.0%	40	19.7%	76
5	24	26.4%	19	35.0%	13	43.3%	83	40.8%	139
Total	91	100%	54	100%	30	100%	203	100%	378

$x^2 = 5.18$ on 4 df $\quad p < 0.25$

On studying the distribution of students in different nutritional groups in relation to their income, it was observed that there was no significant difference among the male students. However, for the females, the highest proportion of students in the nutritional group V (i.e. weight for ht. 84% or more) belonged to the low income groups (Table 9 and 10).

TABLE 9. Number of students in each nutritional group by family income — Males

Nutritional Group	*Family income in Rs. per month*					*All income Groups*
	<300	*301-500*	*501-1000*	*1001-1500*	*> 1500*	
1	19	5	11	6	7	48
2	40	13	18	13	15	99
3	44	20	17	7	15	103
4	24	9	17	9	7	66
5	27	12	7	9	21	75
Total	154	59	70	44	65	391

x^2 — 3.81 on 4 df $p < 0.4$

TABLE 10. Number of students in each nutritional group by family income — females

Nutritional Group	*Family income in Rs. per month*					*All income Groups*
	<300	*301-500*	*501-1000*	*1001-1500*	*> 1500*	
1	7	3	6	8	7	31
2	13	9	13	11	17	63
3	19	11	9	14	15	71
4	22	9	14	13	18	76
5	58	23	14	13	29	137
Total	119	55	56	59	89	378

x^2 — 10.726 on 4 df $p < 0.05$

Mean haemoglobin levels of the study population in different faculties is given in Table 2 (sexes separately). Within each faculty, the mean values for males is higher than that for females. However, between faculties, the highest values were observed for students in the Faculty of Medicine.

TABLE 11. Mean haemoglobin concentration by faculty (sexes separately)

Faculty	*Male*	*SD*	*Female*	*SD*
Medicine	12.46	1.3	11.54	.9
Science	11.97	1.2	10.35	1.1
Law	11.04	1.2	10.29	1.2
Arts	11.9	1.3	10.63	1.2

Haemoglobin levels below which anaemia is said to exist is considered to be in the adult males 13 gm % and adult females (non-pregnant) 12g % .[11] According to the above definition, the prevalence of anaemia among the two "income groups" was studied (Table 12). For males the prevalence of anaemia was significantly lower among the higher income group, whereas for the females the difference observed was not statistically significant.

TABLE 12. Prevalence of anaemia in relation to family income

(a) **Males**

Family income	*Number anaemic*	*Number not anaemic*
Low	167	46
High	114	64
Total	281	110

$\chi^2 = 9.89$ df = 1
$p > 0.01$

(b) **Females**

Family income	*Number anaemic*	*Number not anaemic*
Low	150	25
High	161	42
Total	311	67

$\chi^2 = 2.64$ df = 1
$p < 0.1$

All females in the study population (378) had responded to the question on their age at menarche. The mean age at menarche was 13.3 years while it ranged from 11 to 19 years. 75.2% had attained menarche below 15 years of age. Inter-faculty differences were observed in the mean age, with lowest values in respect of the girls at the Faculty of Medicine and highest in the Faculty of Arts (Table 13).

TABLE 13. Mean age at Menarche in years — by faculty

Faculty	*Menarche in years*	*S.D.*
Medicine	12.68	2.6
Science	12.6	3.0
Law	13.3	1.3
Arts	13.7	2.4
All faculties	13.3	

TABLE 14. Age at Menarche and family income

Family income in Rs. per month	*Age at menarche in years*				
	<11 years	*11.1—12.5*	*12.6—14*	*< 14 ? above*	*Total*
< 300	6	19	44	51	120
301 — 500	6	20	15	14	55
501 — 1000	12	20	14	11	57
1001 — 1500	16	19	15	10	60
1500 >	34	24	21	7	86
Total	74	102	109	93	378

x^2 — 75.12 df — 12
$p < 0.001$

TABLE 15. Age at menarche and social class

Social Class	*Age at menarche in years*				
	<11	*11.1—12.5*	*12.6—14*	*14.1 & above*	*Total*
1	35	42	31	8	116
2	39	60	78	85	262
All classes	74	102	109	93	378

x^2 — 34.7 df — 3 $p < 0.005$

Age at menarche was significantly related to the family income in that the age at menarche increases with decreasing family income.

On studying the pattern among the two social class groupings, it is observed that the daughters of 'professionals' and 'executives' attained menarche earlier than the others.

4. Discussion

In Sri Lanka, University students are a highly selected group in the community, hence they are not representative of the entire young adult population in the country. There were marked socio-economic status differences between the students of different faculties which may be attributed to the criteria governing university entry and to differences in the educational facilities available islandwide, specially those for science education.

Medical students, the majority of whom belonged to higher socio-economic groupings had higher mean values in respect of some of the indices studied i.e. mean height, weight and haemoglobin level. Mean age at menarche was lower among the girls in the Medical Faculty compared to those from the Faculties of Law and Arts.

Observations on mean height and weight made in this study are higher than those made by Collumbine[3] on Sri Lankan university students even though the majority of university students at that time belonged to higher socio-economic status. A factor that may be relevant in the increase observed in height from 1949 to 1981 may be the secular trends observed, where the national averages in heights are increasing worldwide.[9]

Many studies have shown that differences in physical stature can be attributed not only to differences in genetic make up but also to environmental factors, especially nutrition. Within a genetically similar population, if differences were seen between sub-groups, then the importance of environmental factors become more relevant. As such, the significant inter-faculty differences observed in these parameters need to be related to the socio-economic differences among the students in the different faculties.

However, when weight:height relationship was studied the pattern observed was different, specially among the females. There were more 'arts' students who had higher weight:height ratios than medical students. Therefore, on the average, the arts students may be stunted or short for age but their weight in relation to their height seems adequate. A possible explanation may be that this group of students who are from a lower socio-economic grouping may have suffered from chronic malnutrition in childhood resulting in short stature but subsequently improved their nutritional status, thus reaching a satisfactory weight:height ratio. This improvement may be due to a 'selection' of the particular student within the family, having been chosen for higher education, or to a general improvement throughout the country.

The detection of a high prevalence of anaemia in an apparently healthy university population is of importance, as it is known that even though the symptoms

of anaemia are not overt except in severe forms of the disease, reduction in physical capacity and increased susceptibility to infection is associated with anaemia.

The information on some nutritional status indicators available on this select group of young adults identifies the need to review the concept of "at risk" groups in directing nutritional programmes, with special consideration given to lower socio-economic groupings.

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Electrical Transport in Copper and Cobalt Ferricyanides

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Abstract: Copper and cobalt ferricyanides are found to be electrical conductors. The temperature variation of their resistivities are studied. It is found that the activation energy of copper ferricyanide is 0.23 eV provided the sample is not heated above 118°C. If the sample is heated above 118°C a partial chemical degradation of the compound transforms the activation energy to 1.43 eV. Cobalt ferricyanide has exactly similar behaviour, the activation energy changes from 0.25 eV to 0.61 eV if the sample is heated above 132°C.

The ferricyanides and ferrocyanides of most heavy metals are water insoluble stable crystalline solids having similar structure.[1,7] We have found that a number of ferricyanides and ferrocyanides of heavy metals conduct electricity.[5] In this note we report the electrical conduction properties of copper ferricyanides (Co_3 $(Fe\ (CN)_6)_2$ and cobalt ferricyanides (Co_3 $(Fe(CN)_6)_2$). These two compounds were selected because they have identical structures with similar lattice parameters.

Copper ferricyanide is prepared by mixing aqueous solutions of copper sulphate and potassium ferricyanide (analytical grade reagents are used without further purification). The precipitate of copper ferricyanide is washed with de-ionized water and dried at 70°C. The yellowish green polycrystalline powder of copper ferricyanide contains 14 molecules of water of crystallization. If the drying temperature is raised (e.g. 90°C) the water of crystallization is lost but traces of absorbed moisture remain in the crystals. The cobalt ferricyanide prepared in the same manner by mixing aqueous solutions of potassium ferricyanide and cobalt nitrate is a brick red polycrystalline powder containing no water of crystallization.

To measure the resistivity, the powder (dried at 90°C) is compacted into a glass tube (diameter 0.8 cm) and pressed between carbon electrodes to a pressure of 10^5 Pa when a pellet (length 0.5 cm) is formed. The ends of the tube are sealed with epoxy resin, the samples are immersed in a thermostatic oil bath and the d.c. resistance at different temperatures is measured using a digital bridge type resistance meter. The temperature variation of the resistivity of copper and cobalt ferricyanides is indicated in Figures 1 and 2. In both cases the plot of $\log p$ *vs* T^{-1} fits into two straight line portions indicating that the resistivity changes with temperature according to the law,

$$p = p_o\, e^{E/KT}$$

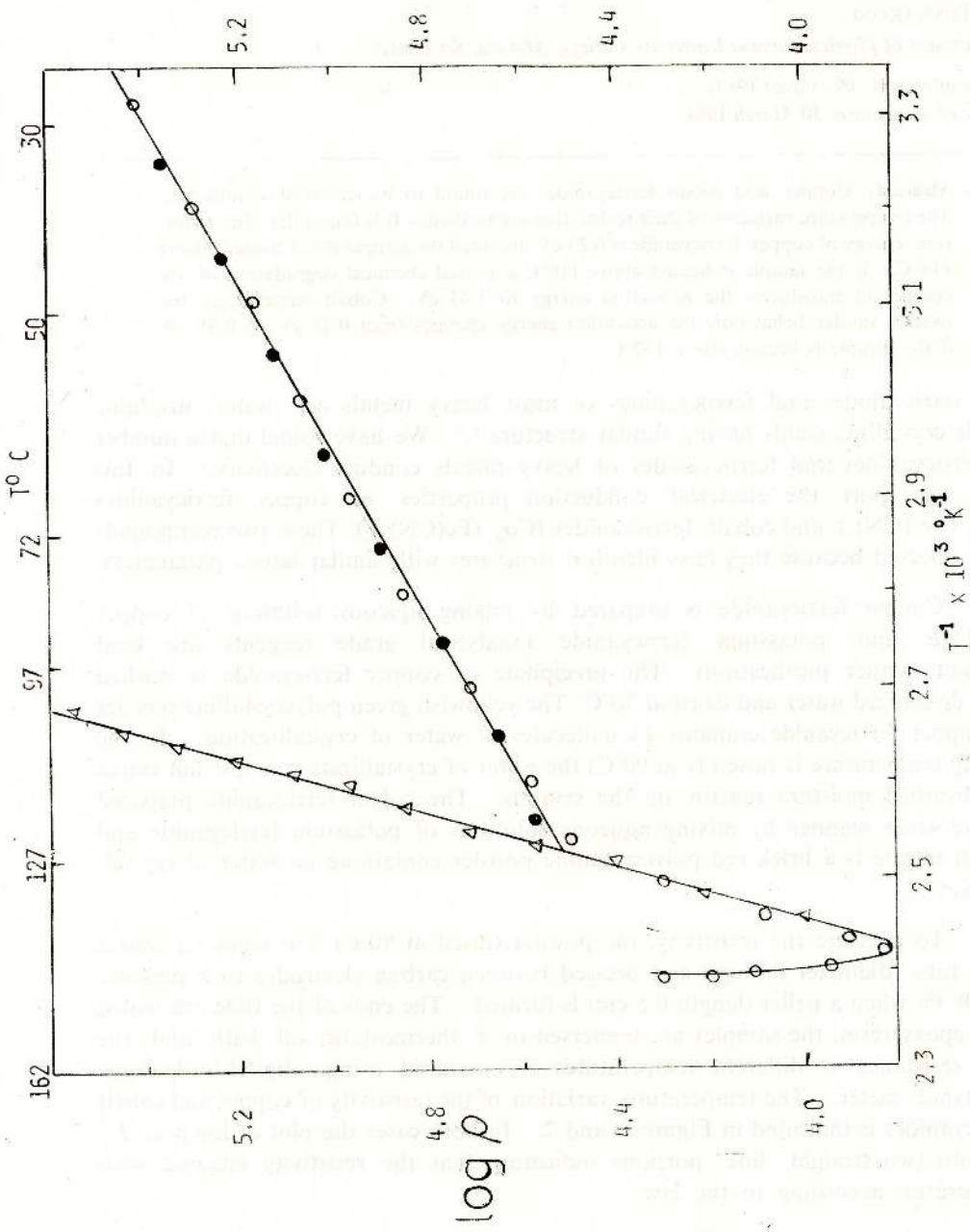

Figure 1. The plot of log ρ (ρ in Ω cm) vs T^{-1} for copper ferricyanide (○ - heating, ● - cooling after heating to temperature less than 118°C, △-cooling after heating to a temperature higher than 118°C)

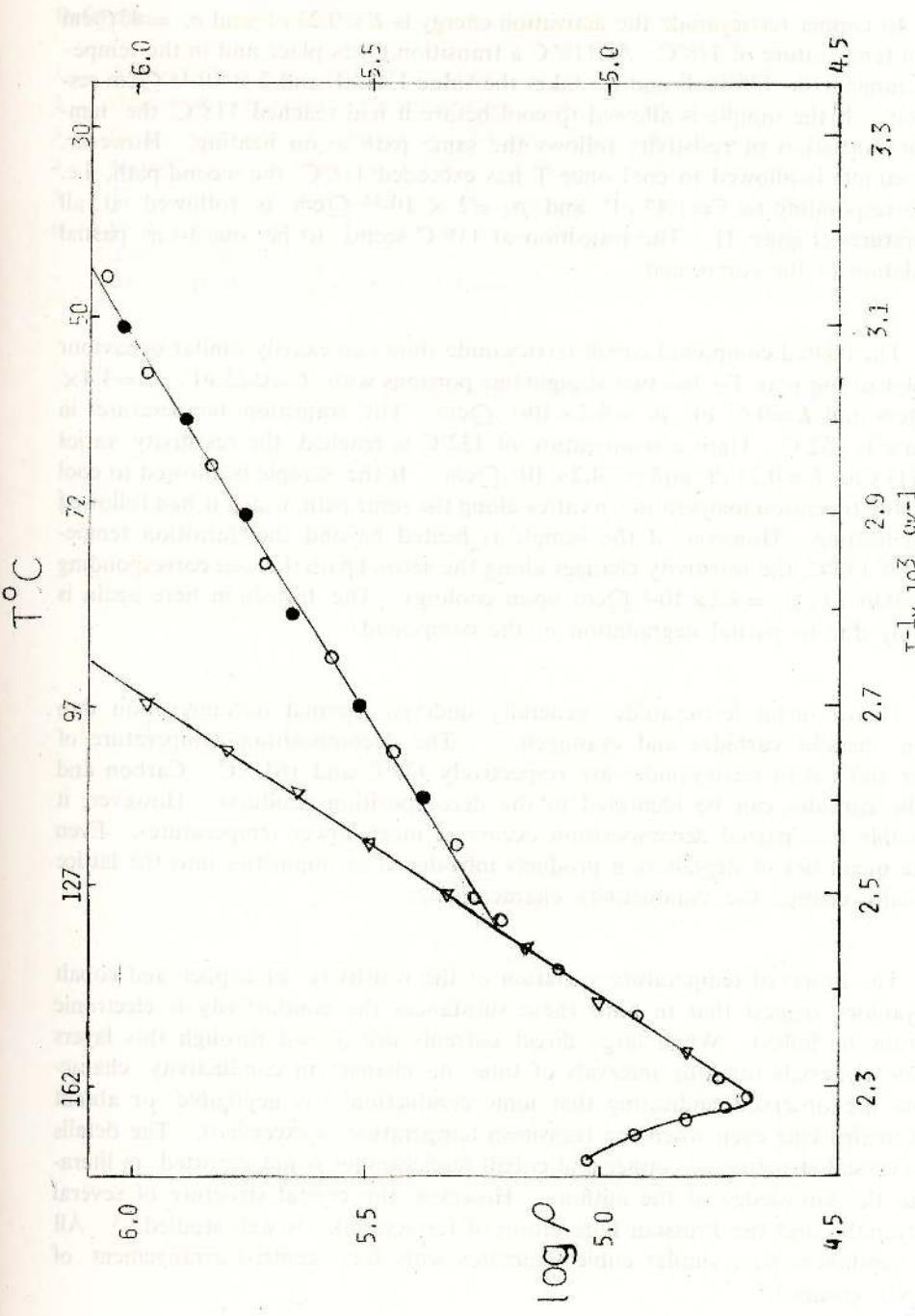

Figure 2. The plot of log p (p in Ωcm) vs T-1 for cobalt ferricyanide (○-heating, ●-cooling after heating to a temperature less than 132°C, △ - cooling after heating to a temperature higher than 132°C)

In copper ferricyanide the activation energy is $E=0.23\ eV$ and $p_o = 43\Omega$cm up to a temperature of 118°C. At 118°C a transition takes place and in the temperature range 118 - 138°C, E and p_o takes the value 1.43 eV and 2×10^{-14} Ωcm respectively. If the sample is allowed to cool before it had reached 118°C, the temperature variation of resistivity follows the same path as on heating. However, if the sample is allowed to cool once T has exceeded 118°C, the second path, i.e. one corresponding to $E=1.43\ eV$ and $p_o = 2 \times 10^{-14}$ Ωcm is followed at all temperatures (Figure 1). The transition at 118°C seems to be due to a partial degradation of the compound.

The related compound cobalt ferricyanide shows an exactly similar behaviour The plot of log p vs T^{-1} has two straight line portions with $E=0.25\ eV$, $p_o = 1.4 \times 10^2$ Ωcm and $E=0.67\ eV$, $p_o = 4.2 \times 10^{-3}$ Ωcm. The transition temperature in this case is 132°C. Until a temperature of 132°C is reached, the resistivity varies as in (1) with $E=0.25\ eV$ and $p=4.2 \times 10^2$ Ωcm. If the sample is allowed to cool before the transition temperature, p varies along the same path, which it had followed during heating. However, if the sample is heated beyond the transition temperature of 132°C, the resistivity changes along the second path (i.e. one corresponding to $E=0.61\ eV$, $p_o = 4.2 \times 10^{-3}$ Ωcm upon cooling). The transition here again is probably due to partial degradation of the compound.

Heavy metal ferricyanides generally undergo thermal decomposition into carbon, metallic carbides and cyanogen.[6] The decomposition temperature of copper and cobalt ferricyanides are respectively 138°C and 163.7°C. Carbon and metallic carbides can be identified in the decomposition products. However, it is possible that partial decomposition occurs at much lower temperatures. Even minute quantities of degradation products introduced as impurities into the lattice drastically change the conductivity characteristics.

The observed temperature variation of the resistivity[3] of copper and cobalt ferricyanides suggest that in both these substances the conductivity is electronic (electrons or holes). When large direct currents are passed through this layers of these materials for long intervals of time, no changes in conductivity characteristics are observed, indicating that ionic conduction[2,4] is negligible or absent (this remains true even when the transition temperature is exceeded). The details of the crystal structure of copper and cobalt ferricyanides is not reported in literature to the knowledge of the authors. However, the crystal structure of several ferrocyanides and the Prussian blue group of ferricyanides is well studied.[1,7] All these substances have similar cubic structures with face centred arrangement of $Fe(CN)_6$ groups.[1,7]

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Electrical Conduction in Triarylmethane Halides and Thiocyanates

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Abstract: The temperature variation of the conductivity of triarylmethane halides and thiocyanates are studied. It is found that in halides the thermal activation energies of charge carriers increase in the sequence I > Br > Cl. Thiocynates show a conductivity transition at $\sim$ 126°C.

1. Introduction

It is well known that organic charge transfer (CT) complexes in the solid state frequently exhibit semiconduction.[3,4] The mechanism of conduction in these molecular solids is believed to be the hopping of charge carriers[2,3] from donor to acceptor sites. Some of the simplest and most extensively investigated organic CT solids are the dyes.[5,6] To understand the nature of electrical transport in CT complexes, it is desirable to study the conductivity properties of cationic (anionic) dyes when the donor (acceptor) site is a simple anion (cation) of known properties. In this paper we report our measurements of the conductivity of triarylmethane (TR) dyes, when the anionic ligand is a halide or a pseudohalide.

2. Experimental

TR dyes (Metyl Violet and Rosaniline) commercially supplied as chlorides (BDH brand) are purified by recrystallization. To prepare the corresponding iodides an alcoholic solution of the dye and potassium iodide is boiled until most alcohol is expelled. The TR iodides insoluble in aqueous KI, separated by filtration are recrystallized and dried in vacuum at 105° C. The thiocyanates of TRs can be prepared by the same method, when KI is replaced by KCNS. However, the double decomposition does not give a good yield of the bromide. TR bromides are prepared by treating the corresponding leuco base with HBr. Purified samples free from moisture are pressed into pellets between carbon electrodes in a pyrex tube (diameter $\lesssim$ 0.4 cm, pellet length $\lesssim$ 0.2 cm) at a pressure of 10^6 Pa. Ends of the tube are sealed with epoxy resin and the conductivity at different temperatures is determined using a d. c. resistance meter. Very thin discs of the material compacted in sealed tubes are used to pass large currents for long intervals of time to see whether ionic conduction is present. Conductivity characteristics remained linear at constant slope indicating that ionic conduction is absent.

Attempts to determine the mobilities by the measurement of Hall voltages were unsuccessful.

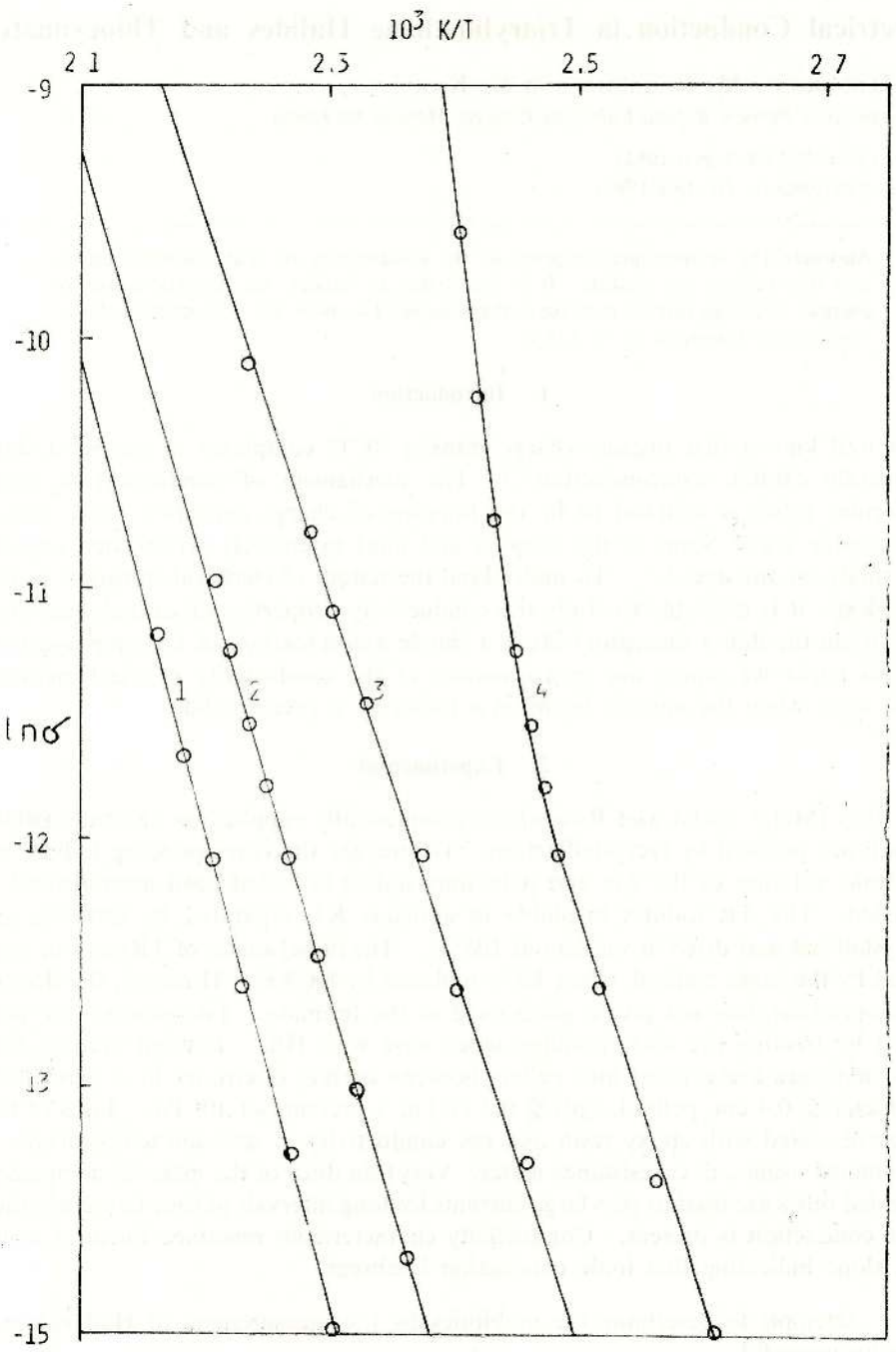

Figure 1. Plot of lnσ (σ in $\Omega^{-1}m^{-1}$) for halides and thiocyanates of Metyl Violet.
(1) Chloride (2) Bromide (3) Iodide (4) Thiocyanate.

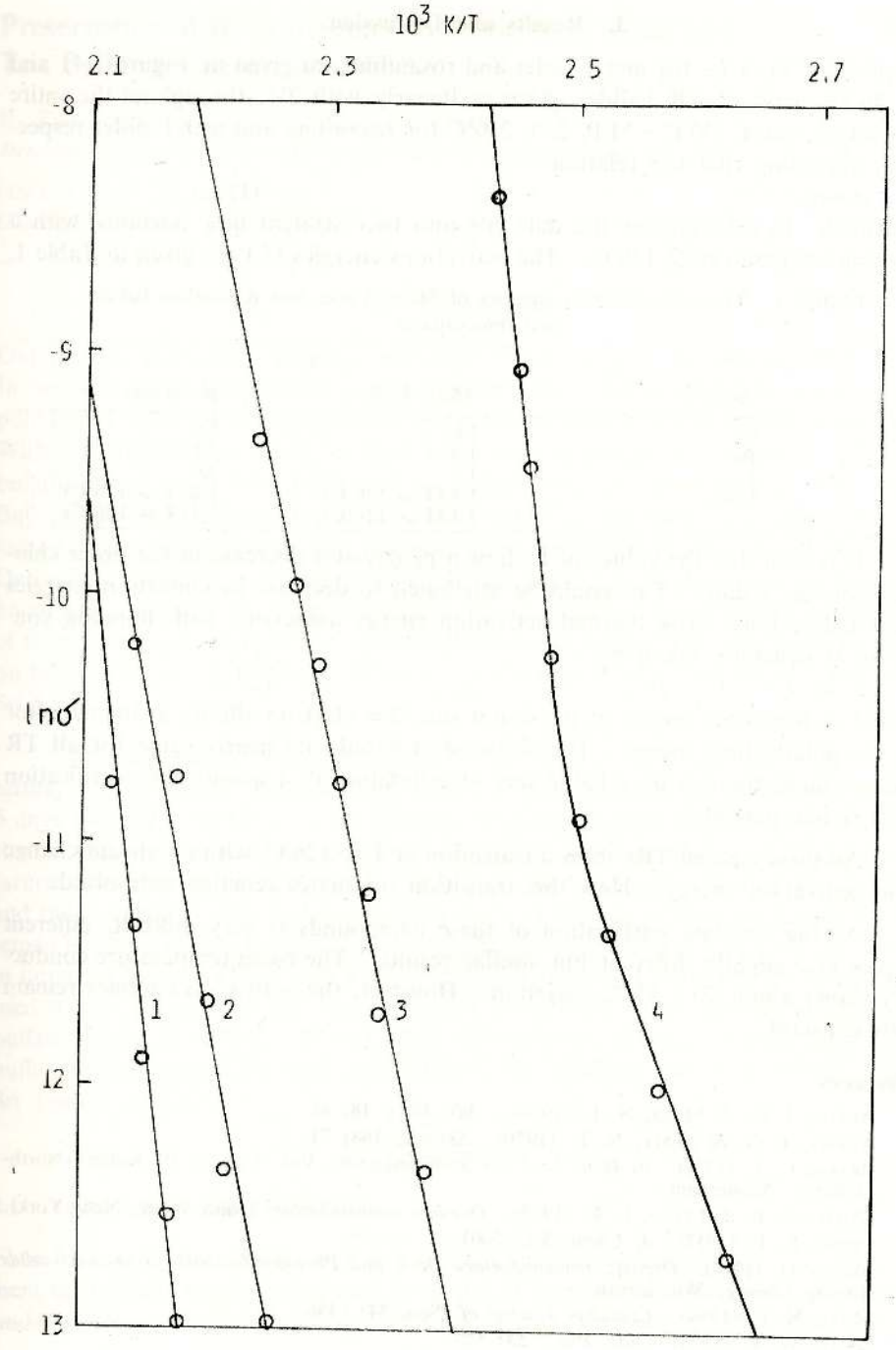

Figure 2. Plot of lnσ (σ in $\Omega^{-1}m^{-1}$) for halides and thiocyanates of Rosaniline.
(1) Chloride (2) Bromide (3) Iodide (4) Thiocyanate.

3. Results and Discussion

The plots of ln vs T^{-1} for metyl violet and rosaniline are given in Figures (1) and (2). In the case of TR halides, σ varies linearly with T^{-1}, throughout the entire temperature range, (30°C - M.P. 270, 210°C for rosaniline and metyl violet respectively) indicating that the relation

$$\sigma = \sigma_0 e^{-E/kt} \qquad (1)$$

is satisfied. In thiocyanates the data fits into two straight line portions with a transition temperature $\lesssim$ 126°C. The activations energies (E) are given in Table 1.

TABLE 1. Thermal activation energies of Metyl Violet and Rosaniline halides and thiocyanates

	E/eV	
Anion	*Metyl Violet*	*Rosaniline*
Cl-	1.6	3.6
Br-	1.4	2.3
I-	1.3	2.0
CNS-	1.5 (T < 126°C)	1.2 (T < 126°C)
	3.3 (T > 126°C)	3.4 (T > 126°C)

It is seen that the values of E show a progressive decrease in the order chloride, bromide, iodide. This could be attributed to decrease in ionization energies of the halide ions. The thermal activation energy associated with hopping conduction is generally taken as,[5]

$$E = I - A - P \qquad (2)$$

where I = ionization energy at the donor site, A = electron affinity at the acceptor site, P = polarization energy. The value of A should be nearly same for all TR halides. Since there is no reliable way of estimating P, a quantitative verification of (2) is not possible.

All thiocyanated TRs show a transition at T $\lesssim$ 126°C, with an abrupt change in the activation energy. How this transition originates remains unresolved.

As the absolute purification of these compounds is very difficult, different samples give slightly different but similar results. The room temperature conductivity shows about 20 - 30 % variation. However, the activation energies remain nearly constant.

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Preservation of Buffalo Semen in Citric Acid Whey and Tris Buffer Extenders at -196° C

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1. Introduction

Our present population of local buffaloes is estimated to be around 0.4 million. In order to meet our draught-power, milk and meat requirements the local buffalo population must be multiplied and upgraded to Indian River Buffalo standards. With this objective in mind, in 1967, large scale importation of Murrah and Surti buffaloes were made from India and are maintained as a closed herd in state farms. Bull calves born in these farms are being issued to the farmers to upgrade their local animals. The genetic improvement achieved by this practice is very minimal. One of the quickest ways of achieving rapid genetic improvement is by artificial breeding. Artificial breeding in buffaloes is not practiced in Sri Lanka due to lack of trained and proven bulls for semen collection and further no work has been done on the evaluation of different diluents for the preservation of buffalo semen in Sri Lanka.

Recent studies on buffalo semen preservation at 4° C[6] and at room temperature,[7] in Sri Lanka, indicate that buffalo semen could be preserved only upto 5 days with 50% motility. This problem of storage length could be overcome by storing semen in a good extender at —196°C in liquid nitrogen. At this temperature semen could be kept for a number of years without affecting the motility and the conception rate in inseminated cows. A further advantage of deep frozen semen is that it is easy to handle and could be transported to any part of the island in liquid nitrogen. Citric acid whey, egg yolk citrate and TRIS buffer have been used as the diluents by the Indian animal scientists[1,2,9] for the preservation of buffalo semen at -196°C. In this study two diluents, citric acid whey and TRIS buffer were compared for their ability to preserve buffalo semen at -196°C, under Sri Lanka conditions.

2. Experimental

2.1 Animals and semen collection

Four Murrahs, three Surtis and one indigenous buffalo belonging to the Department of Animal Husbandry of the University of Peradeniya, which were maintained under normal standard conditions of feeding and management, were used in this

study. Semen was collected once a week from each bull using an artificial vagina and a dummy. A separate artificial vagina was used for each buffalo and this was designed to suit the bull. Warm water at a temperature of 40°C was poured outside the inner lining of the rubber tube and by inflating sufficient air optimum pressure was created to simulate a vagina of a cow in heat. In order to provide a smooth surface for the buffalo bull a lubricant namely a jelly or vasoline was applied at the mounting end of the artificial vagina. Animals after teasing were allowed to mount on a dummy and semen was collected by the operator into a graduated collection tube.

2.2 Evaluation of samples

Immediately after collection the colour, volume, wave pattern or mass movement, the general motility and the live and dead counts of sperms and abnormal sperms. were assessed. Evaluation for wave pattern or mass movement was done as follows. Two drops of each sample was kept on a slide, warmed to body temperature and viewed under the lowest power of the microscope for forward and progressive movement which simulates a wave motion in the sea. In order to evaluate the general motility a thin smear with a coverslip was viewed under the same powered lens of microscope. To ascertain the live and dead counts of sperms, Nigrosin and Eosin stained slides were used under the oil immersion lens of the microscope where the dead sperms were stained violet and the live sperms remained unstained. The abnormal sperms were determined in these stained preparations.

2.3 Preparation of citric acid whey diluent and semen extension

Citric acid whey packets supplied by the National Dairy Research Institute Karnal were used directly in the following way: Ten grams of citric acid whey with penicillin (1000 I.U. per ml of the diluent) and streptomycin (1 mg per ml of the diluent) were dissolved in 100 ml of double distilled water. The suspension was allowed to stand for 5 - 10 minutes and filtered through cotton wool. The pH of this solution was adjusted to 6.8 with freshly prepared 10% sodium hydroxide solution. The solution thus prepared was divided into two equal fractions A and B. Glycerol was added to these fractions so that 3% of fraction A and 11% of fraction B constituted undiluted glycerol. Fresh semen was added to fraction A, keeping in mind after the final mixing of A and B, the ratio of semen of the dilution be maintained at 1:10. Fractions A and B were cooled to 5°C in a refrigerator and part B was added to part A in fractions at a time (about 1/5th of B added to A) at an interval of 10 - 15 minutes and the dilution was completed in 50 - 75 minutes.

2.4 Preparation of TRIS diluent and semen extension

In this preparation following chemicals were used: TRIS - 1.52 gms, citric acid -0.85 gms, fructose - 0.625 gms. These were dissolved in 42.5 ml of double distilled

water. To 37.5 ml of the above solution was added 10 ml of egg yolk, 3 ml of glycerol, penicillin (at the rate of 1000 I.U. per ml of the diluent) and streptomycin (1 mg per ml of the diluent), mixed well, and pH was adjusted to 6.8. This was used as a single step diluent where A and B fractions were not involved. Here again, semen dilution rate was 1:10. Motility percent and live/dead sperm percent was assessed after extending the semen with citric acid whey and TRIS buffer.

2.5 Equilibriation of extended semen

This is the time taken by the extended semen at 5°C to acquire the resistance power to cold shock. Normally it varies from 4 - 6 hours. Hence the extended semen (with citric acid whey and TRIS buffer diluents) was kept in the refrigerator at 5°C for 4 - 6 hours for equilibriation, after which time motility as well as live and dead count of spermatozoa were assessed.

2.6 Semen freezing

The diluted semen samples after a period (4 - 6 hours) of equilibriation were packed in ice, kept in a regiform box and transported by a vehicle to Central Artificial Insemination Centre, Kundasale, 16 km away from the place of collection. Diluted semen was tested for general motility, live and dead sperm counts, soon after transport. At the Artificial Insemination Centre the samples were kept inside a cold cabinet maintained in a temperature of 5°C. Prior arrangements were made in such a way that all the equipment were sterilised and kept inside the cold cabinet so that all equipment required would attain a uniform temperature of 5°C, to prevent any temperature shock to sperms. French ministraws of 0.25 cc.capacity were used for freezing semen. The straws were filled with diluted semen and the open end of the straws were dipped in polyvinyl powder to make a satisfactory seal. The straws were then placed in a water bath at 5°C for further equilibriation inside the cold cabinet for about 1 hour. Straws were held in bundles tabbed on the bottom of the water bath to remove excess powder, rolled and dried in absorbant towels. These straws were then kept in racks, made of stainless steel with a support, where the straws could be dried exposing all the surface and kept for half an hour at 5°C. Once the straws were dried they were exposed to liquid nitrogen vapour (temperature, -120°C) at the junction between the neck and the body of the freezing tank. After seven minutes of exposure the straws were lowered into liquid nitrogen.

2.7 Assessment of frozen semen

After freezing the straws were transferred to a small liquid nitrogen tank and taken to the Department of Animal Husbandry Laboratory. Test straws were removed at 24 hrs and 96 hrs after freezing and thawed in warm water at 37°C for 12 seconds

and assessed for motility and live/dead sperm percentage. In a separate study the motility and live/dead sperm percentage of thawed semen samples were also determined at 0, 2, 4, 6, 8, 10 and 12 hrs after thawing.

3. Results and Discussion

A total of 86 collections were made from 8 bulls during the experimental period. However almost half of the collections could not be frozen due to the insufficient volume, low initial motility ($\leq 65\%$), high dead sperm count ($\geq 20\%$) and due to other technical difficulties. In all 47 collections were frozen in TRIS and CAW diluents. The semen characteristics of the freshly collected semen are shown in Table 1. The motility value observed in our study is in agreement with the value of 65% reported by Gill *et al*,[3] However, others[4] have reported a higher initial motility of 81.5% in Murrah breeds. There was no significant breed effect on motility. Murrah breed gave the highest volume of semen. The value obtained for Murrah breed is in agreement with other reports.[3,5] The low value obtained in Surti and local buffalo can be due to the difference in age and body size. There was no difference in the concentration of sperms in Murrah and Surti semen. However, semen of local buffalo was watery, light in colour and recorded the lowest concentration. The concentration observed in this study was much higher than those reported by others.[3,4]

TABLE 1. Percentage of motile sperm, dead sperm percentage concentration and volume of freshly ejaculated semen

Breed	*No. of samples*	*Motility (in %)*	*Dead sperms (in %)*	*Concentration (in billion/ml)*	*Volume (in ml)*
Murrah	23	70.1 ± 1.8^a	17.6 ± 1.2^a	$4.47 \pm 0\,3^a$	2.82 ± 0.53^a
Surti	17	68.1 ± 2.6^a	17.2 ± 1.3^a	3.58 ± 0.4^a	1.97 ± 0.68^b
Local	07	72.5 ± 4.8^a	25.7 ± 4.5^b	3.17 ± 0.5^b	1.98 ± 0.34^b

Means bearing different superscripts within column are different ($P < 0.05$)

The percentage of motile sperms and dead sperms after dilution in TRIS and CAW diluent are shown in Table 2. There was no dilution or breed effect and again no difference in motility and dead sperm percentage were observed even after 6 hours of equilibriation in TRIS and CAW diluents (Table 3). However, there was a significant reduction in motility and increase in dead sperm percent after equilibriation. In this study the diluted semen samples after equilibriation were transported to a distant place (16 kilo metres away) for freezing. Motility and dead sperm percentage before and after transport of the diluted samples indicates no significant differences in these two parameters. This is of practical importance, as semen could be collected in one place, equilibriated and could be transported to another place in ice and freezing could be done without affecting the semen quality.

TABLE 2. Percentage of motile sperm and dead sperm after dilution of buffalo semen in TRIS and CAW diluent

Breed	*Motility (%)*		*Dead sperm (%)*	
	TRIS	*CAW*	*TRIS*	*CAW*
Murrah	75±2.1	70±1.8	17.5±3.7	18.3±4.6
Surti	76±2.4	77±2.2	14.5±1.7	18.0±2.0
Local	75±1.7	75±1.4	22.8±2.0	26.1±2.1

Data statistically not significant ($P < 0.05$)

TABLE 3. Percentage of motile sperm and dead sperm after equilibriation of buffalo semen in TRIS and CAW diluents

Breed	*Motility (%)*		*Dead sperm (%)*	
	TRIS	*CAW*	*TRIS*	*CAW*
Murrah	60.7±2.9	56.7±4.9	20.4±1.2	22.5±0.8
Surti	60.8±4.1	61.8±3.1	19.4±1.7	24.2±1.0
Local	62.8±4.2	60.2±3.2	21.4±1.4	22.8±1.1

Data statistically not significant ($P < 0.05$)

The motility and dead sperm percentage of sperm in TRIS and CAW diluents after freezing are shown in Table 4. There was significant reduction in sperm motility and elevation in percent dead sperms in both the diluents after freezing and thawing. However in TRIS diluent the reduction in motility was 27% compared to CAW where it was found to be 66%. This observation is in agreement with the finding of Sharma *et al.*[8] Therefore from this study it can be said that TRIS is a better diluent than CAW for the freezing of buffalo semen under Sri Lankan conditions. The effect of time on post thaw motility of buffalo sperm frozen in TRIS diluent is shown in Table 5. According to this observation frozen semen after thawing can be kept for a period of 6 hours under conditions prevailing in our country.

The fertility rate following insemination with frozen semen was tested in post-partum cows, in another study. The maximum fertility rate observed was only 35% and this low fertility was attributed to most of the animals not ovulating after hormonal treatment rather than to the quality of frozen semen.

TABLE 4. Percentage of motile sperm and dead sperm, 24 hours and 96 hours after freezing in TRIS and CAW diluent

Breed	24 hrs post freezing				96 hrs after freezing			
	Motility (%)		Dead sperm (%)		Motility (%)		Dead sperm (%)	
	TRIS	CAW	TRIS	CAW	TRIS	CAW	TRIS	CAW
Murrah	50.2 ± 4.1^{a}	19.6 ± 2.4^{b}	$43.6\pm3.5^{a^1}$	$58.5\pm5.5^{b^1}$	50.4 ± 4.4^{a}	18.8 ± 2.4^{b}	$43.1\pm3.4^{a^1}$	$60.6\pm2.8^{b^1}$
Surti	40.8 ± 5.7^{a}	23.4 ± 3.8^{b}	$47.4\pm6.3^{a^1}$	$55.6\pm4.9^{b^1}$	40.9 ± 5.1^{a}	23.2 ± 3.8^{b}	$59.0\pm6.6^{a^1}$	$54.8\pm5.1^{a^1}$
Local	50.0 ± 7.5^{a}	17.5 ± 3.0^{b}	$47.0\pm5.5^{a^1}$	$56.8\pm4.6^{b^1}$	46.1 ± 7.1^{a}	17.6 ± 4.2^{b}	$43.3\pm8.1^{a^1}$	$60.8\pm4.1^{b^1}$

Mean bearing different superscripts along rows are different (P 0.05)

a-b indicates motility % a^1-b^1 indicates dead sperm %

TABLE 5. Effect of time on post thaw motility percentage of buffalo semen frozen in TRIS diluent

Breed	*0 hrs*	*2 hrs*	*4 hrs*	*6 hrs*	*8 hrs*	*10 hrs*	*12 hrs*
Murrah	44*	44	42	37	34	7	4
Surti	46	53	55	49	28	1	6
Local	47	43	45	36	28	8	4
Mean	45	46	47	40	30	8	5

* number of observations = 10

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The Present Status of the Development of Mineral Resources in Sri Lanka

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Abstract: The development of mineral resources is a vital pre-requisite for the rapid expansion of the economy of Sri Lanka. During the past five years the mineral sector has recorded a significant growth with the expansion of the gem trade, export of petroleum products and ceramic-ware. Increased export earnings from graphite, heavy mineral sands and mica have also been noted. The rapid growth in the cement industry utilizing local mineral raw materials was helpful in meeting the demand for cement due to the unprecedented increase in construction activity. The main constraint in the rapid expansion of the mineral sector is the lack of proper assessment of the mineral resources in the Island. The Geological Survey Department has taken up the challenge of locating new mineral deposits and also to carry out development of known mineral resources with the main objectives of assessment of the quality and quantity available for exploitation. Systematic exploitation of these non-renewable resources is a vital factor, if the local mineral-based industries are to expand to meet increased demands in the future. An attempt has been made in this paper to describe the development of the mineral resources of Sri Lanka that are presently utilized by the various industrial sectors and also exploited for export in raw form. Recent mineral discoveries such as rock phosphate, copper-magnetite ore which are of economic significance and the utilization of these minerals for establishment of new industries are also described. The paper also discusses target areas for future mineral exploration programmes.

1. Introduction

The Island of Sri Lanka is located at the southernmost tip of the Indian Subcontinent and covers a surface area of 65,610 sq. kilometers with a maximum length of 435 km and a maximum breadth of 225 km. The mid year population in 1982 was 15.2 million as compared to 15 million in 1981. The Gross National Product (GNP) at current factor cost prices was provisionally estimated at Rs. 89.7 billion in 1982. The per capita GNP at current prices in 1982 has been estimated as Rs. 5,904 (US $ 284) compared with Rs. 5,179 (US $ 267) in 1981. Since new economic policies were introduced about 5 years ago, a significant growth in the major sectors of the economy such as Agriculture, Forestry and Fisheries was noted. The mineral sector that is identified under "Mining and Quarrying" has also expanded in a rapid manner with the expansion in the Gem Trade and the export of Petroleum products. In order to contribute to the export earnings of the country in a more significant manner the minerals sector has to expand more rapidly. The major constraint in expansion of our mineral sector is the lack of a proper assessment of the mineral resources of Sri Lanka.

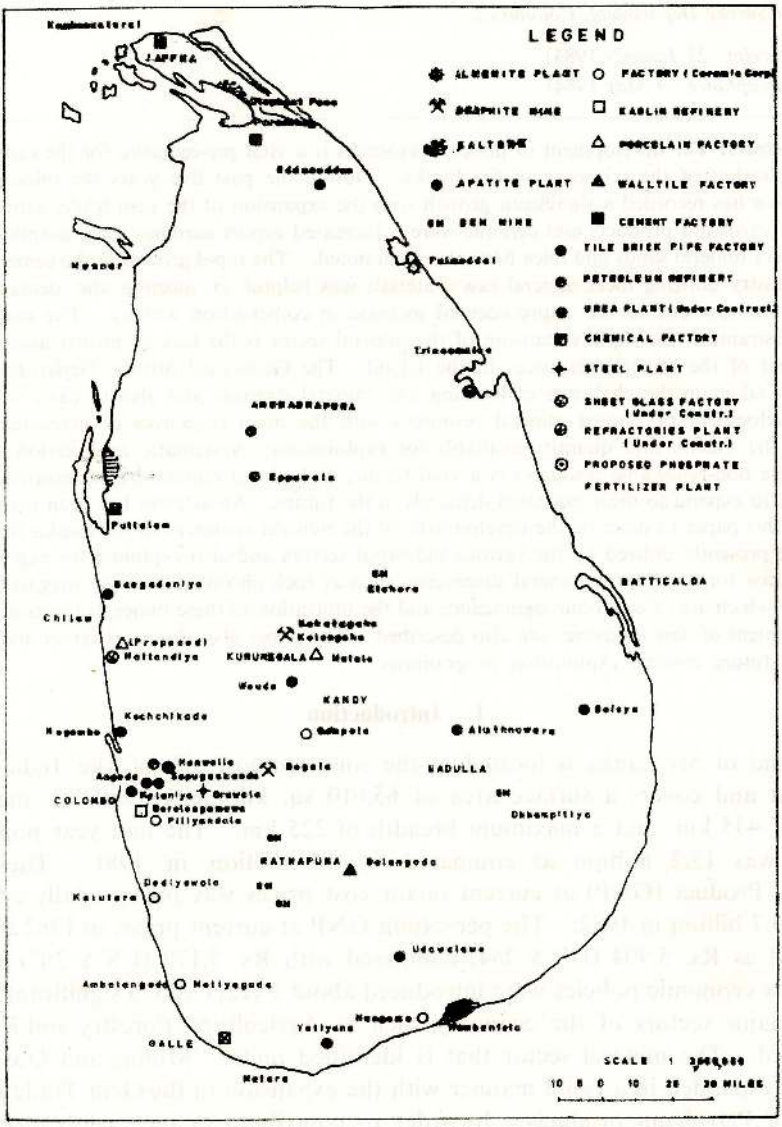

Figure 1. Location of industrial Units and Mines - Sri Lanka (After Herath 1980)

The Geological Survey Department during the recent past has taken up the challenge of locating new mineral deposits with the main objective of expanding the already established mineral based industries such as ceramics, graphite, mineral sands, steel and fertilizer. An attempt is made in this paper to identify the commercially exploitable mineral resources of the Island and how these resources are utilized by the mineral based industries.

2. Development of Mineral Surveys

The first attempt to assess the mineral resources of Sri Lanka was during the period 1903 - 1906, when the British colonial regime set up a mineral survey headed by Dr. Ananda Coomaraswamy. The past records of the mineral survey indicate that all major river beds, streams and the coast line were traversed and panned concentrates were collected to identify any base metals. Most of the samples were sent to the Imperial Institute in London for identification. These heavy concentrates indicated the presence of copper, zinc, chromium, nickel, thorium and other metals. The significant discoveries made during this period were thorianite from Bambarabotuwa in the Ratnapura area and graphite deposits in the South-West sector of the Island. Occurrence of limonitic iron-ores specially in the hill country was also noted and the records of this survey had indicated that a local iron and steel industry was in existence during the past.

In 1940, systematic and organised geological survey activities were undertaken by the then Department of Mineralogy under the direction of Dr. D. N. Wadia whose main objective was in identifying the main lithological divisions of the Island.

In 1945, L. J. D. Fernando was appointed Head of the Department of Mineralogy and his main task was to build-up a permanent staff consisting of trained Geologists to undertake systematic geological mapping and mineral exploration programmes. The Mineralogy Department was re-organised and was named the Geological Survey Department in 1961.

Detailed geological mapping of the Island commenced in 1954 and mineral exploration activities were undertaken mainly to assess mineral raw materials for the mineral based industries such as cement, ceramics, steel and mineral sands.

The state sector industrial corporations which presently utilize minerals as basic raw materials were established without a proper assessment of the quality and quantity of such raw materials that are available. The Geological Survey Department was called upon to play a major role in locating such raw material and give necessary advice on exploitation. The lack of modern equipment and trained personnel were the major drawbacks in the assessment of the mineral potential of Sri Lanka at this early stage. In 1958, the Department purchased core drilling machines and other geophysical instruments and these equipment helped in a

significant manner to undertake systematic mineral exploration programmes. The analytical facilities were also improved and from 1960 the Department was capable of assessing minerals by way of quantity and quality for the major mineral based industries such as cement and ceramics. The Department also was entrusted with the task of developing all the major floor sheets for heavy mineral separation which was to be undertaken by the Mineral Sands Corporation at their commercial heavy mineral processing plant at Pulmoddai.

The above history of the development of the Geological Survey Department is closely tied with the discoveries of mineral resources in Sri Lanka. It must be stated that the Geological Survey Department was the major organisation in this country that identified the presently exploitable mineral resources.

3. The present Assessment of Mineral Resources

The Geological Survey Department completed the systematic Geological mapping of the Island in 1976 on a reconnaissance scale of 1:63,360 (1" to 1 Mile). During the course of this programme two significant mineral discoveries were made. These two discoveries are (a) The Eppawela Rock Phosphate Deposit in the Anuradhapura District and (b) The Seruwila Copper Magnetite Deposit in the Trincomalee District. These two discoveries will be dealt with later in this paper.

The Department also undertook a systematic stream sediment and heavy mineral panning programme with the main objective of detection of uranium mineralisation and base metals in 1979. These surveys are presently continuing and have given satisfactory results.

A proposal to upgrade the Institutional facilities of the Geological Survey Department to undertake mineral exploration programmes in a more systematic manner was presented to the Government in 1980. This proposal is now under consideration and if accepted by the Government the Asian Development Bank will provide funds to the extent of about US $ 30 million for the modernisation of the Institutional facilities. The setting up of a Marine Geology Unit within the Department has also been proposed.

The planned expansion of the Geological Survey Department will be a vital pre-requisite in the complete assessment of the mineral resources of Sri Lanka and will help in preparing a mineral resources inventory which will in turn help all the major mineral sector industrial organisations in their expansion programmes.

3.1 The Mineral Resources of Sri Lanka

An attempt is made to describe the mineral resources of Sri Lanka according to the various industrial sectors that presently utilize or exploit such resources for industry or export.

3.2 The Ceramic Industry

The major ceramic raw materials presently utilized in industry are:

(a) Clays
(b) Kaolin
(c) Ball Clay
(d) Feldspar
(e) Vein Quartz

(*a*) *Clays:* The pioneer work of Herath[2] has established three main clay mineral provinces in the Island. These three clay provinces are identified as (1) montmorillonite-kaolinite clays with minor amounts of calcareous materials confined to the dry zone in the north and south-east. (2) Gibbiste-kaolinite clays with mixed layer mineral confined to the wet zone and (3) clays of the intermediate zone between (1) and (2). These clay mineral provinces closely follow the three climatic zones of the Island and the exploitable clay deposits for tiles and bricks are located mainly in the intermediate zone. Areas where such clays are presently exploited on a commercial scale are in the Maha-Oya basin north of Negombo, Weuda, Aluthnuwara, Yatiyana and Uda-Walawe. It is estimated that the total annual requirements of clays mainly for the brick, tile and pipe industry is about 1500 acre feet both by the public and private sectors. The Ceylon Ceramics Corporation operates 10 tile factories and produce about 75 million tiles per annum.

A proper assessment of clay resources suitable for brick and tile manufacture has not been undertaken. The Geological Survey Department has carried out clay surveys for almost all the major state sector tile factories and it is now opportune to compile a report on the availability of such clays and assess the future requirements. A complete assessment of the exploitable clay resources in the Maha-Oya basin is suggested as this area sustains the major brick and tile factories in the Island operated both by the public and private sectors. Reclamation of land where clay is presently exploited has to be given serious thought and advice on exploitation is vital specially when such clay deposits are located close to valuable paddy lands.

An assessment of the Jurassic shales present in large quantities at Andigama and Tabbowa as a source of raw material for the manufacture of heavy clay products including refractories should be undertaken.

(*b*) *Kaolin:* The occurrence of china clay or kaolin in the low lying areas around Colombo have been known in the past. The Boralasgamuwa kaolin deposit presently exploited by the Ceylon Ceramics Corporation is estimated to contain about 1 million tons. However, no detailed surveys have been undertaken to estimate the reserves of raw kaolin present in the vicinity of the Boralasgamuwa kaolin

field. Kaolin is also reported from the Horton plains area and other deeply weathered zones of the Central Highlands. The Meetiyagoda kaolin field located in the south-west sector of the Island is also exploited by the Ceylon Ceramics Corporation but a proper assessment of this field has not been undertaken.

The Ceylon Ceramics Corporation presently operates two kaolin refineries and produces about 7,000 tons of refined kaolin per annum.

It is suggested that a proper assessment of the kaolin fields in the Island should be undertaken and a planned exploitation programme initiated so as to conserve this valuable raw material for the expansion of the ceramic industry.

(*c*) *Ball Clays:* Clays which approach ball clay in composition are known to occur in the flood plains of rivers confined to the south-west sector. The best known ball-clay deposit is located at Dediyawala near Kalutara and the reserves are estimated at 500,000 tons. A detailed survey has not been undertaken as yet and the reserves are estimated to be much more than known at present. These clays are classed as a refractory bond clay or fire clay (fusion point 1700°C.)

At present the Ceylon Ceramics Corporation and Lanka Wall Tiles Ltd., utilize the ball clay deposits at Dediyawala. The private sector is also exploring the possibility of extraction of ball-clay and it is suggested that a detailed assessment of the available resources of ball-clay in the Dediyawala area should be undertaken as a matter of priority so that the presently established industries will be assured of a continuous supply of this ceramic raw material. It is also suggested that the Ceramics Corporation and Lanka Wall Tile Ltd., should work out the requirements of ball-clay for the next two decades so that the private sector too could utilize this resource for setting-up new ceramic industries.

(*d*) *Feldspar:* In Sri Lanka feldspar is mainly used in the ceramic and glass industry. Microcline feldspar (potash, feldspar) occurs in pegmatites in various parts of the Island specially in the Rattota, Talagoda, Kaikawela, Namal-Oya and Koslanda areas. The largest deposit of feldspar so far discovered is at Owella Estate (Kaikawela) and is being exploited by the Ceylon Ceramics Corporation.

The total reserves of feldspar in the Island has not been estimated as yet, and every effort should be made to carry out detailed surveys with the main objective of assessing the exploitable deposits. It has also been noted that graphic granite (a rock containing quartz and feldspar) occur in various parts of the Island and this rock could be used in the ceramic industry if the correct proportion of quartz and feldspar are present or after crushing to separate the two minerals.

(*e*) *Vein Quartz:* Vein Quartz deposits of extreme purity (over 99.8 per cent— SiO_2) are found in various parts of the Island. The best known deposits occur

in the Opanaike, Pelmadulla, Pussella, Rattota, Ratnapura and Galaha (Ambalamna Estate) areas. Herath[2] believes that the total reserves exceed 500,000 tons but recent surveys carried out by the Geological Survey have indicated that these reserves could far exceed this figure. Vein quartz is mined at present for use in the ceramic and allied industries.

3.3 Glass Industry

At present this industry is not well established although high quality glass sands were known to occur over a century ago. Except for a few private glass factories turning out bottles at present there are no major factories manufacturing sheet glass, ornamental glass and other products. Proposals for the setting up of a sheet glass factory with assistance from the People's Republic of China were pursued by the Ceylon Ceramics Corporation from 1975 but had to be abandoned due to technical reasons.

Deposits of glass sands are located in the Island and the best known deposits occur in the Marawila-Nattandiya and Madampe areas. A significant deposit of glass sand occur in the Ampan-Vallipuram areas of the Jaffna Peninsula. The total extent of the Madampe deposit is about 640 acres.

The average thickness of the glass sand is about 4 feet without any overburden. However, the sand layer is uneven and it is estimated that nearly 6 million tons are available both above and below the water table. The sands are well graded containing over 98% SiO_2, 1% Al_2O_3 and less than 0.5% Fe_2O_3 and TiO_2. The sands are occasionally mixed with organic matter and other heavy minerals which could be removed by washing.

The glass sand deposit in the Ampan-Vallipuram area occurs in the form of dunes. The area is devoid of any infra-structure facilities such as roads and the development of this deposit will depend on improving of such facilities. The main drawback is the absence of fresh water in the area. It is suggested that a detailed survey should be carried out to ascertain the tonnages and other parameters of this deposit.

There is potential for manufacture of ornamental crystal-ware from high quality quartz present in the Island. Plans are also underway to set up a sheet glass factory within the Free Trade Zone and this factory will utilize the glass sands present in the Marawila-Nattandiya area.

3.4 The Cement Industry

The cement industry is well established in the Island as the main raw materials limestone and clay are available specially in the north-western coastal stretch of the Island. The two cement plants at Puttalam and Kankesanthurai are geared to manufacture about 600,000 metric tons of portland cement per annum by the dry process.

The present expansion programme at Kankesanthurai when completed will add another 400,000 metric tons of cement per annum to the above production.

The Miocene limestone that is presently used for cement manufacture is well developed in the Jaffna Peninsula and stretches as a narrow belt along the north west coast as far as Puttalam. The calcium carbonate content of this limestone is over 95% and the reserves proved by the Department both at Puttalam (Aruwakalu) and Kankesanthurai are over 100 million tons.

The limestone deposit at Mannar which was earlier earmarked for a third cement plant has a reserve of over 30 million tons and could far exceed this figure once detailed surveys are completed. This deposit is not exploited at present as the infra-structure facilities available in Mannar are inadequate at present to set up a cement plant.

The limestone at Aruwakalu which is exploited for the Puttalam cement works has excess silica due to the presence of marl intermixed with the limestone. Serious problems were experienced at the Puttalam plant due to the impure nature of this limestone and the Geological Survey Department was called upon to carry out additional drilling investigations in order to locate pure limestone in 1975 - 1976.

These surveys revealed that pure Miocene limestone is present in the south-western part of the Aruwakalu Hill and the Ceylon Cement Corporation has now opened a new quarry in this area. In addition to these surveys the Geological Survey Department carried out drilling investigations in the Dutch Bay adjacent to this area and proved about 35 million tons of miocene limestone of acceptable quality on the bed of the Dutch Bay to a depth of about 50 meters. Environmental problems have dissuaded the Cement Corporation from exploiting these reserves.

In order to plan the future expansion of the cement industry a careful assessment of the total exploitable reserves of miocene limestone in the Puttalam-Mannar-Jaffna coastal belt has to be undertaken. The Islands off the Jaffna Peninsula contain pure coral deposits and an example of such an occurrence is the Delft Island. Coral limestone is ideal for cement manufacture by the wet or dry process and mining costs will be low.

It is interesting to note that the Akurala swamp close to Ratgama contains coral which could be profitably exploited as it is an inland deposit. A proper assessment of the quality and quantity available may help in deciding whether a small scale cement kiln could be established. This proposition will also help in running the Ruhunu cement works on a profitable basis as this plant has excess capacity for grinding clinker and other facilities such as packing Portland cement. The clinker from a plant close to Akurala could be easily transported to Galle for this purpose.

The private sector has entered the cement industry with the commencement of construction work on a clinker grinding and cement packing plant at China Bay, Trincomalee. This joint venture is between a local collaborator and a Japanese firm. Most of the cement manufactured from this plant will be exported thus earning valuable foreign exchange.

3.5 The Gem Industry

The Gem industry is of the greatest antiquity and in the old scriptures it has been recorded that Sri Lankan gems were brought to the Court of Solomon. Greek writers also refer to Sri Lankan gems during the 1st and 2nd centuries. The Arabs and the Persians also exercised a considerable influence over the gem trade of the Island, during the 4th and 5th centuries. It is believed that nowhere in the world are there so many gem minerals concentrated in a comparatively restricted area of mountainous country such as the Ratnapura gem field. Upto recent times it was generally believed that gemstones occur only in the Ratnapura District but during the recent past gemstones in abundance have been located in the Elahera, Okkampitiya, Embilipitiya and Madampe areas.

The precious and semi-precious stones of Sri Lanka with the exception of Moonstones which are mined from fresh or weathered rock are won from gravels in river beds, buried river valleys and swamps. These gem bearing gravels consist of residual minerals which have withstood the process of weathering, erosion and transport during the past geological ages.

At present extensive gemming activities are carried out in the Ratnapura, Elahera, Okkampitiya, Embilipitiya, Madampe, Eheliyagoda and Rakwana areas. Gemstones have been recently found in the Kantalai area. Most of the gem mining activities are carried out by small scale miners using traditional methods. Coomaraswamy (1903 - 1906) describes these traditional gem mining methods in great detail in the Administration Reports for 1903-1906.

With a view to develop the gem mining industry of Sri Lanka the State Gem Corporation was established in 1971. The Corporation handles the issue of permits for gem mining, cutting and polishing of gemstones and the export of gem parcels. The Corporation has also entered the jewellery trade and has made significant contributions in putting the gem industry on a sound footing. In 1981, gemstones to the value of US $ 32 million were exported, from Sri Lanka. Attractive tax concessions such as exemption from export duty on gemstones have been introduced in order to promote exports.

The main varieties of gemstones present in Sri Lanka are sapphires, rubies and cats' eyes. Apart from these precious stones a large variety of semi-precious stones belonging to the garnet, spinel, zircon and tourmaline varieties are also present.

In 1979, the State Gem Corporation invited offers from foreign and local companies for allocation of lands to carry out large scale gem mining in areas that are to be inundated under the multipurpose Mahaweli programme. Nearly 35 firms were interested at the initial stage but only 9 firms submitted detailed proposals. This project was unsuccessful due to the fact that the companies had to negotiate with private land owners for access to the proposed reservoir beds. The highly rugged nature of the terrain earmarked as reservoirs were not suitable for large scale mechanised gem mining as heavy machinery could not be moved into such areas.

3.6 The Steel Industry

The Ceylon Steel Corporation was established in 1961 for the purpose of implementing the steel project which included the setting-up of a rolling mill and a wire mill under stage I. The rolling mill and wire mill was commissioned in 1967. This mill has a capacity of 80,000 metric tons per annum (on three shifts) and imported steel billets are converted to standard shapes to meet the requirements of the building industry. Cold twisted high strength ribbed tor-steel for the purpose of reinforcing concrete is also produced. The wire mill has a capacity to produce 12,000 metric tons per annum. Under stage II of the expansion programme a continuous casting electro-smelting plant has been commissioned and this plant is capable of utilizing the local scrap iron.

Stage III of the expansion programme envisages the utilization of local iron-ore.

The iron-ore deposits of Sri Lanka could be broadly categorised as follows:-

(a) Deposits of hydrated iron oxide-limonite and goethite present as boulders and near surface deposits.

(b) Magnetite deposits

The limonitic iron ores are mainly concentrated in the south-west part of the Island particularly in the Ratnapura District and to a lesser extent in the Galle and Matara Districts. The ore is generally found in the form of boulders and hill cappings and generally extend to a depth of about 12 feet. The deposits are highly scattered and nearly 50 such deposits are known in the Ratnapura, Rakwana, Balangoda and Kalawana areas. Individual deposits are known to be highly variable in tonnage ranging from 10,000 to 150,000. The total reserves of limonitic iron-ores are estimated at about 2.2 million tons of exploitable grade. The most important deposits occur in the Dela, Noragolla, Opata and Poranuwa areas of the Ratnapura District with an average iron content varying from 53 to 54 percent.

The main drawback in utilizing the limonitic deposits in the local steel industry is the scattered nature and the high phosphorous content (0.74%P_2O_5).

Three magnetite deposits were discovered by the Geological Survey Department at Wilagedara (1959), Panirendawa (1962) and at Seruwila (1971).

The Wilagedara deposit is too small and is of no economic significance. The deposit at Panirendawa is known to contain 5.6 million tons of high grade magnetite which is easily amenable to beneficiation and could be concentrated to give a +65 percent Fe fraction. This deposit however is broken into four separate blocks structurally and cannot be mined as a single unit. The other drawback in the exploitation of this deposit is that it occurs at depths ranging from 30 to 125 meters below ground level and expensive mining methods will have to be adopted for extraction.

The Seruwila magnetite deposit is on the surface and is the most promising deposit of iron-ore found so far in the Island. The magnetite is known to be associated with apatite and copper minerals such as chalcopyrite, bornite and cupreferous pyrite. An advanced exploration programme conducted jointly by the Geological Survey Department and the French BRGM has proved nearly 4 million tons with 40% soluble iron upto a depth of about 100 meters.

A pre-feasibility study on the utilization of the Seruwila magnetite for the local steel industry will have to be undertaken keeping in mind the separation and concentration of copper minerals and apatite.

3.7 Industries Based on Export of Minerals

1. *Graphite Industry:* The graphite industry is over 150 years old and had its boom periods during the 1st and 2nd World Wars when nearly 35,000 metric tons per annum were exported. During this period nearly 6,000 shallow workings, pits and small scale mines were in operation. The industry had its downfall during the post 2nd World War period when the demand for natural graphite and prices in the world market fell considerably. Since 1950, only about 4 large scale mining operations were in existence and from 1965 only the Bogala, Kahatagaha and Kolongaha Mines continued their mining activities.

The graphite mining industry was nationalised in 1971 with the takeover of the Bogala Mines from the private sector. In 1972 the Kahatagaha / Kolongaha mining operations were taken over and the State Graphite Corporation (now State Mining and Mineral Development Corporation) was established.

Graphite occurs in the Island in veins, pegmatites and disseminated flakes in the country rocks. At present only vein graphite is exploited and two working mines are operated by the State Mining and Mineral Development Corporation

at Bogala and Kahatagaha/Kolongaha. These two mines have gone down to depths over 2000 feet and the present machinery in these mines are over 50 years old. The Corporation has replaced certain machinery in order to maintain a production level of about 8,000 - 10,000 metric tons of raw graphite per annum.

Sri Lankan natural graphite is of the highest purity and grades over 95% carbon are common. This variety of graphite is of the crypto-crystalline type and is utilized in the refractory industry, manufacture of carbon brushes, crucibles, dry torch cells, batteries, carbon cinema arcs, paints and lubricants. The State Mining and Mineral Development Corporation is also engaged in the marketing of natural graphite and the main customers are in Japan, U.K. and USA. Graphite is marketed according to the carbon content and particle size. Sri Lankan natural graphite is presently facing severe competition from other sources of origin such as the People's Republic of China and Brazil.

The traditional markets for Sri Lankan natural graphite have been lost during the last 2 years due to indiscriminate price increases and lack of proper market intelligence within the Corporation. In order to regain our traditional markets a more realistic pricing policy has to be adopted and the requirements of customers specifications have to be met. Every effort should also be made to identify collaborators for setting up graphite based industries in Sri Lanka. The total reserves of natural graphite is not known and a systematic exploration programme has to be initiated to assess the potential specially in the graphite bearing belt that runs from the south-central part of the island to the north-east.

2. *The Beach Mineral Sands Industry:* The Ceylon Mineral Sands Corporation was established in 1957 primarily for the exploitation of the Pulmoddai heavy sands deposit. The Corporation now operates an integrated mineral separation plant at Pulmoddai for the separation of ilmenite, zircon and rutile. The present facilities have a capacity to produce 85,000 tons ilmenite, 11,000 tons of rutile, and 8,000 tons of zircon per annum. Ilmenite, rutile, zircon and monazite occur in the beach sands of Sri Lanka but the heavy concentration at Pulmoddai has made only this deposit economically viable for exploitation.

Pulmoddai is located along the north-eastern coast of Sri Lanka and is about 80 km from Trincomalee. The deposit is about 10 km in length with an average width of about 100 meters. It is estimated to contain about 6,000,000 tons of heavy sands with an average composition of 70-72% ilmenite, 8-10% zircon, 8% rutile and 0.3% monazite. About 1% sillimanite is also present. The Pulmoddai deposit is one of the best known in the world. The heavy sands are collected by scraping the beach and it is known that this deposit is seasonal where the sands are brought by waves during the north-east monsoon. The seasonal replenishment of the sands have not been studied and such studies will help in ascertaining the quantities that are brought to the shore annually.

As a part of the expansion of the beach mineral sand industry a complete assessment of the coastal area between Mullaitivu and Nilaweli was undertaken by the Geological Survey Department in 1979. As a result of this survey three very promising deposits at Nayaru, Koduwakattumalai and Tavikkalu were located. A detailed exploration programme undertaken by a foreign firm has conclusively proved a reserve of 475,000 to 700,000 tons of rutile, 350,000 to 500,000 tons of zircon and 2 to 4 million tons of ilmenite.

The future expansion programmes of the Ceylon Mineral Sands Corporation include the setting up of wet-magnetic separators for increasing the production of heavy sands, electro-smelting of ilmenite to produce titanium slag and the setting up of a titanium pigment plant. The upgrading of ilmenite to produce synthetic rutile is also being considered by the Corporation.

4. Recent Mineral Discoveries in Sri Lanka

Two significant mineral discoveries were made in 1971 by the Geological Survey Department during the systematic geological mapping programme of the Island. These two discoveries are:

(a) The Eppawela rock phosphate deposit;

(b) The Seruwila copper-magnetite deposit.

(*a*) *The Eppawela Rock Phosphate Deposit:* The Eppawela rock phosphate deposit was discovered by the Geological Survey Department during the systematic geological mapping of the 1" topographical sheet of Anuradhapura. Eppawela is located on the Kekirawa-Talawa Road and is approximately 110 miles from Colombo.

This phosphate deposit is of the carbonatite type and the main phosphatic minerals are (1) chlor-fluorapatite and (2) francolite (carbonate apatite). The other minerals present in this rock are iron carbonates of the martite and goethite type.

The major deposit has a surface area of about 1000 acres and consists of six elevated hillocks rising to a maximum altitude of 200 meters above mean sea level (Kiriwelhinna Hill). The exploitable ore zone consists of a brecciated rock with a modal composition of over 80% phosphate bearing minerals. This zone extends below the surface to an average thickness of about 70 meters from the crests of the hills.

The average P_2O_5 grade of this phosphate rock is about 36% and the main drawback in utilizing this ore for wet process phosphoric acid manufacture is its high chloride content (av. 1%) and the high $Fe_2O_3 + Al_2O_3$ contents (av. over 5%). The acceptable limits for industry is 0.05% chloride and 4% $Fe_2O_3 + Al_2O_3$.

Since the discovery of the Eppawela rock phosphate deposit the Geological Survey Department carried out an extensive exploration programme that included the drilling of 27 deep holes. These investigations have proved a firm reserve of 25 million tons of phosphate rock with an average grade of 36% P_2O_5 for only a part of the northern sector of the deposit. The proved and inferred reserves are now estimated at about 60 million tons.

The various Agricultural Research Institutes in Sri Lanka initiated research studies from 1972 to ascertain the use of this valuable mineral resource as a phosphate fertilizer for direct application. These studies were successful for the tea sector and the rubber sector. At present the State Mining and Mineral Development Corporation is producing an average of 15,000 metric tons per annum of ground phosphate rock with a minimum of 35% P_2O_5 and 85% passing the 100 BSS Mesh. The recent field trials by the Rubber Research Institute have shown that the ground Eppawela rock phosphate is suitable for the entire rubber sector except a small area in marshy soils of the south-west where granulated NPK fertilizer is used.

In order to assess the suitability of the Eppawela rock phosphate for the manufacture of wet process phosphoric acid, a research programme was under taken by the International Fertilizer Development Centre in Alabama, USA in late 1979. These studies have revealed that the Eppawela phosphate rock could be used for manufacture of high analysis phosphatic fertilizer such as di-ammonium phosphate and triple super phosphate but an industrial method of removal of the high chloride, iron and aluminium has to be identified by carrying out further pilot plant tests.

The Ministry of Industries and Scientific Affairs in April 1979 called for proposals from international firms engaged in manufacture of phosphate fertilizer to participate on a joint venture basis to develop the Eppawela phosphate deposits. Twenty-five inquiries from plant contractors, consulting firms and organisations engaged in operating phosphatic fertilizer plants were received and on the recommendations of an Evaluation Comimttee, the Cabinet Sub-Committee on Economic Development has approved in principle the proposal from Agrico Chemical Company, Tulsa, USA, to develop the phosphate deposit at Eppawela.

A special Committee is now scrutinising the agreements and it is hoped that the final approval from the Government to go ahead with this project will be given soon.

This project envisages the manufacture of 530,000 tons per annum di-ammonium phosphate entirely for export and 50,000 tons per annum of triple super phosphate for local use. The research studies conducted by the Agrico Chemical Co.,

at their own expense since 1979 have been successful and a practical methods of processing the Eppawela rock to manufacture wet process phosphoric acid has been identified.

If all approvals by the Government are received before the end of 1983, the proposed phosphate fertilizer plant with foreign collaboration will be on-stream by 1989 - 1990.

(*b*) *The Seruwila Copper-Magnetite deposit:* The Seruwila copper-magnetite deposit was discovered by the Geological Survey Department in 1971 during the systematic geological mapping of the 1" topographical sheets of Trincomalee and Kathiraveli. Seruwila is located in the Trincomalee District and can be approached from the Kantalai-Seruwila-Muttur Road. This prospect is about 275 km from Colombo and is located in one of the most inaccessible areas of Sri Lanka.

The exploration work conducted by the Geological Survey during the period 1971 - 1977 included geological mapping, geochemical and geophysical surveys and drilling operations. This work revealed that the ore is widely scattered and exposed in three areas namely Arippu, Block "C" and Kollankulam. In 1979 a joint advanced exploration programme was initiated by the Geological Survey Department in collaboration with the French BRGM. This programme was carried out over a period of one and a half years and four reports on the quantity and quality of the ore are now available.

The final report has revealed that approximately 4 million tons of exploitable ore upto a depth of 100 meters are available **only in the Arippu area.** The average grade of the ore is 1.5% copper with 40% soluble iron as Fe.

The Seruwila copper-magnetite prospect is most promising as a source of iron-ore for the Oruwela Steel plant and a feasibility study has to be conducted to draw up long term plans for its exploitation.

The Seruwila ores consist primarily of magnetite and the copper-sulphide minerals are chalcopyrite, pyrite, and cupreferous pyrite. Traces of pentlandite, borenite, azurite, tellurides, etc., were also detected during this exploration programme.

5. Target Areas for future Exploration

(*a*) *Eastern Highland/Vijayan Boundary:* With the discovery of the Seruwila copper magnetite deposit which is the first base metal find in Sri Lanka, a new area for exploration was opened. The location of the Seruwila ores on the boundary between the Highland/Vijayan (the two major lithological zones) indicate that this boundary is a potential target area for base metal mineralization. This boundary

which is approximately 25 km wide and 550 km long has to be examined very carefully for detection of base metals such as copper, cobalt, zinc, etc. The analytical data of the Seruwila ores have also revealed minor amounts of silver, gold, and tellurides (platinum bearing minerals). Basic rocks such as pyroxenites, amphibolites and peridotites are identified as host rocks for base metals and these rocks have been found in the Seruwila drill cores.

A systematic exploration programme should be undertaken as a matter of priority to detect any base metal mineralization along the Highland/Vijayan boundary. Such a programme should include detailed geological mapping, integrated geochemical and geophysical surveys and diamond core drilling.

It is also suggested that an integrated airborne magnetic/radiometric survey be carried out to pinpoint target areas for exploration on the ground if funds could be obtained under existing aid programmes.

The present geological information along the Highland/Vijayan boundary in the south-eastern part of the Island has also revealed that serpentinite outcrops in the form of ring structures exist and some of these serpentinites showing lateritic characteristics have anomalous nickel value.[1] This discovery will be followed-up by the Department during the detailed programme for investigating the Highland Series/Vijayan Series boundary.

(*b*) *Stream sediment panning programme for Detection of Uranium:* The Geological Survey Department initiated a stream sediment panning programme covering the entire Precambrian basement of the Island in 1979 with the main objective of detection of uranium and other base metal mineralization. This programme was conducted with the assistance of the International Atomic Energy Agency (IAEA) of the United Nations.

The IAEA in Vienna made available an expert to plan out this stream sediment sampling programme. The results of this initial survey were reviewed by another expert at the beginning of 1983 and nine target areas have been identified for further follow-up work which will include the collection of samples on a closer grid, radon gas-surveys collection of chip samples and diamond core drilling.

The total area for the follow-up work is 6780 sq km and this area has been selected from the original area of 60,000 km^2 covered by the preliminary survey.

The Geological Survey Department is carrying out these follow-up surveys on a continuous basis and hopes to complete the entire programme during a period of 5 years. Assistance from foreign geological surveys and exploration companies will be of great help to complete these surveys before the target date.

6. Conclusions

An attempt has been made to describe the mineral resources of Sri Lanka and highlight the present status of mineral resource development in context with the established mineral based industries. Minerals are non-renewable resources and the exploitation and utilization of such resources should be carried out on a carefully planned long-term programme. A comprehensive inventory of the available mineral resources presently utilized in industry should be drawn up as a matter of priority keeping in mind the annual consumption. Immediate steps should be taken to assess the potential of the mineral resources presently utilized in industry and adequate safeguards should be taken to ensure regular supplies. The exploration for new mineral deposits should also be undertaken by the Geological Survey Department on a long-term plan so as to sustain and expand the existing mineral sector industries and start new industries based on future mineral discoveries. The 5 year Public Investment Programme of the Government drawn up by the Ministry of Finance and Planning for 1983 - 1987 has stressed the need for increased export earnings and the mineral sector has been identified as an area where rapid growth could be achieved. In order to realise this objective the Government should provide all assistance to upgrade the present institutional facilities of the Geological Survey Department, as such facilities will be a vital pre-requisite in the proper assessment of the economically exploitable mineral resources of Sri Lanka.

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An Investigation of the Factors Affecting Paddy yields from Two Districts

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Abstract: Factors affecting paddy yield in the Anuradhapura and Ratnapura districts are investigated. Regression analyses are performed using data from 1962 - 1978, and particular attention is given to the growth stages of the Paddy plant and its water requirements at each stage. The results indicate that if the total extents cultivated has been increasing then this has a large influence on yield per acre. This was seen at Ratnapura for both seasons and in the Maha season at Anuradhapura. The study also shows that the non-climatic factors influenced by technological research, (called technological factors in this paper), such as transplanting, type of variety, fertilisers and irrigation have played a major role in paddy production, particularly at Anuradhapura. Variations in climatic variables have not influenced variation in yield, as greatly as changes in technological factors. Also the results indicate that the climatic variables which are important depend on the type of technology employed. For example at Anuradhapura, the Yala season has increasingly relied on major irrigation schemes and temperature was shown to be important, but in the Maha season some farmers still rely, to a certain extent, on rainfall, and consequently rainfall was indicated as an important climatic factor. The study has highlighted many areas of further work and the direction further research should take to enable a comprehensive knowledge of the effects of factors and their interactions to be developed.

1. Introduction

Self sufficiency in rice has been a target that Sri Lanka has been striving to achieve for many years. This can be achieved basically by

(a) increasing acreage under paddy.
(b) increasing paddy plant yields.
(c) reducing risk of crop failure.

There have been several measures taken to achieve this goal of which the development of the Dry Zone for irrigated paddy cultivation has been a major one.[1] In the mid 1960's the emphasis for self sufficiency was on increasing paddy plant production as opposed to area expansion.[12] For the paddy farmer this meant improved credit facilities, subsidised fertilizers and an improvement of cultural practices, through better extension. Consequently paddy production increased

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by 55% during 1966 - 1970.[7] This was then followed by the introduction of the new high yielding varieties[1] which were capable of yielding 100 bushels per acre compared to the 60 bushels per acre of the traditional varieties.

In 1972 the Ministry of Planning developed "The five year plan"[13] which aimed at self sufficiency in 1977. The plan recognised the scope for more extensive use of land and labour, for increasing output with high yielding strains and for better use of water sources. Large scale irrigation schemes were planned and developed. Also increased supplies of fertilizer, weedicide and pesticide were made available in conjunction with programmes for rural credit. However, in 1974 the government withdrew the fertilizer subsidies which subsequently meant that most farmers were using fertilizers at levels of efficiency much lower than recommended. Chambers, in 1975[4] pointed out that both the severe shortage of the necessary imputs, on which the green revolution is based, and the economic difficulties of Sri Lanka at the same time, made the immediate prospect of self-sufficiency less feasible. Chambers stressed that a greater emphasis ought to be placed on water management. The above can be summarised by a quote from Seneviratne and Appadurai.[14] "Self-sufficiency in rice has been declared the objective of agricultural policy in this country for decades and numerous measures have been adopted in an attempt to realise this goal with varying degrees of success."

This paper is not intended, to propose methods designed to achieve self-sufficiency. If a clearer understanding of the role played by the various factors affecting paddy yield can be formed, then paddy farmers can make efficient use of available resources to obtain maximum results. If this could be achieved then self-sufficiency would not be such a distant target. There has been much speculation and discussion of the factors affecting paddy plant growth but very few real statistical analyses with concrete results have emerged. This paper sets out the results of a preliminary study carried out on the factors affecting paddy. The results obtained are primarily intended only to give an indication of areas into which further research regarding crop-climatic relationships could be pursued more deeply.

2. Material and Methods

To simplify our initial study we analysed paddy yields for Maha and Yala seasons from two districts; one in the dry zone (Anuradhapura) and one in the wet zone (Ratnapura). This enabled us to obtain a picture of the regional differentiation in productivity potentials and also to provide an indication as to why these differences exist. Factors which affect paddy yields can be categorised as those related to:

(i) **methodology** eg. variety of seed, method of irrigation, fertilizer.
(ii) **climatic** eg. rainfall, temperature, number of rainy days.
(iii) **economic** eg. fertilizer subsidy schemes, rent acts, insurance.
(iv) **physical location** eg. soil, drainage, vegetation cover.

The factors covered by this study are to be found in categories (i), (ii) & (iii).

The paddy statistics and data related to category (i) were obtained from the Agricultural Division of the Department of Census & Statistics. This data is available at district level from 1962. The paddy yields per acre are estimated from crop cutting surveys.

The climatic data was obtained from the Colombo Meteorology Department. The Statistical Unit, Colombo University has been collecting and processing climatic variables from most of the districts in Sri Lanka. An efficient data entry system has been developed for entering, checking and editing the data, thus the climatic variables are thought to be reliable. Although daily weather data is available, monthly values were used.

For each season and each district the data set thus consisted of paddy yield per acre, total extent cultivated, percentage of area cultivated under major, minor, or rain fed irrigation schemes; per cent acreage under transplanted methodology; per cent acreage under pure-line seeds; fertilizer issues; monthly rainfall; monthly maximum temperature; monthly minimum temperature; monthly average temperature; total monthly rainfall and number of rainy days observed in each season.

3. Method of Analysis

In crop climatic studies there are several different approaches to understanding the degree of influence that various climatic factors have on crop yields. These can be roughly classified as follows:[3]

(a) Models which consider the impact of meteorological variables on specific processes e.g. transpiration, photosynthesis. These models then simulate the processes by mathematical equations.

(b) Models which use meteorological variables on a daily basis and which relate to the development periods of the plant.

(c) Models which use a sample of yield and meteorological data and produce estimates of the coefficients of a regression equation.

The approach used in this paper is influenced by methods (b) and (c). Since this study is a preliminary investigation then interest is in using a method which will indicate the important factors rather than in developing a model. Consequently regression analysis is used to highlight the relative importance of the variables under consideration. It is intended that the work done in this study will lead to a more detailed investigation where a model will be developed. This is discussed later.

Before any statistical analyses were performed, histograms and time series plots of each variable were constructed to check the data for anomalies, possible errors and to obtain an idea of how each of the factors have been changing over the time period considered. The data was then summarised in the form of means and standard deviations to enable one or two simple comparisons between districts to be made.

For the climatic data, to consider monthly figures meant that for each season a maximum of 8 monthly figures for each variable is possible, however not all 8 monthly values for all the 10 weather variables can be incorporated simultaneously into a regression analysis. We have only 18 yield observations so it is not possible to conduct a multiple regression with 80 explanatory variables. This means that the explanatory variables need to be condensed or reduced into a manageable set before it is possible to include them in a multiple regression analysis. There are several methods of doing this. Examining the work of other authors in this area showed that some authors used multivariable techniques such as principal components [9] and others have used techniques which screen the meteorological variables,[2] i.e. reject or select variables depending on their correlation with yield. Kendall has indicated that there are disadvantages and advantages implicit with both of these techniques.[10] Also it is known that some of the weather variables have a considerable effect on the paddy plant during specific growth periods and no effect during others. Therefore some of the explanatory variables could well be unnecessary, consequently the latter method of screening is employed in this study, although it is realised that it has its limitations, and a variable was only discarded if it was indicated statistically and known agronomically as not being important.

The aim of the paper is to discover which factors play a significant role in explaining the variation in paddy yields. This is done through a multiple regression analysis[15] which is conducted in two steps. The first step, as outlined in the above paragraph, identifies the factors which appear to be related to yield. The second step uses forward selection to choose a subset, from the explanatory variables identified at the first step. There are several other methods of selecting an appropriate subset of explanatory variables, apart from forward selection. The drawbacks of most of these techniques are discussed in Draper and Smith and although forward selection may not be the most appropriate technique,[6] it was the only one available at the time of this study.

STEP I: The correlation structure of the factors was examined as it was necessary to understand the interrelationships which exist between the variables. Simple linear regressions between the yield per acre and those factors believed to affect

paddy yields were performed. In order to decide which regressions were appropriate the percentage of variation accounted for by each regression and the corresponding F-values were noted. From these simple regressions and supported by agronomic knowledge the factors could be classified into 3 groups:

(A) Those which affected yields directly.

(B) Those which did not appear to have marked effect on yield but whose rejection was not obvious.

(C) Those which had no effect on yield at all.

The factors categorised into A are those which appear to be the most effective in changing the yield per acre. However, most of these factors are highly correlated so when they are all incorporated into a multiple regression the total amount of variation explained by them all may not be as large as expected and usually only one or two need to be included in the final subset. Also, multicollinearity amongst the explanatory variables can have serious consequences on a multiple regression analysis.

The factors grouped in B are those variables which seem ineffective on their own but may be operationally important when considered with other variables in the regression model. A non-significant term in the simple regressions analysis cannot always be ignored especially if it is close to the tabulated F-value. In this case it is preferable to include those factors with a large but non-significant F-ratio and to test them with other variables rather than reject them at this stage.

Hence the above classification and the inter-relationships highlighted by the correlation analysis produced a final subset of variables to be considered in the final multiple regression analysis. For the simple regressions we have used

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \text{ where } E(\varepsilon_i) = 0, \quad \text{Cov } (\varepsilon_i, \varepsilon_j) = 0, \; i \neq j$$

$$V(\varepsilon_i) = \sigma^2 \text{ and } \varepsilon_i \sim N(0, \sigma^2)$$

y_i = Yield/acre (the dependant variable),

x_i = the factor being considered (the independent variable).

STEP 2: The final subset of variables comprised of groups A and B for both of the seasons, Maha and Yala in each of the districts. A forward selection, multiple regression analysis was performed on the above subset, by using a statistical computer package available at Colombo University. This is a sequential procedure in which explanatory variables are added into the regression analysis one by one. At each stage, the explanatory variable included is the one which contributes most, out of those not yet selected, to the regression sum of squares. The selection stops

when the contribution is judged to be statistically insignificant. The final regression analysis then consists of a set of explanatory variables whose combination cannot be improved on in terms of explaining the variation in yield (i.e. any other variable added to the final combination does not significantly improve the proportion of yield variance explained by climatic factors).

It is the variables included in this set which are of interest for helping to understand which factors play an important role in the production of paddy.

When the selected independent variables are $x_1, x_2, \ldots x_t$ then the final multiple regression equation takes the form

$$y_i = \beta_0 + \beta 1 \times_{ij} + \beta_2 \times_{2i} + \beta_3 \times_{3i\ldots} + \beta_t \times_{ti} + 3_i \; i = 1 \; (1) \; n$$

where ε_i are assumed to be independently and identically distributed random variables with an $N(0, \sigma_2)$ distribution. However the regression equation is not a sum of factors "making" a yield but a combination of factors which explain the variation in yield, and as it was not intended in this paper to develop a model, then, apart from the sign, the coefficients are of little interest. The estimation of effects is discussed later in areas of further work. The relative importance of the explanatory variables finally chosen and the implications these have on areas of further work are the main concern of this paper.

4. Analysis

4.1 Descriptive Analysis

(a) Paddy yield per acre

The variable of most interest is the yield per acre of paddy whose variation is what we are trying to explain. Table 1 presents the yield per acre at each location and each season. It shows paddy yields at Anuradhapura exhibiting greater variation when compared to yields at Ratnapura.

TABLE 1. Statistics related to yield per acre at Anuradhapura and Ratnapura

District	*Season*	*Mean*	*Std. Deviation*
Anuradhapura	Maha	51.54	10.71
	Yala	46.07	10.21
Ratnapura	Maha	37.75	06.30
	Yala	38.23	04.47

Table 2 presents differences between the means at the two locations (1 & 2) and the difference between the two seasons at Anuradhapuara. A significant difference in the yields between the two districts for both Maha and Yala is indicated. In each case Anuradhapura reveals a significantly higher yield per acre. Hence paddy plant production at Anuradhapura is higher than that at Ratnapura. There is no significant difference in the mean yields per acre between the two seasons at Anuradhapura, hence the paddy plants perform equally well in the two seasons.

TABLE 2. t-test for differences in mean between locations and between seasons at one location

	Differences between Means	*Std. Error of Difference*	*Observed t-statistic*	
1. Maha	13.79	02.93	04.71*	⎫ based
2. Yala	7.84	02.63	02.98*	⎭ on 17 d.f.
3. Anuradhapura	05.47	03.48	01.57	based on 34 d.f.

(* - Significant at the 5% level)

The differences between the locations and seasons, over the period of interest, can also be seen from Figure 1. In studying the factors affecting paddy production, we should be able to explain why these differences in the means and standard deviation exist. (The yields for Maha 74/75 at Anuradhapura was considerably lower than others. This was due to a severe drought in the area at that time).

(b) Extent Cultivated

For Anuradhapura there is a large difference, in the extent cultivated, between the two seasons. The extents cultivated in Maha have a very definite increasing trend over the period 1960 - 1980, whereas in Yala acreage fluctuates about a constant value. This implies that at Anuradhapura in the Maha season conditions are (or becoming more) conducive to supporting a much larger acreage for paddy production than in Yala. One obvious factor which causes this difference is the difference in the rainfall patterns. Extents cultivated in both seasons at Ratnapura, are almost the same and show a similar pattern over years of a small steady increase which levels off eventually.

(c) Irrigation

Anuradhapura

A larger percentage of the acreage in Yala than in Maha is under the major irrigation scheme. This is to be expected as rainfall received in Yala is a lot less than in Maha. The percentage of paddy acreage under rainfed in Yala is almost nil.

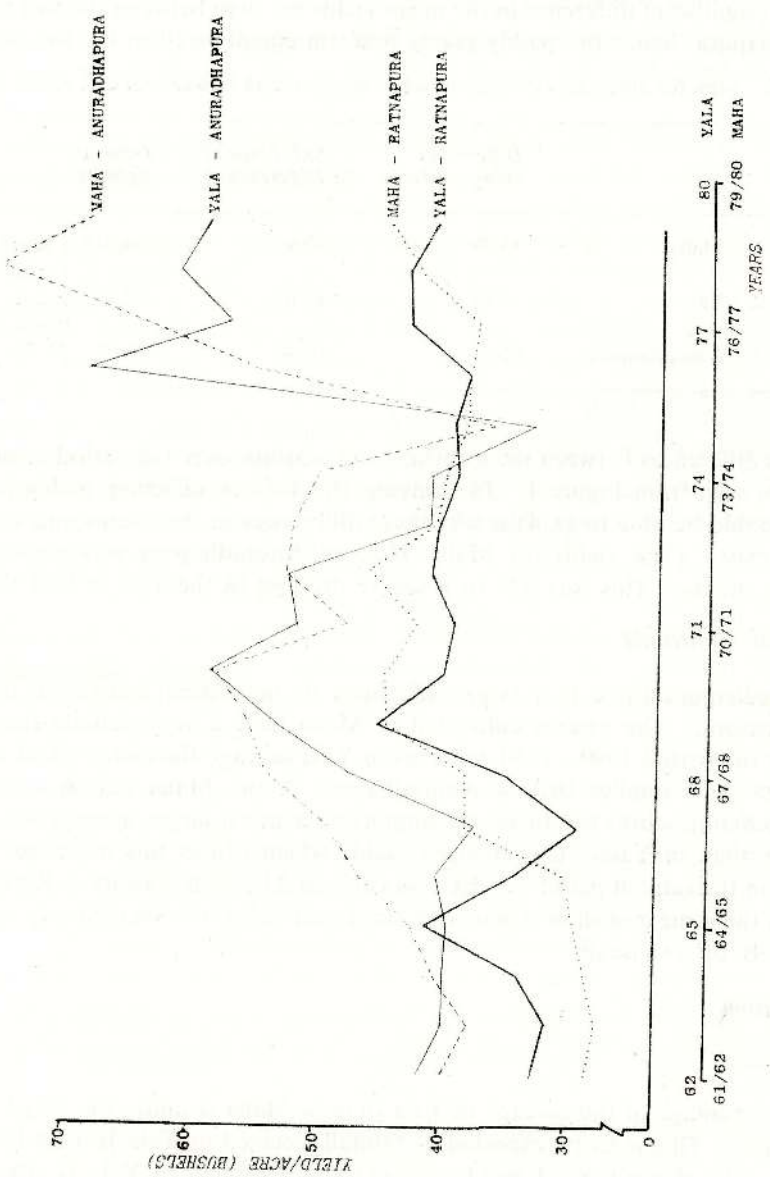

FIGURE 1. Yield per acre at Anuradhapura and Ratnapura (1962 - 1979).

Also within Yala there is an increasing trend in percentages under major irrigation schemes. In Maha there has been only a slight increase in percentages under major irrigation over the past 10 years but still a greater percentage are dependent on minor irrigation with a small almost constant percentage dependent on rainfall alone. Hence in Yala, farmers at Anuradhapura are totally dependent on irrigation schemes and thus have almost completely changed over from minor irrigation schemes to supplement the water received from the Maha monsoon.

Ratnapura

There is very little difference in the patterns of the irrigation schemes between the two seasons. This is to be expected, as the difference in the rainfall experienced in the two monsoons is not as great as that in Anuradhapura. In Ratnapura the farmers rely mainly on minor irrigation and rainfall. The percentage under rainfed has remained fairly constant over the period of study. The percentage under rainfed in Ratnapura is much higher than percentage under rainfed in Anuradhapura during the Maha season.

(d) Weather variables

Paddy production in Sri Lanka is dependent on two monsoon seasons. An idea of the pattern of the climatic variations experienced in the two districts is necessary before correlating yields with climatic factors.

For a representative picture of the rainfall, data was collected from meteorology stations within each district. The daily rainfall figures from 5 stations scattered throughout the Anuradhapura district were averaged to give the pattern of daily rainfall expected for Anuradhapura district. Similarly, for Ratnapura 3 meteorology stations were used. Figures 2 and 3 show the differences between the two seasons at each place.

Anuradhapura

The total precipitation experienced in the Maha season is almost twice the amount in the Yala season. The graph also shows there is a decreasing trend in rainfall amounts recorded in the Maha season, over the period of study.

Ratnapura

The difference between the rainfall in the two seasons is not as large as at Anuradhapura. Generally the Yala season receives almost the same amount of rainfall as the Maha season.

During the Yala period and the inter-monsoonal periods, the amount of rainfall and the number of rainy days is much less for Anuradhapura than Ratnapura.

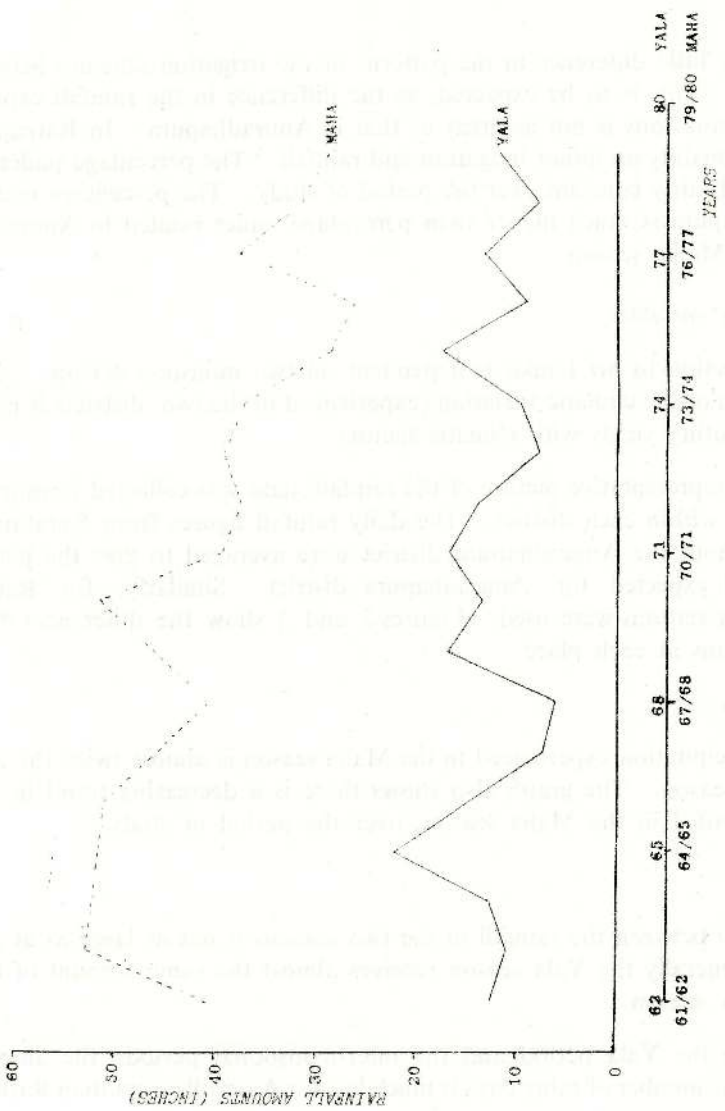

FIGURE 2. Rainfall amounts at Anuradhapura (1962 - 1979).

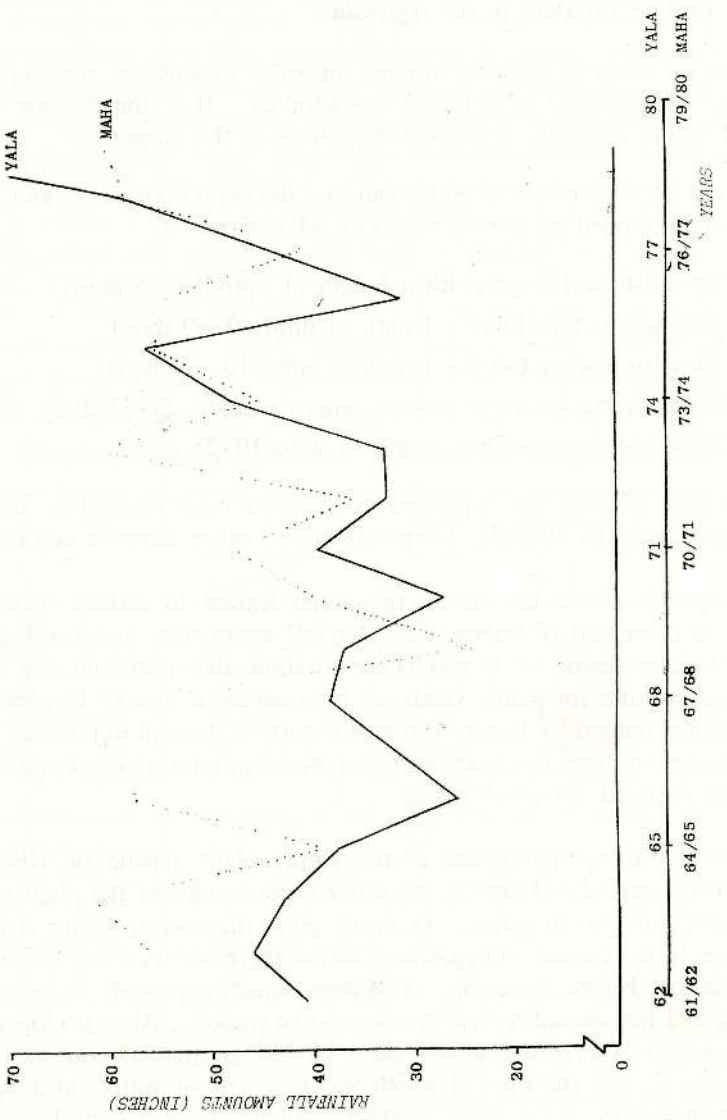

FIGURE 3. Rainfall amounts at Ratnapura (1962 - 1979).

The other climatic variables considered were maximum and minimum temperatures. Both of these temperature variables were more variable in Anuradhapura than in Ratnapura. Although the temperatures experienced were not identical for the two places, differences were not as marked as those found in the rainfall figures.

4.2 Use of weather variables in the regression

In considering the effect of weather variables on paddy production, the crop weather analysis approach discussed in section 3 was adopted. Here the climatic variables were related to the different development periods of the crops.

The total growing period of paddy can vary in length between 95 and 150 days and this can be classified by growth stages as follows (see 7).

(i) Establishment stage (with a length of upto 10 - 15 days)
(ii) Vegetative stage (with a length of upto 40 - 60 days)
(iii) Flowering stage (with a length of upto 10 - 15 days)
(iv) Yield formation stage (with a length of upto 25 - 35 days)
(v) Ripening stage (with a length of upto 10 - 25 days).

The length of, and the requirements at, each stage depend on the paddy variety, its sensitivity to sunlight, temperature and other climatic conditions.

For example, Grist[8] has shown that Joponicarice in certain environments can yield up to twice that of Indica rice. Kung[11] states that, in general, germination does not occur below 12° C and Domros[5] states that optimum day time, air and water temperatures for paddy yields are between 28° C and 32° C, which agrees with temperatures quoted by Kung, who also reports that small differences between day and night temperatures (i.e. maximum and minimum) during flowering and yield formation are required for good yields.

The total water requirements of the paddy plant depend on climate and length of growing period. However, the water requirements of the plant are different at the different growth stages. Domros[5] gives the corresponding details for rice cultivation in Sri Lanka. Evapotranspiration increases with vegetative growth and is highest just before flowering. The most sensitive periods of water deficit are flowering and the second half of the vegetative period. Also prolonged submersion of paddy rice adversely affects plant growth, particularly during the yield formation stages.[11] So the time at which water deficits or water surpluses occur is an important factor. Thus some weather variables have a considerable effect on the paddy plant during specific growth periods and no effect during others.

In order to investigate the effect on yield, of water deficits and other climatic factors at certain crop development periods of the plant, these periods had to be interpreted in terms of particular months of the year. The total growth period for a Maha season crop is between September/October and February/March and for Yala between April and August. These monsoon periods coincide with the paddy cropping seasons and can be divided into the different crop development stages. The breakdown of the total growing period into the five stages in terms of the number of days was shown above. This was used to obtain a corresponding breakdown for the Maha and Yala cropping seasons. By calculating what proportion of the total growing period each of the five development stages takes, the time periods in each season, which correspond to each stage were found. Table 3 gives an idea of the length of each of the growth stages, the corresponding months and an indication of the water requirements.[11] This breakdown is not exact as it would be difficult to obtain a precise correspondence between the months and the growth stages since these will vary over the years, depending on planting dates. This aspect will be discussed later. The amount of rain falling in September/October and April was considered important as this is the time when the rains should have started and consequently affects planting dates. Water requirements are also large in the flowering period. i.e. January and June. The effect of the amounts of rain in the ripening stage, i.e. February/March and August was also examined.

TABLE 3. Length of each growth stage of the paddy plant and their water requirements

Stage	*No. of days in period*	*Months corresponding to growth stage*		*Water requirements*
		Maha	*Yala*	
1. Establishment	10 - 15	Sept.-Oct.	April	Deep
2. Vegetation	40 - 60	Oct.-Dec.	April-May	Medium
3. Flowering	10 - 15	January	June	Deep
4. Yield formation	25 - 35	February	July	Shallow
5. Ripening	10 - 25	Feb.-March	August	No water

To determine the adequacy of the total amount of rainfall available during the growth period

(a) average monthly rainfall totals for Maha and Yala;

(b) number of rainy days within each season;

were examined. For the effect of differences in day and night temperatures during the flowering and yield formation, the difference of maximum and minimum temperatures in January and February for Maha and in June and July for Yala were considered. Average temperatures for these periods and the yield formation stage were also considered.

5. Results and Discussion

5.1 Results of Step I

It was noted in section 4.1a that the yields for Anuradhapura Maha '74/'75 were very low. For the simple linear regressions performed the analysis was repeated, omitting this point and the corresponding data. If the effect of this produced a significantly different regression to that obtained earlier, then the '74/'75 data would be regarded as outliers of an extreme nature. However, this was not found to be the case and so it was not necessary to reject the '74/'75 data points.

The large number of factors which were expected to affect yields were categorised into the three groups by the method outlined in section 3, i.e. by looking at the correlation structure of the independent variables and by performing simple linear regressions between yields and each independent factor. The corresponding results are set out in Table 4. Only the factors in categories A and B are given since category C contains factors which were considered to have no effect on yields.

So a set of twenty possible factors which were believed to effect paddy yields was reduced to a smaller subset of 13 and 9 variables for Anuradhapura Maha and Yala respectively and 11 variables for both Ratnapura Maha and Yala. Each of these smaller subsets comprises of the factors listed in categories A and B, which have been shown statistically to be associated with the yield per acre.

5.2 Discussion of Results

The following section discusses the relative importance of each of the variables chosen in the final subset. This is done by examining the changes in R^2 and $\overline{R}^2$ on the introduction of each variable.

$$R^2 = \frac{\text{variation of yield explained by all regressors}}{\text{total variation of yield}}$$

$$\overline{R}^2 = \left(R^2 - \frac{k}{n-1}\right)\left(\frac{n-1}{n-k-1}\right) \quad \text{(called the adjusted or corrected } R^2\text{)}$$

where k = number of regressors in the (analysis) model

n = number of observations

R^2 provides an overall index of how well y can be explained by the regressors. Since the inclusion of an irrelevant regressor will increase R^2, then it is desirable to correct for this, as shown above by $\overline{R}^2$.[16]. Table 6 shows the values of R^2 and $\overline{R}^2$ at each stage of the analyses.

TABLE 4. Variables having greatest influence on paddy yields at different locations and different seasons

Anuradhapura Maha	R^2	*Anuradhapura Yala*	R^2	*Ratnapura Maha*	R^2	*Ratnapura Yala*	R^2
A							
Transplanted extents	0.80	Extent under major irrigation	0.52	Total extent cultivated	0.79	Total extent cultivated	0.47
						Pureline seed	0.38
Total extent cultivated	0.75	Extent under minor irrigation	0.51	Extent under minor irrigation	0.56	Extent under minor irrigation	0.313
Rainfall in September	0.60	Transplanted extents	0.37	Extents under pureline seeds	0.55	Extent under major irrigation	0.26
Extent under pureline seeds	0.58	Extent under pureline seeds	0.32	Fertiliser	0.46	Fertiliser	0.19
				Extent under major Irigation	0.41		
Rainfall in March	0.40	No. of rainy days	0.29	No. of rainy days	0.36	Rainfall in May	0.20
Mean Temp. in March	0.38						
Fertiliser	0.32	Fertiliser	0.21			Transplanted	0.19
Rainfall in January	0.30			Extent under transplanted	0.35	Average temperature July	0.19
Number of rainy days	0.21			Average temperature in March	0.23	Rainfall in April & May	0.13
B							
Extents under minor irrigation	0.17	Average temperature in August	0.17	Average monthly rainfall total	0.14	Difference in temperature June	0.09
Extents under rainfed conditions	0.17	Temperature range in June	0.09	Mean temperature in February	0.16	Rainfall August	0.08
Difference in Jan. Maximum & Minimum temperature	0.15	Temperature range in July	0.13	Rainfall in March	0.08		
Average temperature in February	0.14						
Number of variables	13		9		11		11

TABLE 5. Variables selected as having a significant effect on paddy yields.

Anuradhapura		*Ratnapura*	
Maha	*Yala*	*Maha*	*Yala*
1. Transplanted extents.	1. Extents under major irrigation	1. Total extents cultivated.	1. Total extents cultivated.
2. Total extent cultivated.	2. Temperature range in June.	2. Rainfall in March.	2. Rainfall in August.
3. Extents under pureline seed.	3. Extents under pureline seed.	3. Extents under pureline seed.	3. Extents under major irrigation
4. Rainfall in September.	4. Temperature range in June and July.	4. Average temperature in March	4. Extents under minor irrigation.
5. Number of rainy days.	5. Number of rainy days.	5. Fertilizer.	5. Transplanted extents.
6. Rainfall in March.	6. Average temperature in August.	6. Extents under minor irrigation.	6. Temperature range in June.
7. Rainfall in January.	7. Fertilizer.	7. Transplanted extents.	
8. Extents under minor irrigation.			
9. Average temperature in February.			
10. Fertilizer.			
$R^2 = 98.0\%$	$R^2 = 81.4\%$	$R^2 = 95.0\%$	$R^2 = 73.9\%$

TABLE 6. Values of R^2 and $\overline{R}^2$

	Anuradhapura				*Ratnapura*			
	Maha		*Yala*		*Maha*		*Yala*	
	R^2	$\overline{R}^2$	R^2	$\overline{R}^2$	R^2	$\overline{R}^2$	R^2	$\overline{R}^2$
1.	0.7	0.68	0.522	0.489	0.793	0.779	0.43	0.392
2.	0.836	0.812	0.569	0.508	0.89	0.874	0.56	0.507
3.	0.886	0.859	0.632	0.547	0.904	0.882	0.64	0.558
4.	0.91	0.879	0.686	0.581	0.916	0.888	0.682	0.576
5.	0.927	0.894	0.712	0.582	0.923	0.889	0.699	0.562
6.	0.937	0.9	0.776	0.64	0.951	0.922	0.737	0.579
7.	0.955	0.919	0.814	0.669	0.958	0.925		
8.	0.964	0.927						
9.	0.974	0.941						
10.	0.981	0.946						

5.2.1 Anuradhapura Maha

The forward selection stopped after 10 variables had been included in the analysis. Including all 10 variables explains 98% of the total variation and would appear to explain a substantial amount of the variation. However a closer look at the changes in $\bar{R}^2$ gives an indication of the relative importance of the explanatory variables. The 10th variable, fertilizer, gives a negligible increase in $\bar{R}^2$ and cannot be regarded as really contributing to the explanation of variation in yields. The first three variables which produce quite sizeable changes in $\bar{R}^2$, are non-climatic factors more associated with technology and account for 89% of the variation. The separate plots of these three factors over time showed a steady increase and the multiple regression analysis showed that all three were positively related to yield. Thus an increase in the use of new technology has helped improve paddy production. The other variables only gradually increase $\bar{R}^2$. Variables 4-7 are concerned with rainfall and their combined total change in $\bar{R}^2$ is = 0.05. Therefore they seem less important in explaining changes in yields as compared to the first three factors which are more associated with technology.

However the indication is that once certain aspects of technology have been accounted for then rainfall is the important factor which affects yields. The monthly rainfall variables chosen were those for September, January, March which indicates the growth periods where rainfall can affect yields. The yields could be adjusted for technology to allow the effects of rainfall to be studied, however technology-weather interactions may drastically affect this approach. This will be discussed later.

5.2.2 Anuradhapura Yala

The forward selection stopped after 7 variables had been included in the analysis. Extents under major irrigation explains 52% of the variation in yields. Extents under major irrigation have increased over the period of study from 40% to 90% and since the total extent cultivated has remained constant then this implies that farmers have turned to using major irrigation schemes to cultivate their crops and have become less dependent on rainfed systems. The third variable included is extents under pureline seed which produces a change in $\bar{R}^2$ of 0.04 and fertilizer produces a change of 0.03, although it was the seventh variable to be included. (Transplanted extents were not included in the final set. In the simple linear regressions the correlations between yield and each of the technology factors such as transplanted extents, extents under pureline, and fertilizer was quite high, thus transplated extents may not have been included due to the nature of its correlation with other technological factors already included in the final set). So again the technological factors seem important, have been steadily increasing and are positively related to yield. The other variables included are mainly based on temperatures

and these produce increases in $\overline{R}^2$ which indicate that they are important in explaining variation in yield. The growth periods which seem to be affected by temperatures are flowering and ripening. It is interesting to note that in this analysis the climatic variables included are based on temperature, presumably because rainfall is not such a limiting factor when irrigation is used. Again it would be interesting to remove the effect of technology, if no interaction with climate existed to study the effect of temperature.

5.3 Ratnapura Maha

The forward selection stopped after 7 variables had been included in the analysis. Total extents cultivated explains 79% of the variation in yield. Increases in yield per acre are related here, to increases in use of lands previously uncultivated for paddy. A time plot of total extents cultivated at Ratnapura Maha showed an increase over the period of study. If the nutrient content of soil is higher in these uncultivated lands, then this may explain this relationship. The technological factors included in this set were extents under pureline seed, transplanted extents, fertilizer and extents under minor irrigation. These do not produce increments in $\overline{R}^2$ like those in the Anuradhapura Maha analysis. Also they do not account for a large proportion of the yield variation as in the Anuradhapura analysis. Here the effects of technology are present but not so pronounced, either because they are not suited to the environment, or because farmers do not practice them extensively. Certainly there appears to be less of a need for major irrigation than in Anuradhapura. However plots of extents under pureline seed against time showed that at the end of the study, 40% of the farmers in Ratnapura use pureline seed as opposed to 70% in Anuradhapura. The climatic variables were mainly concerned with the weather in March, namely rainfall and temperature. Rainfall in March produced a change of 0.095 in $\overline{R}^2$ and was the second variable included into the regression analysis. The analysis showed that rainfall in March had a detrimental effect on yield.

5.4 Ratnapura Yala

The forward selection stopped after 6 variables had been included in the analysis. Total extents cultivated explains 43% of the variation in yield. The discussion about total extents cultivated in Ratnapura Maha also applies here. The technological factors included were extents under major and minor irrigation and transplanted extents, altogether these produce an increase in $\overline{R}^2$ of 0.07. Again the discussion in Ratnapura Maha with respect to the technological factors applies here. The decrease in $\overline{R}^2$, on including the 5th variable, is due to the increase in $\overline{R}^2$ being less than $\frac{1}{n-1}.16$ The weather variables included are rainfall in August and temperature range in June. Although neither of these produce large changes in $\overline{R}_2$.

5.5 Summary

		Std. Deviation	$\overline{R^2}$	$\hat{\sigma}$
Anuradhapura	Maha	10.71	0.946	2.19
	Yala	10.21	0.669	5.75
Ratnapura	Maha	6.30	0.925	1.7
	Yala	4.47	0.579	2.85

The estimate, $\hat{\sigma}$, is based on the residual sums of squares from the final regression analysis in each case. Thus it can be seen that more of the variation in the Maha yields can be explained with the variables studied than that in the Yala yields. This could be due to several reasons. Since less rainfall is received in the Yala season there is a greater dependancy on the irrigation schemes than the adequacy of pre-cultivation rainfall may be a factor to be considered. There has been much more variation in paddy production at Anuradhapura than at Ratnapura. The results seem to indicate that this could be due to the increasing extent at which the cultural practices are affected by technology, particularly at Anuradhapura.

A summary of the general overall indications of the results are:

1. That the yields have been positively influenced by changes in technology, which affect the cultural practices, such as increases in transplanted extents, extents under pureline seed, extents under irrigation and fertiliser issues. Where there has been a marked extension of these changes in cultural practices then the corresponding effect on yield is more pronounced than the effect of weather.
2. Rainfall during certain growth periods affects yields especially in the case of Anuradhapura Maha. The detrimental effect of rainfall in the ripening period was highlighted in 3 of the 4 cases studied. (Anuradhapura Yala season was the only case where this was not shown).
3. Differences in the temperature range during the flowering period and the temperature during the ripening period were also shown to be important variables in Yala cultivation.
4. Where extents under pureline seed has been chosen as being important then so has fertiliser issues. The interaction of these two factors cannot be studied here and would be an important aspect to follow up.
5. The effect of the climate on the paddy production depends on the cultural practices which are used. When most of the extents cultivated are irrigated, as in the Anuradhapura Yala case, then rainfall is not a limiting factor and variations in temperature are important.

6. Conclusion

6.1 Areas of further work indicated by the results

Developing a statistical model to describe how variations in paddy yield are affected by certain factors is an ultimate aim. However, the intention here was to perform a preliminary investigation before conducting an analysis which would be concerned with model development. The main objectives of this preliminary investigation were:

(a) to assist in developing an appropriate methodology for such an analysis
(b) to provide information on whether certain areas need to be investigated in more detail and if so which
(c) to indicate the important/unimportant factors
(d) to indicate any problems which could arise.

Consequently the results presented above will be discussed in the context of meeting these objectives and the implications these results have on modelling variations in paddy yield.

7. Discussion

(a) Methodology

The statistical techniques used in this preliminary investigation were based on regression analysis, which is what the majority of crop-climatic studies use.[3] Certainly regression analysis is appropriate for such studies, however, forward selection for model development and estimation of effects may not be the best method.[10] Kendall recommends looking at all of the possible combinations of explanatory variables.

The results of this investigation have indicated that the effects of the technological factors are more pronounced than those of climatic factors. To gain a better understanding of how climate affects yields it may be constructive to remove the effect due to technology from the yields and study the variation of these residuals with respect to climate. However this may not be possible in the presence of weather and technology interactions and consequently their presence needs to be checked first.

The interpretation of coefficients when unknown interactions are present can be misleading. Due to the form of data used it was not possible in this investigation to investigate interactions but the results have indicated that these are present. Subsequent modelling should investigate these possibilities.

Another aspect of methodology, to be investigated further, is the aggregation of the meteorological data. In this investigation the average of 5 stations, in the Anuradhapura district, and 3, in the Ratnapura district, was used to give an indication of the weather in each district. If the weather experienced varies greatly within a district,then a straightforward average may not give a very representative figure, depending on how the meteorological stations are situated in relation to the areas cultivated with paddy.

(b) Areas where a more detailed study may be needed

One important result that emerged was that when water was not a limiting factor i.e. Anuradhapura Yala, then temperature was shown to be important. This suggests that the results will differ depending on the different levels of irrigation used and separate models may need to be developed for each. This is not possible with the data set used here and a breakdown of the district data is needed where yield figures can be matched with the different levels of irrigation.

A further breakdown of the district figures to enable the presence of interactions to be studied, is another area where a more detailed study could be conducted. Information on the yields of the different varieties and the corresponding figures of fertiliser used could also be studied with weather. Such data would also enable an assessment of which varieties are best adapted to which environments. The Department of Census and Statistics crop cutting survey data gives a more detailed breakdown of paddy yield from which it would be possible to investigate the presence of some interactions. This data also allows other factors to be investigated such as the effect of fungicide and weedicide.

If the data available on planting and harvesting dates then the total growth period could also be studied in relation to yield and weather. Knowledge of planting dates provides a more accurate assessment of the growth periods and also will enable pre-season climate to be investigated as a possible factor. For example the extents cultivated is highly dependent on when the rains start and sometimes on the amount of irrigated water available. The type of paddy planted can also depend on when the rains start.

(c) Factors shown to be important

Further areas of work may be in the type of explanatory variables used. The results have indicated which variables appear to be important, however the form of these variables may be incorrect.

Variations in temperature in the Yala season have been shown to be important, however it may be worth investigating whether temperature is the correct variable. Sunshine hours of radiation may be the more relevant. In the case of rainfall then the maximum length of dry spells or wet spells may be more relevant variables. This would mean that daily meteorological data would need to be used.

(d) The results have indicated that problems can arise due to the presence of multicollinearity. Also the interpretation of coefficients could be meaningless unless the possibility of interactions is properly investigated. This could mean it may be necessary to develop separate models for certain aspects of paddy cultivation, such as different levels of irrigation or different varieties, for interpretations of coefficients to be meaningful.

Overall the preliminary investigation has highlighted the difficulties which need to be considered before developing a realistic model of how paddy yields are affected by important factors. Investigating these difficulties constitutes areas of further work.

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Uptake of *Terminalia chebula* Tannin Components by Hide: Analysis Using tlc-uv Densitometry

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Abstract: A method of separation and quantitative analysis of *Terminalia chebula* tannins by tlc-uv densitometry is described. The method is applicable over a range of 0.5 to 2.5 μg/tlc spot and has coefficient of variation of 4-6% for the individual tannins. Using the method on individual tannin components, mixtures of components and myrobalan extracts it has been found that at a level of 0.5% concentration, chebulinic acid and chebulagic acid are taken up rapidly by hide, their rate of uptake being faster than the products of decomposition (by heat in aqueous solution) of chebulinic acid. The latter indicates an advantage in extracting myrobalan tannins under mild conditions. The study also showed that the optimum pH for uptake of chebulinic acid by hide is 4.1 indicating that the ionisation of the carboxylic acid group may play a role in tanning by this compound.

1. Introduction

Although use of myrobalans, the tannin extract of *Terminalia chebula*, has been well established in the leather tanning industry[5,6] and its chemistry also well known for sometime[4,10] there appears to be little detailed study on the relative tanning value of its tannin components. In fact the studies by Barat[1,2] as far back as 1953, is one of the few studies of the type reported. In this study, we report an analytical technique for the assay the major tannin components of *Terminalia chebula*[8] and its application to situations concerning the tanning of hide using myrobalan extracts. The *rate* of uptake of tannin components by hide has been specially considered here.

2. Experimental

2.1 Separation of tannin components

Chebulinic acid was separated from myrobalans by the method of Barat,[1] while 3,6 digalloylglucose was prepared from chebulinic acid by the method of Freudenberg and Fick.[3]

Chebulagic acid was isolated from the mother liquor after chebulinic acid precipitation, by the following procedure. The mother liquor (200 ml) was adjusted to pH 6.7 and extracted with ethylacetate (50 ml × 3). The aqueous portion was adjusted to pH 4.5 and extracted similarly with ethyl acetate. The pH was then adjusted to pH 2 and extracted with ethylacetate (50 ml × 3). Chebulagic acid was found in the most purified state in the aqueous mother liquor after the final extraction. This was purified by the method of Reddy *et al.*[9]

2.2 Experiments with hide

In order to apply the assay a laboratory model of leather tannin was designed. In most experiments the major tanning components of the extract was maintained at a low level of concentration (0.5%) and 10% acetone added in order to prevent precipitation. Unless otherwise specified, pH was adjusted to 4.6.

Into the tannin containing solutions (100 ml) was dipped a small piece (5 g fresh wt., 65-70% moisture) of chromed hide. Care was taken to keep weight, area and shape of the hide constant. The solution contained in a closed vessel was stirred for 24-48 h at room temperature (28-30°C) using a magnetic stirre aliquots withdrawn at various time intervals. The aliquots were diluted with ethanol to the range of 0.5 to 2.5 μg/tannin component concerned and spotted on a tlc plate.

2.3 TLC-UV densitometry

Separations were carried out using 500 μ silica gel G_{60} tlc plates developed in ethyl formate : formic acid : toluene (2:1:1). The tannins in ethanolic extract were spotted on the tlc plates so that the content of each component tannin per spot was no more than 2.5 μg. Using this technique, the myrobalans tannin clearly separated into 2 major and 6 minor spots. In order of increasing Rf value the spots were : chebulic acid, 1, 3, 6-trigalloylglucose, chebulagic acid (major) chebulinic acid (major) 3, 6-digalloylglucose, unknown glucogallin and gallic acid.

The plates were allowed to dry in the dark for 5-10 min and then dried further with an even stream of hot air for 3-5 min. The tannins then autooxidise to produce grey spots. Uv-densitometry was carried out on the tlc plates immediately after colour development.

The instrument used for tlc-uv densitometry was a Camag automatic scanning, variable wavelength densitometer (model 76500) equipped into a strip chart recorder (Camag, w + w 1107) at 625 mm. (Band with 30 nm, slit 6 mm). Standard curves were plotted for chebulinic acid, chebulagic acid, digalloylglucose and gallic acid. The curves were linear in the range of 0.5 to 2.5 μg/spot and the coefficient of variation was 4-6%. As there were small variations from plate to plate

calculations were made by comparing spots on the same plate and expressing results as a percentage of the control by running standards on the same plate *and* rejecting all readings out of the normal range of linearity. Samples were run in duplicate and values recorded are a mean of duplicate values which agreed to within 5% error.

3. Results

3.1 Sri Lankan myrobalans—main tannin components

The main components were chebulinic acid (approximately 14%) and chebulagic acid (approximately 7%); all other components were less than 2%. All results are expressed on dry weight of the fruit. Drum drying of extracts results in decomposition of 15-20% of the chebulinic acid and the appearance of digalloylglucose.

3.2 Effect of heat on aqueous chebulinic acid solutions

Chebulinic acid solution when heated at temperatures of 70°C and 80°C for 8 hours does not produce 3, 6-digalloylglucose but another compound suspected to be 1,3, 6-trigalloylglucose as it is derived from chebulinic acid and decomposes to give equimolar amounts of digalloylglucose and gallic acid on decomposition. At temperatures of 90°C and 100°C 3,6-digalloylglucose is produced (Table 1).

TABLE 1. Effect of heating a dilute chebulinic acid solution

Temperature (°C)	*70*			*80*			*90*			*100*		
Time (hours)	0.5	2	8	0.5	2	8	0.5	2	8	0.5	2	8
Digalloylglucose (mm^2)	0	0	0	0	0	12	0	0	78	0	28	92
Trigalloylglucose (mm^2)	0	27	44	18	49	82	34	57	54	37	56	34

Chebulinic acid (0.1%) in water was maintained at the above temperatures for the given times and aliquots analysed by tlc-uv densitometry.

Concentration is referred to in terms of peak area (mm^2). For digaloylglucose and trigalloylglucose 100 mm^2 is approximately 1 μg. For the same aliquot, original chebulinic acid peak area= 158 mm^2. Residual chebulinic acid (after 8 hours) was 45, 10, 0 and 0% at 70, 80, 90 and 100°C respectively.

3.3 Uptake of individual tannins by hide

During preliminary experiments uptake of tannin components was monitored by measuring optical density of the solution at 277 nm after dilution. Loss of tannins from the solution was assumed as indicative of uptake of tannins by hide, as control experiments (without hide) resulted in no significant losses of tannins on stirring even after 48 hours and further that hide released 277 nm absorbing substances to

the medium to a very small extent (less than 2% total absorbance) upto 24 hours. Results (Figure 1) shows that chebulagic acid was taken up by hide more rapidly than either chebulinic acid or digalloylglucose.

Studies also showed that increases in concentration of chebulinic acid to 2.5% resulted in marked increases in the rate of uptake. Notwithstanding the controls used it was felt that anomalies could be experienced; for example, as a result of reaction between substances released by hide and the component tannin thus producing 277 nm absorbing material. This was verified when chebulinic acid uptake was followed using tlc-uv densitometry (Figure 1). Similar results were obtained but uptake was greater by this method for readings taken beyond 8 hours, confirming interference by non-chebulinic 277 nm absorbing components in the direct uv method. Thus the advantages of using the tlc-uv densitometric technique where such impurities are separated by tlc and the tannin concerned quantified independently is emphasised.

3.4 Effect of pH

Results (Figure 2) showed that a pH optimum of 4.1 was shown for the uptake of chebulinic acid.

3.5 Dual components

Studies using mixtures of chebulinic acid and digalloylglucose confirmed that the former was bound by hide to a much greater extent (Figure 3). Studies using a mixture of chebulinic acid and its decomposition product (at 70°C), suspected to be trigalloylglucose, showed that chebulinic acid exhibits a far higher rate of uptake (Figure 3).

3.6 Myrobalan extracts

The use of these extracts have the advantage of the presence of non-tannins and minor components of tannin value and therefore results are of added significance. Study of uptake of tannin components by hide by a myrobalan extract clearly showed that uptake of chebulinic acid was most significant (Figure 4). As this may be merely an effect of higher concentration, the same experiment was conducted with the mother liquor after chebulinic acid extraction which had approximately the same molar concentration of the two components. Results again showed that the rate of chebulinic acid uptake was much higher than that of chebulagic acid (Figure 4).

4. Discussion

The fact that chebulinic acid appears to be taken up by hide faster than chebulagic acid in mixed extracts, while the opposite is true for the component tannin in the pure form is indicative of the complex nature of tannin uptake by hide. However,

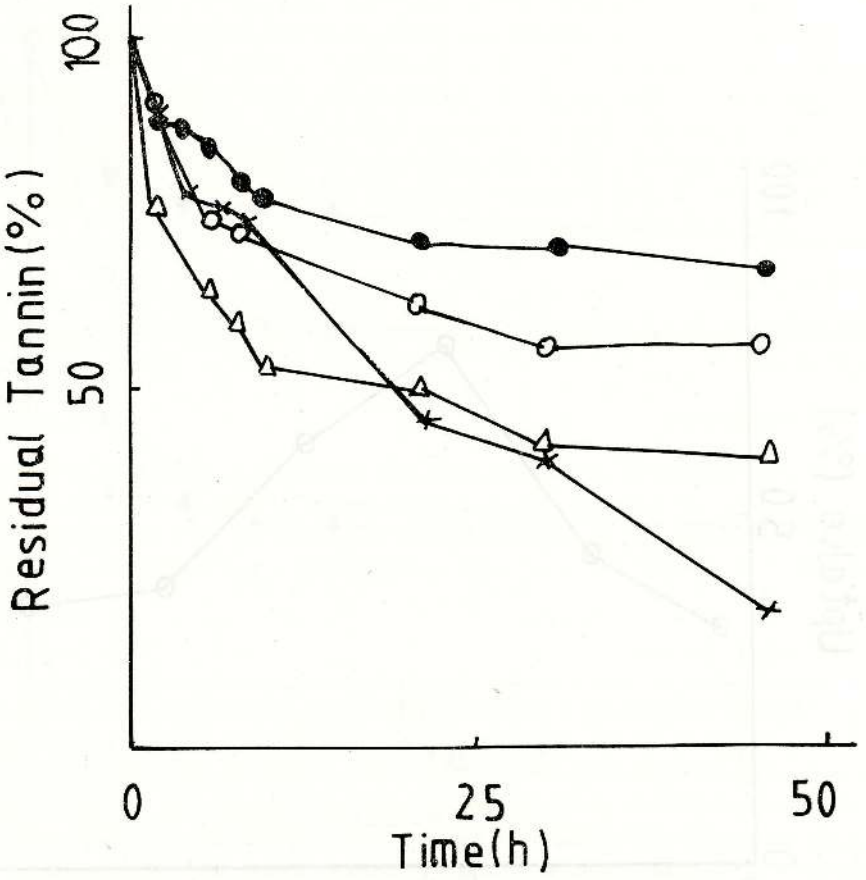

Figure 1 — Uptake of individual tannin by hide

×——×, Chebulinic acid by tlc-uv densitometry
○——○, Chebulinic acid by direct UV absorbence
▲——▲, Chebulagic acid by direct UV adsorbance
●——●, Digalloylglucose by direct UV absorbance

Uptake was calculated by measuring residual tannin in medium by the method given above. 100% refers to 5 mg cc^{-1} tannin concentration. Other details as in experimental.

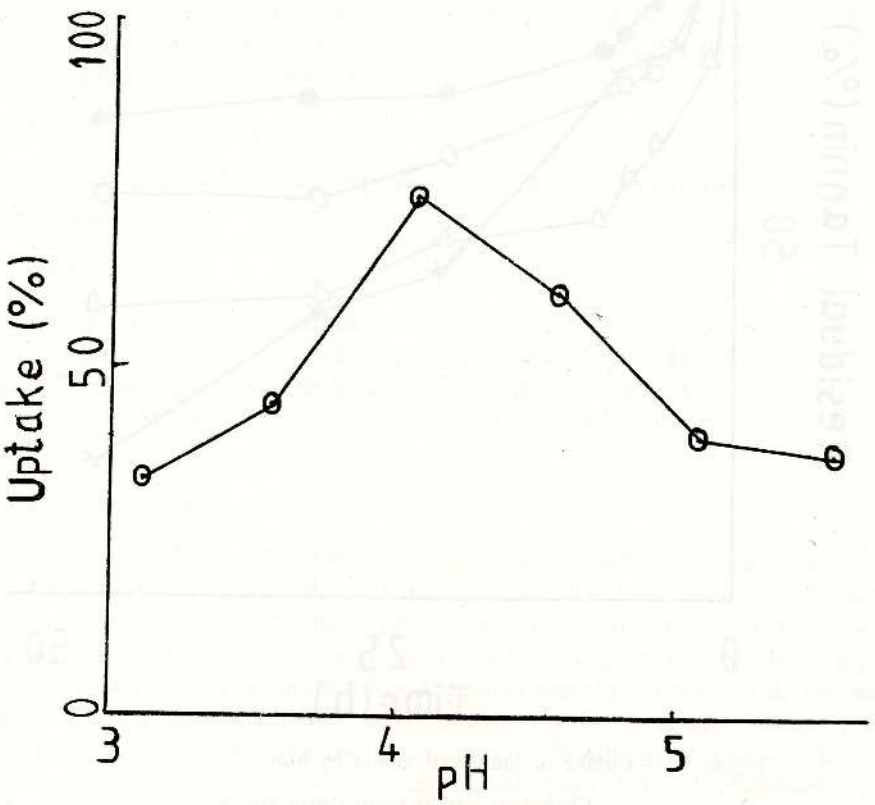

Figure 2 — Effect of PH on chebulinic acid uptake by hide.

PH was maintained by use of 2 m Acetate buffer. Original chebulinic acid concentration = 5 mg cc-1. Uptake was calculated by measuring residual tannin in medium by tlc-uv densitometry over a time course of 8 hours. Uptake at 4 hours is plotted versus PH.

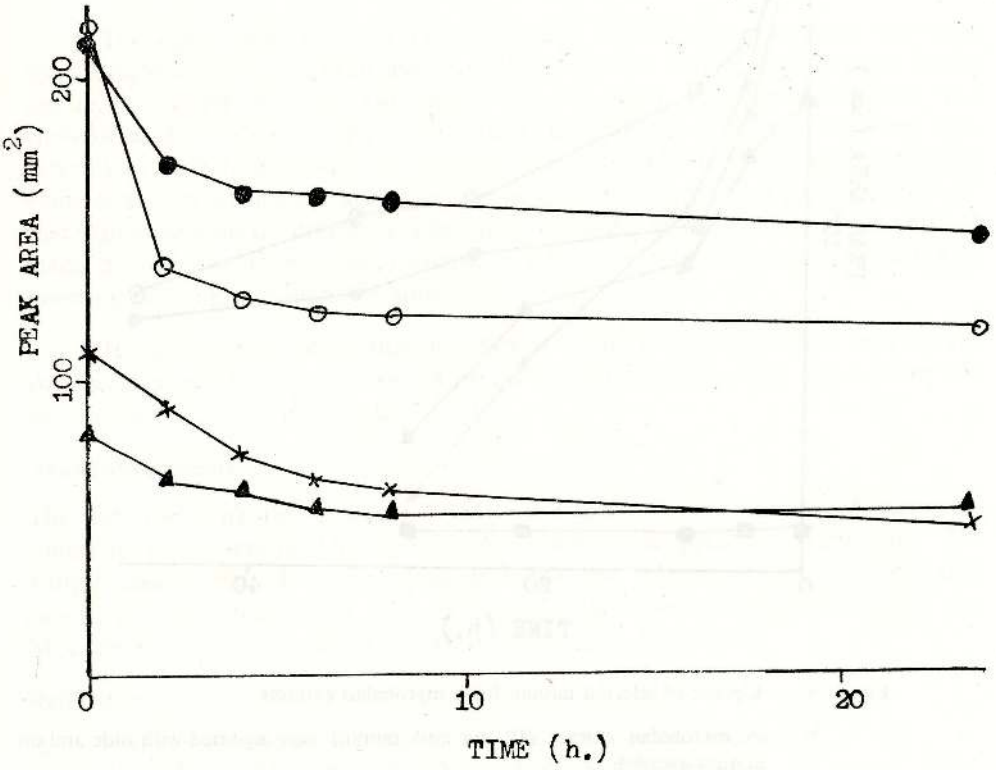

Figure 3 — Uptake of selected myrobalan tannin components

Expt A Concentration is expressed in mm²- A peak area of 100 mm² represents approximately 1.5/μg chebulinic acid and 1/μg digalloylglucose in an aliquot. Initial concentration of chebulinic acid and digalloylglucose was approximately 2.0 mM and 2.5 mM respectively.

○———○ , Chebulinic acid

●———● , Digalloylglucose

Expt B A peak area of 50 mm is approximately 1.5/μg for chebulinic acid and trigalloylglucose respectively. Initial concentration of the two compounds were 5 mM and 4 mM respectively

▲———▲ , Chebulinic acid;

×———× , Trigalloylglucose.

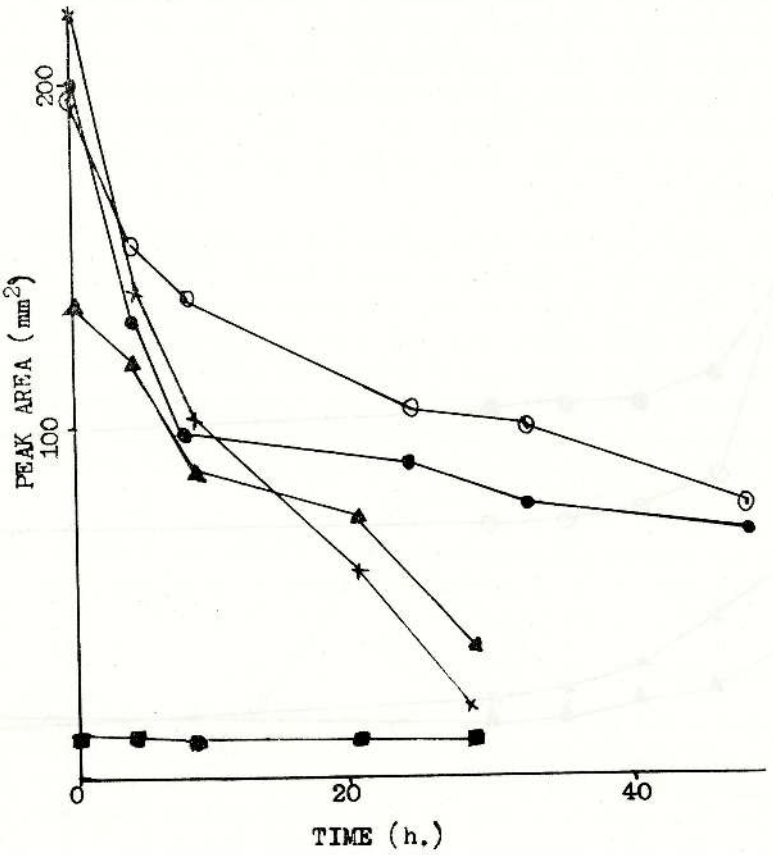

Figure 4 — Uptake of selected tannin/ from myrobalan extracts

A A myrobalan extract (10 mg cc^{-1} tannin) was agitated with hide and an aliquot assayed.

×———× , Chebulinic acid;
▲———▲ , Chebulagic acid;
■———■ , Digalloylglucose.

B The mother liquor obtained after precipitation of chebulinic acid by the method of Barat[1] was used. Tannin concentration of the mother liquor (as determined by the hide powder method) was diluted to 10 mg cc^{-1}.

○———○ , Chebulinic acid;
●———● , Chebulagic acid.

100 mm² is equivalent to approximately 1.5, 1.5, and 1 μg chebulinic acid, chebulagic acid and digalloylglucose respectively.

it must be pointed out that the experimental designs of experiments involving pure components on one hand and extracts on the other have one major difference and that is the presence of acetone in the former (to attain solubility). This factor could introduce differences that influence the rate of uptake, since it is highly probable that myrobalan extracts are not true solutions but polydisperse agglomerates. Another factor that could influence rates of uptake of tannin components is the presence of non-tannins and minor tannins in extracts but not in the case of the pure components.

The uptake (by hide) of chebulinic acid decomposition products (di - and trigalloylglucose) is lower than that of chebulinic acid. Taken together with earlier findings[7,9] namely that the two other decomposition products—gallic acid and chebulic acid have no tanning value, this leads us to the conclusion that any operation that leads to decomposition of chebulinic acid will result in reduced tanning value of the myrobalan extract. This conclusion is consistent with previous findings[7] that tannin content (as determined by the hide powder method) is highest in extracts made at 80°C for 15 min; an increase in either temperature or time resulting in lowering of tannin content in solution.

In this study the pH optimum obtained for maximum chebulinic acid uptake strongly suggests that the ionisation of the carboxylic acid group plays some role in tanning by this compound.

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Food Beliefs and Practices among Sri Lankans. 3. Estate Sector

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Abstract: Food avoidances during pregnancy and lactation and weaning practices among 300 mothers in estates in the Districts of Kandy and Nuwara Eliya have been studied. Although several comparisons are seen between practices among these mothers and those in South India, food taboos have less influence on the diet among Sri Lankan estate workers than among those in South India, probably due to the greater accessability to clinics and hospitals on estates. The reasons given for avoidances are the "hot-cold" nature of food, their possible effect on the course of the pregnancy, on discharge of lochia after delivery and the effects on quantity and quality of milk secreted. Most mothers start breast-feeding within 48 hours after delivery and about one-third continue partial breast-feeding beyond the second year. Bread and biscuits are the first solid foods to be fed, most infants being fed rice towards the end of the first year.

1. Introduction

Two previous reports dealt with temporary food avoidances and weaning practices among Sinhala Buddhist women.[5,8] During a study of socio-cultural malnutrition in the estate sector, food avoidances during pregnancy and lactation and weaning practices among a predominantly Tamil Hindu population were ennumerated. The results obtained are compared with those reported earlier and with reports of such avoidances and practices in South India from where the estate population originated.

2. Methods

Four estates in the Kandy Superintendent of Health Services Division were selected, two in Kandy District and two in Nuwara Eliya District. Seventy-five families were selected from each estate by random sampling. Nearly 93% of the population studied were Tamil 92.1%, Hindu. The Sinhalese formed 7% and there were 6.5% Buddhists and 1.4% Christians.

By means of a questionnaire, information was collected from the 300 mothers on food habits, prejudices and practices and the history of feeding the child from birth to pre-school age. The questionnaire was first tested on an estate near Kandy, to ensure clarity and non-ambiguity of the questions, and to orient two Tamil female undergraduates who assisted as interviewers. A satisfactory relationship was first established with the mothers in maternity homes, dispensaries and creches. Once rapport was established, interviews were conducted in the privacy of their homes.

3. Results

3.1 Food avoidance during pregnancy and lactation

Table 1 lists the foods most frequently avoided by women during pregnancy and lactation.

TABLE 1. Frequently avoided foods during Pregnancy and Lactation and the percentage of women avoiding them

Foods avoided	*Pregnancy*	*Lactation*
Heaty foods	8.0	10.0
Cooling foods	6.0	10.0
Rice, raw	6.0	—
Rice, parboiled	4.0	—
Yams	—	1.0
Jak, bread fruit	—	6.0
Leafy vegetables	7.0	14.3
Tomato..	4.0	8.0
Milk, (Cow, Goat)	—	7.0
Curd	2.6	6.0
Egg	4.6	8.0
Fish	2.6	44.0
Small fish	4.0	48.0
Dried fish	1.0	40.0
Papaw	11.3	13.0
Pineapple	54.0	24.0
Mango	8.0	12.0

The reasons for such avoidance are many and varied, the most commonly mentioned being that a particular food is either "heaty" or "cooling". Among "heaty" foods listed by the women are fish, chicken, sardines, egg and meats, country rice (under-milled), white rice, roti made of wheat or rice flour, yams, jak fruit, beans, dhals, knolkol, raw papaw, brinjals, carrots, tomatoes, green leafy vegetables, colocasia and manioc leaves, and foods fried in oil. During pregnancy, these are believed to be gas-forming, produce vomiting, stomach-ache, pain in limbs, irritation and redness in eyes, diarrhoea, difficulty in urination, excessive sweating, giddiness, burning sensation in breasts and stomach, ulceration in mouth and tongue, splitting of skin at the heels, fissures in tongue, swelling over limbs, lips and eyelids in the mother, and diarrhoea and stomach-ache in the newborn. Many admitted they avoided these "heaty" foods because it was the custom.

During lactation, heaty foods are believed to reduce the secretion of milk, and cause diarrhoea in infant, inflammation in the throat of mother and infant, in addition to producing other effects listed earlier.

Among "cooling" foods are pumpkin, banana, ripe papaw, avocado, "undu" (*Phaseolus mungo*), okra, beetroot, agathi, salad leaves, leeks and mutton. During pregnancy cooling foods are believed to produce chills, fever, diarrhoea, severe uterine bleeding, fits, gastro-intestinal disturbances in the newborn, asthma and chest pain in the mother. Some avoided these foods following advice of the mother-in-law. During lactation such foods are believed to produce colds, fits, chills, and fever, even diarrhoea in infant, asthma and chest pain in mother and lowered secretion of milk.

Apart from being either "heaty" or "cooling" certain specific reasons were given for avoiding some foods.

Raw rice eaten during pregnancy was believed to result in the new-born having protruding eyes. During lactation it would be too heaty for the infant. Parboiled rice was thought by some to be difficult to digest, not nutritious, and could lower milk secretion. Yams are not nutritious, too "heavy", could produce vomiting in mother and infant, and is generally forbidden by the elders in the community. Jak and bread fruit eaten during lactation could be too heaty and heavy for the infant, produce diarrhoea in infant, pain in lower abdomen of mother and reduce milk flow.

Curd is avoided during pregnancy because it is considered too acidic, and may lead to inflammation in stomach and oesophagus. Some considered it sinful to eat curd during this period. During lactation, curd is believed to make breast milk sour and produce vomiting, and to produce diarrhoea in mother and throat pain in infant.

Green leafy vegetables are believed to be difficult to digest during pregnancy; they may get stuck on the intestinal wall, and produce diarrhoea, fever, vomiting, headache. Eaten during lactation they are believed to reduce milk secretion, discolour breast-milk and in the infant develop gastro-intestinal disorders.

Tomato, eaten during pregnancy, is said to increase uterine bleeding and in the new-born produce irritation of throat, dry skin and mandama (marasmus). During lactation it will produce vomiting in both mother and infant and skin rashes on infant. Elders strongly advise against eating it.

Most women avoid fish during lactation. It is believed to give a bad odour to the lochia and urine, bad odour to breast milk, and produce mandama in infant. Bones of small fish cannot be digested. Fish eaten during lactation could produce irregular uterine bleeding. The few who avoided eggs thought egg gives a bad odour to sweat and lochia, is indigestible, produces vomiting and headache in the mother. The infant could develop boils on the skin and vomiting.

A small percentage of women avoided milk during lactation. Milk was consumed during pregnancy in spite of the belief among elders that milk could produce irritation in body and excessive uterine bleeding. When taken during lactation milk is said to produce dry skin in infant and make it prone to infectious diseases, even produce asthma and fits in infant. Some believed that milk secretion is reduced when cows' or goats' milk is consumed.

Among fruits pineapple was the most avoided. When eaten during pregnancy it is believed to produce severe bleeding, even abortion, and skin rashes on mother and new-born. When a lactating woman eats pineapple her milk is said to become sour, making the infant vomit it. Women are advised against eating papaw during pregnancy as it might result in abortion, or swelling of the limbs, headache, stomach-ache, even fever. It is avoided till about 7 months after delivery as it is thought to make the milk sour and produce diarrhoea and vomiting in the infant. Mango could also produce bleeding, sometimes abortion, and result in a marasmic infant. Eaten during lactation, it is said to make breast milk sour and discoloured, produce boils on both mother and child, and even result in colds and fever in the infant.

3.2 Breast feeding and weaning

By breast feeding is meant "sucking at the breast", whether it be frequent or limited to two or three times a day. The word "wean" is used to mean "to teach the child to feed otherwise than at the breast", a process that might take a few weeks or several months. Table 2 indicated that about 75% of the mothers commence breast-feeding within 48 hours after delivery. Less than 18% started nursing within a few hours after delivery.

TABLE 2. Commencement of Breast-feeding

Plantation	*A*	*B*	*C*	*D*	*All*	
Number of mothers	*75*	*75*	*75*	*75*	*300*	
					No.	*%*
Few hours post partum	22	05	11	15	53	17.7
One day	15	13	12	17	57	19.0
Two days	26	49	17	23	115	38.3
Three days	09	07	30	12	58	19.3
Four days	01	00	03	05	09	3.0
Five days	02	01	12	03	08	2.7

The beliefs held regarding the feeding of colostrum are : difficult to digest the yellow milk, it is impure, infants will develop diarrhoea, it is not palatable, the infant rejects it due to its sour taste, it is not necessary for the child, it is mixed with waste matter and is therefore not good for the infant. Some said it would be a strain on the mother to feed immediately after delivery. Many thought that boiled and cooled water with a little castor oil would suffice and that milk is not needed till the third day post-partum.

The duration of breast-feeding was ascertained by inquiring as to how long the youngest child in the family had been nursed. The pattern appears to be uniform in all four estates studied. Only about 10% stop nursing by the end of the 6th month, nearly 85% continue to breast-feed partially for one year. One-third of the mothers continue for 2 years and another third for more than 2 years.

TABLE 3. Duration of Breast-feeding of the Youngest Child

Plantation	*A*	*B*	*C*	*D*	*All*	
Number of mothers	*75*	*75*	*75*	*75*	*No.* *300*	*%*
3 months	3	2	2	5	12	4.0
6 months	6	5	2	5	18	6.1
9 months	4	2	0	9	15	5.1
12 months	14	19	10	14	57	19.2
1 to 2 *yrs.*	25	23	25	24	97	32.8
2 *yrs.*	22	23	34	18	97	32.8

Four mothers had not breast-fed the youngest child.

Table 4 lists the food items frequently given to children during the period of weaning.

TABLE 4. Food items frequently given to children below 3 years and percentage of children receiving these items at different ages

Food Item	*Percentage of children getting the item at different ages* *0-3m*	*4-6m*	*7-12m*	*13-18m*	*19-24m*	*24-36m*
Cows' milk, fresh	18.3	30.6	36.6	39.9	41.2	42.2
Milk powder	44.0	56.6	62.2	64.5	66.8	68.1
Rice cunjee	1.6	7.6	16.6	24.2	26.5	28.1
Kola kande (leaf cungee)	0.3	2.3	6.6	11.9	14.5	15.5
Bread, biscuits	03	8.6	31.6	70.5	86.7	100.0
Coriander water	28.6	47.9	55.9	64.1	65.7	67.3
Pulses	—	3.6	21.9	67.9	87.4	100.0
Yams, potatoes	—	3.6	12.9	63.9	85.2	99.8
Rice and curry	—	2.3	21.9	78.8	93.8	100.0
Boiled vegetables and soups	—	1.3	11.6	33.5	42.5	46.5
Egg	—	2.0	17.3	55.5	70.8	82.4
Fish	—	—	8.6	46.2	65.2	83.2
Meat	—	—	5.3	43.3	61.3	79.3
Small fish	—	—	6.0	35.0	47.0	59.0
Papaw	1.0	8.3	26.9	61.8	81.8	98.4
Pineapple	—	1.3	11.9	31.1	49.4	74.0
Mango	0.3	6.3	22.3	59.2	73.8	79.8
Banana	—	3.3	21.6	56.9	74.2	91.8

Milk powder feeding is introduced after 3 months in nearly half the households and in more than 60% by the end of the first year. It is used as a supplement rather than as a substitute, as nearly one-third of the children continue to be partially breast-fed at the end of 2 years. Sweetened coriander water is the next most popular weaning food. However, even by the end of the third year neither milk powder nor coriander water had been given to about one-third of the children. Rice cunjee is given by very few mothers. It is considrered a food for the sick, not for healthy babies. "Kola Kande" is even less popular. Bread, biscuits and rice cunjee are the first solid foods to be introduced, by the 6th month, and bread and biscuits continue to gain in popularity as the child grows older. Rice and curry were given to a small proportion of the children before the 6th month, and only about 22% of children had received such a meal before the end of the first year. Most children shared the family's rice and curry meals when they were 12 to 18 months old. In contrast to Sinhala children, less than 15% were fed boiled potatoes or yams before their first birthday. When these are fed, they are usually in the form of curries. Fruits such as mango and papaw are introduced very early and about one-quarter of the children are fed fruit regularly by the end of the first year. Among foods of animal origin, other than milk, egg is the most popular. After the first birthday nearly half the children are fed either egg, meat or fish.

4. Discussion

Table 5 lists some food items avoided during pregnancy and lactation by women in Tamilnad.[3,4] A comparison with the data in Table 1 shows that food taboos influence the diet of the Sri Lankan estate sector less that they do in South India from where they came, probably due to the fact that the estate population have for generations been exposed to clinics and hospitals in the estate. Only a few of them avoid milk during lactation, and that too mainly in the first month, as long as the flow of lochia continues. Non-vegetarian foods, other than milk, are avoided by both groups and for similar reasons. However, the fear that eggs, milk and meat eaten during pregnancy would result in too big a baby, is not as evident in Sri Lanka as in South India. In Tamilnad, although fish and small fish are taboo for several months, dried fish is eaten from the third day after delivery, in the belief that it would increase milk flow.[4] In the present study, too, the women said they would eat it were it available more freely. In both groups fruits constitute a major source of danger after delivery. In contrast to temporary abstentions from other foods, where the number of women avoiding them decreases with the period of lactation, several women do not eat fruits for the whole of the lactation period. This is done almost exclusively in the interest of the child. Avoidance of papaw is linked to female discharge during pregnancy and lactation, although the taboo is not as strong in Sri Lanka as in South India. Among both groups pineapple is avoided, more during pregnancy than during lactation, due to its presumed power to induce

TABLE 5. Percentage of women in Tamilnad who usually eat foods listed but avoid them during pregnancy and lactation, with reasons for avoidance*

Food Item	*Pregnancy*		*Lactation*	
	% avoiding	*Reason*	*% avoiding*	*Reason*
All non-vegetarian foods	12.9	Adverse to smell, vomiting	—	—
Meat	5.7	Vomiting, skin disease	29.0	Indigestible, leg pains, skin eruptions in baby
Fish	6.5	Heaty, abortifacient	33.0	Diarrhoea and fits in child, fish bone sticks in nipple
Egg	8.7	Infant becomes too big	53.7	Causes wind, breathlessness vomiting, fits. Mother's milk indigestible,
Milk	2.5	Infant becomes too big	50.0	Too cooling
Fruit	—	—	88.0 for 1 Month or more	Diarrhoea in infant, constipation, gas, fits, vomiting. Too heaty, too cooling, too sour
Papaw	81.9	Heaty laxative, abortifacient	61.0	
Pineapple	96.0	Heaty, abortifacient		
Mango, jak	—	Heaty	74.6	

* References 3 and 4

abortion. This fear occurs beyond the borders on India and Sri Lanka among the Malays and Chinese in Malaysia,[4,9] among Chinese in Singapore,[4] in Indonesia,[4] and in Central America.[6]

After delivery vegetables are avoided mainly because they are "cooling". In Tamilnad, 65.9% avoided such vegetables, at least for a month. Ash pumpkin (*Cucurbita maxima*), the most feared for this effect, is also forbidden to Sinhala mothers.[6]

Among Tamils in the estate sector and in Tamilnadu, and among Sinhalese,[7,8] pregnancy is considered a heaty condition. Therefore, a pregnant woman is advised to avoid heaty foods as well as those that are very cooling. Other foods are avoided because they are gas forming, cause wind and make the woman very uncomfortable. The third category include those that are considered abortifacients.

Delivery is a cooling process and the woman is given a "rasam" (a spiced broth containing garlic, pepper, ginger and onions), and black coffee.

Lactation is considered a cooling condition and she avoids very cooling foods as well as very heaty ones. The greatest number of restrictions apply during the first few months of lactation, in an attempt to avoid foul smelling lochia and to stop the flow of lochia. Also avoided are foods that are believed to reduce milk secretion or alter the colour or consistency of the milk.

It is difficult, and probably unwise, to attempt to change drastically customs and habits that have been hallowed by tradition, especially when scientific reasons are lacking for discouraging a particular belief. For instance, the fear that pine-apple acts as an abortifacient is almost universal. That pineapple does not produce this effect has not been proved. That papaw could discolour the milk has to be admitted. Evidence, both published[2] and unpublished, indicates that eating one or two papaws daily for about 5 days produces yellow discolouration of skin and conjunctiva due to carotenaemia. In a health education programme it should be pointed out that one serving of papaw daily would be harmless. Women could also be told that the pigment in the milk, far from being harmful to the infant, would protect the child from developing eye disease. The eating of dried fish should be encouraged, both during lactation as well as during pregnancy, and more of it should be made available at the co-operative store at a subsidised rate.

Most women avoid feeding colostrum to the new-born (Table 1 and refs.[2,7,8]). Water mixed with a few drops of castor oil and some powdered sucrose is given to "cleanse the intestine" and this is followed by sweetened coriander water. Estate women, like the Sinhalese, introduce milk powder early, in contrast to their counterparts in South India, although about one-third might continue feeding breast-milk as the only milk food throughout the first year. However, due to the

high cost of milk powder the milk is likely to be fed in high dilution. The dangers of bottle-feeding should be explained as well as the need to boil the utensils and the water used. An effort should be made to encourage breast-feeding very early after delivery.

Early introduction of biscuits and rice cunjee could be encouraged, to ensure adequate energy intake. Addition of pulses, well-boiled and mashed, to the rice, could be encouraged from the sixth month onward, once solids are accepted by the infant, and an attempt made to ensure that all children are fed rice by the end of the first year.

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Purification of α-Galactosidase from Coconut Endosperm by Affinity Chromatography

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Abstract: Four specific adsorbants for the purification of α-galactosidase (α-D galactoside galactohydrolase EC 3.2 1.22) from coconut endosperm were prepared. The affinity gels prepared were Sepharose-4B-lysine-galacturonate, Sepharose-4B-lysine-galactosamine, Sepharose-4B-lysine-galactose-p-carboxyanilide and CH-Sepharose-4B-galactosamine. α-Galactosidase from coconut endosperm extract was partially purified by ammonium sulphate fractionation, DEAE-Sephadex chromatography and this partially purified preparation was further purified by affinity chromatography using these specific adsorbants. The adsorbed α-galactosidase was eluted either by using a linear gradient of increasing buffer concentration or by using the specific desorbant p-nitrophenyl-α-D-galactopyranoside. The specific activity of the purified enzyme tested with p-nitrophenyl-α-D-galactopyranoside as substrate was 20 units/mg protein. This represents a 900 fold increase in purification of the original crude extract and the yield was 67%. The purified enzyme was homogeneous by polyacrylamide gel electrophoresis.

1. Introduction

α-Galactosidases (α-D-galactosyl galactohydrolase E.C. 3.2.1.22) are widely distributed in nature and are commonly found in plant seeds.[2,1] Polysaccharides and oligosacchadrides containing α-D-galactosyl units accumulate in seeds during maturation and serve as storage products in resting seeds.[7] During germination oligosaccharides are utilized first followed by the polysaccharides. D-galactose, the initial product of hydrolysis is rapidly transformed and utilized through the glycolytic pathway and is an important source of energy for the growing seedling.[8]

α-Galactosidase is an important enzyme in the coconut endosperm as raffinose is the predominant oligosaccharide[4] and galactomannans, the major (61%) polysaccharide.[1] Balasubramaniam *et al*[2] showed the presence of two interconvertible α-galactosidase isoenzymes in the coconut kernel. The authors have purified the low molecular weight isoenzyme from coconut kernel to homogeneity and characterized it.[3] However the yield was only 12% and the amount of pure enzyme obtained was insufficient for studies to elucidate the mechanism of its

action. α-Galactosidase from coffee beans[11] and from human serum[13] have been purified by affinity chromatography using α-D-galactosylamine and Melibiose as affinity ligands.

In this paper the purification of α-galactosidase by affinity chromatography using galactosamine, galacturonic acid and galactose-p-carboxyanilide as affinity ligands is described.

2. Materials and Methods

Analytical grade BDH and Sigma Chemicals were used. Mature fresh coconuts were purchased locally. Sepharose 4B, CH-Sepharose-4B and DEAE-Sephadex A-25 were purchased from Pharmacia fine Chemicals. Cyanagen bromide was synthesized in the laboratory.[14]

Absorbance was measured using a Pye Unicam SP 800 UV Spectrophotometer. Centrifugation was carried out in an IEC B 20A refrigerated centrifuge.

2.1 Enzyme assay

α-Galactosidase activity was assayed as described by Dey and Pridham.[10] Suitably diluted enzyme preparation (0.1 ml) were incubated at 30°C with 0.5 ml of p-nitrophenyl-α-D-galactopyranoside (1mM) and 0.4 ml of 0.08 M McIlvaine buffer[15] (pH 5.5) for 15 min. The reaction was terminated by the addition of 0.1M Na_2CO_3 (5 ml) and absorbance measured at 405 nm. A unit of enzyme activity is defined as the amount of enzyme that hydrolyses 1 μ mole of substrate/min under these given conditions.

2.2 Protein estimation

Protein content was determined by the method of Lowry *et al*[16]. using crystalline bovine serum albumin as standard or by measuring the absorbance at 280 nm.

2.3 Estimation of sugars

Galacturonic acid, galactosamine and galactose-p-carboxyanilide in the washings were determined by the Dubois[11] method using authentic samples of the same sugars as standards.

2.4 Synthesis of galactose-p-carboxyanilide

Galactose-p-carboxyanilide was synthesized as described by Honeyman.[16] Thin layer chromatography was done on the synthesized material as described by Stahl *et al*.[20] The synthesized material gave a single spot on thin layer chromatography.

2.5 Inhibition of α-galactosidase by galactose-p-carboxyanilide, galactosamine and galacturonic acid

α-Galactosidase was incubated with constant concentrations of galactose-p-carboxyanilide (1 mM), galactosamine (10 mM) and galacturonic acid (6 mM) in 0.08 M McIlvaine buffer (pH 5.5) and with varying concentrations of substrate (2×10^{-4} to 5×10^{-4}M). The p-nitrophenol released was determined as described in section 2.2.

2.6 Preparation of Sepharose-4B-lysine

Activation of Sepharose-4B and binding of lysine was done as described by Cuatrecasas.[6] Sepharose-4B (7 ml packed volume) was washed and suspended in 3 m of distilled water. The suspension was held in an ice bath and stirred (continuously) with a glass rod. CNBr (in warm distilled water) was added to the suspension and the pH maintained at 11 for 15 min by the addition of 10 N NaOH. The activated gel washed with cold 0.2M $NaHCO_3$ (pH 8.5) was suspended in the same buffer. Lysine (0.2 m moles) dissolved in 6 ml of 0.2 of M $NaHCO_3$ (pH 8.5) was added to the suspension and mixed 'end over end' overnight at 6°C. The gel was washed with the same buffer. The washings were collected and the lysine content was determined using ninhydrin.[19] Sepharose-4B-lysine was prepared in batches and the lysine content was varied by changing the amount of CNBr used.

2.7 Preparation of Sepharose-4B-lysine-galactouronate gel

Lysine bound Sepharose-4B (Section 2.6) was washed with distilled water and stirred in 3 ml distilled water at room temperature (29°C). Galacturonic acid (0.5 mmoles) was added in 3 ml of distilled water to 1 m mole of 1-ethyl-3-(3-dimethyl amino-propyl) carbodiimide. The pH was maintained at 4.5 for 6 h by addition of 0.1N HCl. The gel was washed with distilled water and the galacturonic acid content in the washings was determined by the Dubois[11] method.

2.8 Preparation of Sepharose-4B-lysine-galactosamine gel

Sepharose-4B-lysine (Section 2.6) and galactosamine (0.15 m moles) were coupled using 0.3 mmoles of 1-ethyl-3-(3-dimethyl aminopropyl) carbodiimide as described in Section 2.7.

2.9 Preparation of Sepharose-4B-lysine-galactose-p-carboxyanilide gel

Sepharose-4B-lysine (Section 2.6) and 1 m mole of galactose-p-carboxyanilide in 25 ml of 40% dimethyl formamide were coupled using 2 m moles of 1-ethyl-3 (3-dimethyl aminopropyl) carbodiimide as described in Section 2.7 but washing was done with 40% dimethyl formamide.

2.10 Preparation of CH-Sepharose-galactosamine gel

CH-Sepharose-4B (1.5 g) was swelled in 0.5 m NaCl and washed with 0.5 M NaCl followed by distilled water. Coupling of galactosamine was carried out as in Section 2.7 using 0.15 m moles of galactosamine and 0.3 m moles of 1-ethyl-3-(3-dimethyl aminopropyl) carbodiimide.

2.11 Purification of α-galactosidase

All operations were carried out at room temperature (29°C) unless specified otherwise. Centrifugation was carried out at 4°C. Fractions collected after column chromatography were assayed for enzyme activity (Section 2.2) and the protein concentrations of each fraction was determined by measuring the absorbance at 280 nm.

2.11.1 Extraction

Coconut kernel scrapings were homogenized in McIlvaine buffer (pH 5.5) using a Waring blender. The extract (2ml/g) was passed through a cheese cloth and centrifuged at 25 000 g for 20 min. The supernatant obtained was adjusted to pH 3.8 using 0.5M citric acid. On standing for 30 min the acidified solution was centrifuged at 25 000g for 20 min. The pH of the acid supernatant was readjusted to pH 5.5 using saturated solution of Na_2HPO_4.

2.11.2 Ammonium sulphate fractionation

The acid supernatant (pH 5.5) was fractionated using solid ammonium sulphate. The precipitate collected between 45 - 60% saturation was dissolved in McIlvaine buffer (pH 5.5) and dialysed against 0.008M McIlvaine buffer (pH 5.5).

2.11.3 DEAE-Sephadex A-25 gel chromatography

α-Galactosidase from ammonium sulphate fractionation step (40 mg in 60 ml) was applied to a column of DEAE-Sephadex A-25 (2.4×28 cm) previously equilibrated with 0.008 M McIlvaine buffer (pH 5.5). The column was washed with 60 ml of the same buffer. The column was eluted with a 2:1 gradient consisting of 0.008 M (200 ml) and 0.16M (100 ml) McIlvaine buffer (pH 5.5). The fractions containing enzyme activity were pooled and dialysed against 0.008M McIlvaine buffer (pH 5.0).

2.11.4 Sepharose-4B--lysine-galacturonic acid gel chromatography

To Sepharose-4B-lysine-galactouronate gel (0.5×3 cm) was applied 2 ml (0.1 mg) of DEAE-Sephadex A-25 eluted enzyme (Section 2.11.3). The gel had been equilibrated with 0.008M McIlvaine buffer (pH 5.0). After application allowed a period of 15 min for the adsorption of the enzyme. The column was eluted with 8 ml of the same buffer and later with the same volume of 0.08 M McIlvaine buffer (pH 5.0).

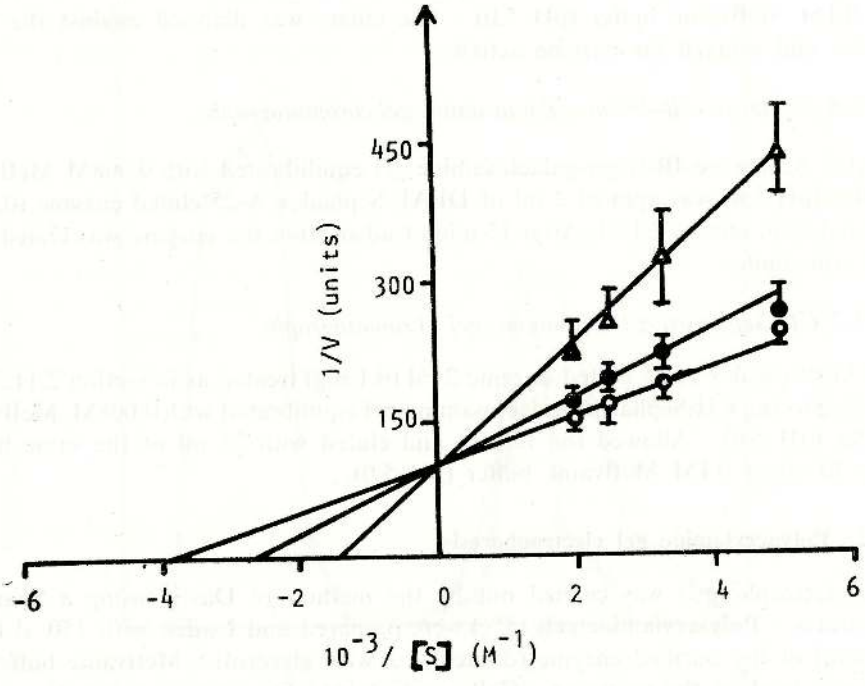

Figure 1: Lineweaver-Burk plot for the inhibition of α -galactosidase by galacturonic acid and galactose-p-carboxyanilide. O, none; ●' galacturonic acid (10 mM); △, galactose-p-carboxyanilide (1mM). Bars indicate standard deviations obtained from four experiments. No inhibition was observed when galactosamine (10 mM) was used.

2.11.5 Sepharose-4B-lysine-galactose-p-carboxyanilide gel chromatography

To Sepharose-4B-lysine-galactose-p-carboxyanilide column (0.5 × 9.0 vm) equilibrated with 0.008M McIlvaine buffer (pH 5.0) was applied 2 ml of DEAE-Sephadex A-25 eluted enzyme (0.1 mg) prepared as in section 2.11.3. After 15 min of adsorption the enzyme was eluted with 30 ml of 0.008 M McIlvaine buffer (pH 5.0) and 15 ml of 0.1 M McIlvaine buffer (pH 5.0). At this point 1 ml of 20 mM p-nitrophenyl-α-D-galactopyranoside was applied to the column and eluted with 15 ml of 0.1M McIlvaine buffer (pH 5.0). The eluate was dialysed against the same buffer and assayed for enzyme activity.

2.11.6 Sepharose-4B--lysine-galactosamine gel chromatography

To the Sepharose-4B-lysine-galactosamine gel equillibrated with 0.008M McIlvaine buffer (pH 5.0) was applied 2 ml of DEAE-Sephadex A-25 eluted enzyme (0.1mg) treated as in section 2.11.3. After 15 min of adsorption the enzyme was eluted with the same buffer.

2.11.7 CH-Sepharose-galactosamine gel chromatography

DEAE-Sephadex A-25 eluted enzyme 2 ml (0.1 mg) treated as in section 2.11.3 was applied to the CH-Sepharose-galactosamine gel equilibrated with 0.008M McIlvaine buffer (pH 5.0). Allowed for 15 min and eluted with 25 ml of the same buffer and 30 ml of 0.1M McIlvaine buffer (pH 5.0).

2.12 Polyacrylamide gel electrophoresis

The electrophoresis was carried out by the method of Davis[6] using a Shandon apparatus. Polyacrylamide gels (5%) were prepared and loaded with 150 μl (5 μg protein) of the purified enzyme (diluted 2:1 with glycerol). McIlvaine buffer pH 6.5 was used in the reservoir. Gels were stained for proteins using Coomassie Brilliant Blue. α-Galactosidase activity was determined by incubating with 4-methyl umbelleferyl-α-D-galactoside (2.5 mM) at room temperature for 30 min. The reaction was terminated with 0.5 M NaOH and the fluorescent bands were observed under UV-light.

3. Results

3.1 Inhibition of α-galactosidase

Galacturonic acid and galactose-p-carboxyanilide, are competitive inhibitors of α-galactosidase while galactosamine did not inhibit the enzyme at a concentration of 10 mM (Figure 1). The Ki values calculated from the graph were 2×10^{-2}M and 1.8×10^{-4} M for galacturonic acid and galactose-p-carboxyanilide respectively.

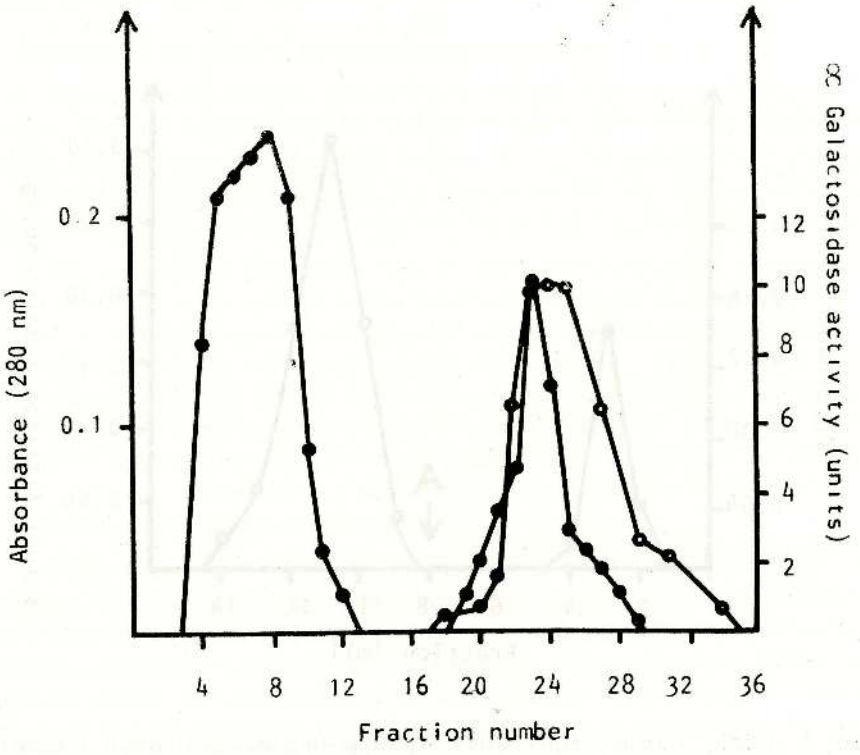

Figure 2: DEAE-Sephadox A-25 chromatography of α -galactosidase. The column 2.4 x 28 cm) was eluted with a 2:1 gradient of 0.008M (200 ml): 0.16M (100 ml) McIlvaine buffer (pH 5.5), flow rate was 30 ml/h. and 10 ml fractions were collected. ●—●, Absorbance at 280 nm; O—O , enzyme activity.

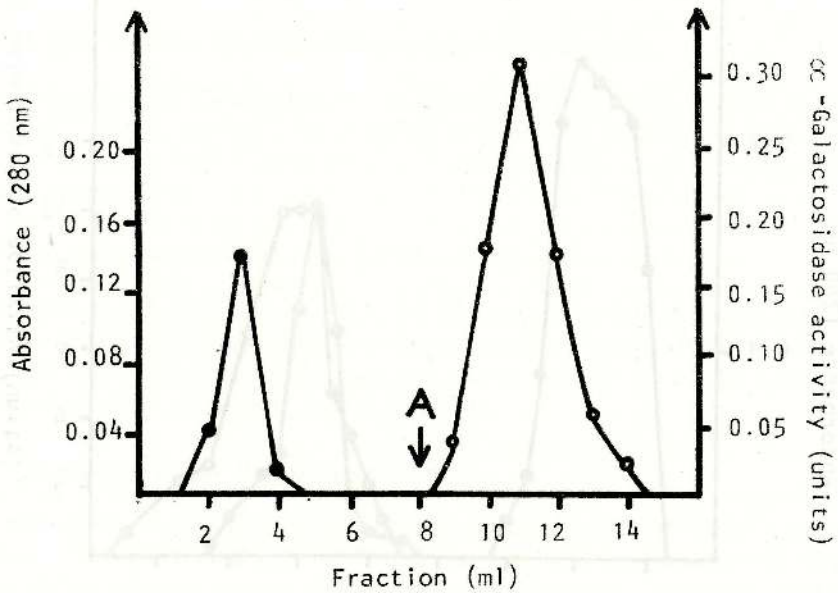

Figure 3: Affinity chromatography using Sepharose-4B-lysino-galacturonate column (0.5 x 3 cm). Applied 2 ml (0.1 mg) of DEAE-Saphadex A-25 eluted enzyme dialysed against 0.008M McIlvaine buffer (pH 5.0) and eluted with the same buffer. At A, eluted with 0.1M McIlvaine buffer (pH 5.0). Flowrate 10 ml/h, fraction volune 1 ml. ●—●, Absorbance at 280 nm; 0--0, Enzyme activity.

3.2 Preliminary purification of α-galactosidase

Preliminary purification of α-galactosidase (Table 1) by acidification, $(NH_4)_2SO$ fractionation and DEAE-Sephadex A-25 chromatography gave on overall yield of 78% and the α-galactosidase was purified 320 fold. DEAE-Sephadex A-25 chromatographic step (Figure 2) gave an 8 fold increase in purity (Table 1). When tested by polyacrylamide gel electrophoresis this enzyme solution had two protein bands and a single enzyme activity band.

3.3 Purification by affinity chromatography

In all affinity chromatography purifications DEAE-Sephadex A-25 eluted α-galactosidase, dialysed against 0.008M McIlvaine buffer (pH 5.0) was applied to the columns equilibrated with the same buffer. The control experiment showed that the dialysed enzyme when applied to a Sepharose-4B column was eluted out in void volume. This indicates that α-galactosidase had no affinity to Sepharose-4B.

The synthesized Sepharose-4B-lysine-galactouronate gel had a bound lysine content of 124 μ moles/ml and a galacturonic acid content of 112 μmoles/ml. The addition of large amounts of CNBr (330 mg/ml) had probably led to a highly activated gel leading to increased coupling of the ligand. When DEAE-Sephadex A-25 eluted enzyme was applied to the column, contaminating proteins were eluted out with the same buffer while the enzyme was eluted out only with increasing molarity of the buffer (Figure 3). Specific activity of the purified enzyme was 20 units/mg protein. Recovery for the affinity chromatographic step was 86% and the capacity of the gel for α-galactosidase was 42 μg/ml.

The synthesized Sepharose-4B-lysine-galactosamine gel had a bound lysine content of 43 μmoles/ml and the bound galactosamine content was 21 μmoles/ml. The DEAE-Sephadex A-25 eluted enzyme was only partially separated from contaminating proteins by this affinity gel (Figure 4). The synthesized CH-Sepharose-4B-galactosamine gel had a galactosamine content of 20 μmoles/ml. The major part of the enzyme applied to this column was eluted out by increasing the molarity of the buffer (Figure 5). Selected fractions were concentrated and the specific activity of the pooled enzyme was found to be 20 units/mg protein. The recovery for the purification step was 60%. The capacity of the gel for α-galactosidase was 4 μg/ml.

Sepharose-4B-lysine-galactose-p-carboxyanilide gel had a lysine content of 29 μmoles/ml and the galactose-p-carboxyanilide content was also 29 μmoles/ml. When the DEAE-Sephadex A-25 eluted enzyme was applied to this column, 50% of the enzyme was eluted out by increasing the morality of the buffer while the rest was eluted out by the substrate. (Figure 6). Both fractions were pooled dialysed and concentrated. The specific activity was determined to be 20 units/mg protein and the capacity of the gel for α-galactosidase was 11 μg/ml. The recovery for the purification step was 67%.

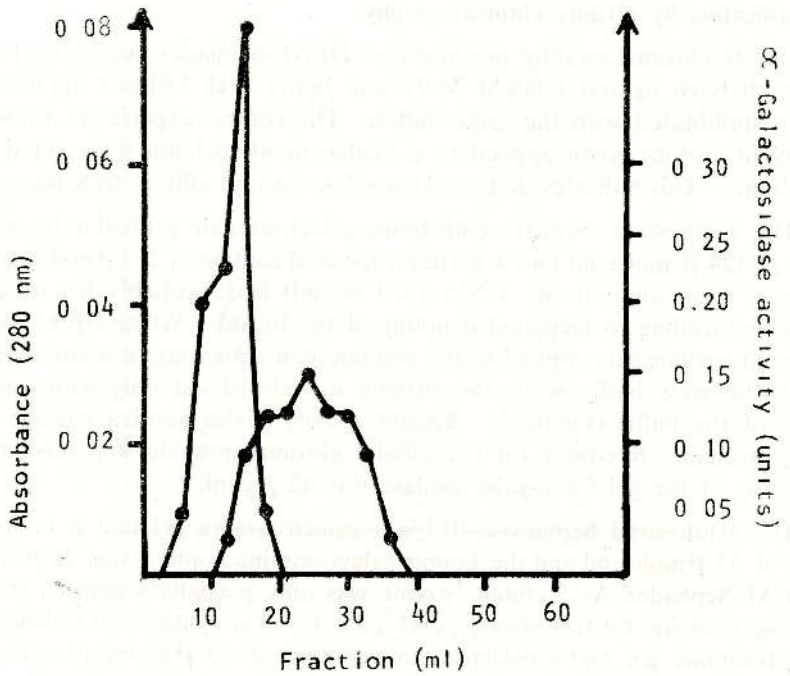

Figure 4: Affinity chromatography using Sepharose-4B-lysino-galactosamine column (0.5 x 8 cm). Applied 2 ml (0.1 mg) of DEAE-Sephadex A-25 eluted enzyme dialysed against 0.008M McIlvaine buffer (pH5.0). Eluted with the same buffer flowrate 10 ml/h and 3 ml fractions were collected. ●—●, Absorbance at 280 nm; O—O enzyme activity.

TABLE 1. – Purification of α - galactosidase from coconut endosperm

Purification step	*Volume (ml)*	*Total enzyme activity (units)*	*Total protein (mg)*	*Specific activity (units/mg protein)*	*Recovery (%)*	*Purification (fold)*
Extract	650	228	10400	0.022	100	1
Supernatant of extract centrifuged at 25 000 g	550	215	2035	0.106	94	5
Supernatant of Acidified solution centrifuged at 25 000 g	660	211	264	0.799	93	36
Ammonium-sulphate fractionation	140	182	196	0.929	80	42
DEAE-Sephadex A-25 chromatography	422	177	25	7.08	78	322
Affinity chromatography by Sepharose-4B-lysine-galacturonate column and concentration	211	152	7.6	20.0	67	909

3.4 Polyacrylamide gel electrophoresis

Polyacrylamide gel electrophoresis of purified α-galactosidase having a specific activity of 20 units/mg protein gave single and coincident protein and α-galactosidase activity bands.

4. Discussion

Insoluble derivatives of l-amino sugars have been successfully employed in the affinity chromatography of lectins.[12] N-ε-amino caproyl-Nε-aminocaproyl-α-D-galactopyranosyl-Sepharose-4B conjugate was successfully used for purification of α-galactosidase from coffee beans.[13] This ligand is a competitive inhibitor of α-galactosidase from coffee beans and the Ki value is 3×10^{-4}M. As α-D-galactophyranosylamine is not available commercially, we have used galacturonic acid, galactose-p-carboxyanilide and galactosamine (2-amino-2-deoxy-D-galactopyranose) as affinity ligands.

Galactosamine (2-amino-2-deoxy-D-galactopyranose) does not inhibit α-galactosidase from coconut endosperm. Thus it is unsuitable for use as a affinity ligand. However CH-Sepharose-galactosamine gel has a weak affinity for α-galactosidase. This affinity is probably due to the hydrophobic properties of the spacerarm and the purification of α-galactosidase by hydrophobic interaction chromatography is worth looking into.

Sepharose-4B-lysine-galactose-p-carboxyanilde gel has the highest affinity for α-galactosidase though the capacity is lower than the Sepharose-4B-lysine-galacturonic acid gel. Decrease in capacity may be due to the lower ligand content of the immobilized galactose-p-carboxyanilide compared to the immobilized galacturonic acid. Both these gels could be used for purification of α-galactosidase but the use of galacturonic acid ligand is preferable due to the ease in eluting the enzyme out of the column and as capacity and percentage recovery are also higher.

The percentage recovery for purification by Sepharose-4B-lysine-galacturonic acid gel is 67% and the specific activity is 20 units/mg protein Both values are higher than the values obtained by purification using gel filtration.[3] Recovery for gel filtration method is 12% and specific activity is 14 units/mg protein. Increase in specific activity could be due to conversion of the low molecular weight isoenzyme to a higher molecular weight isoenzyme during purification by affinity chromatography.[9]

The authors are presently studying the use of hydrophobic ligands to purify α-galactosidase from coconut endosperm.

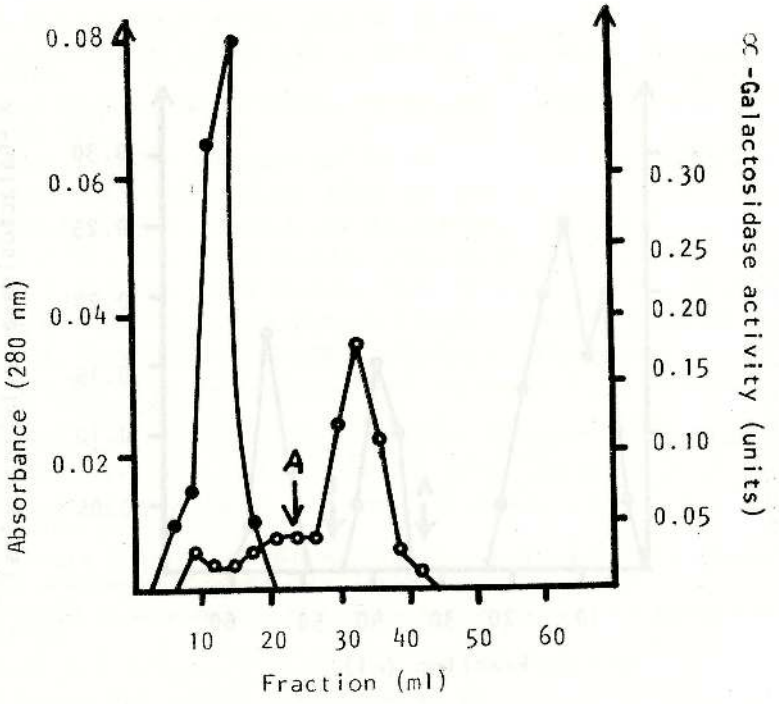

Figure 5: Affinity chromatography using CH-Sepharose-galactosamine column (0.5 x 8 cm). Applied 2 ml (0.1 mg) of DEAE-Sephadex A-25 eluted enzyme dialysed againts 0.008M McIlavaine buffer (pH 5.0) and eluted with the same buff At A, eloted with 0.1M McIlvaine buffer (pH 5.0). Flow rate 10 ml/h and collected 3 ml fractions. ●—● , Absorbance at 280 nm; O—O, enzyme activity.

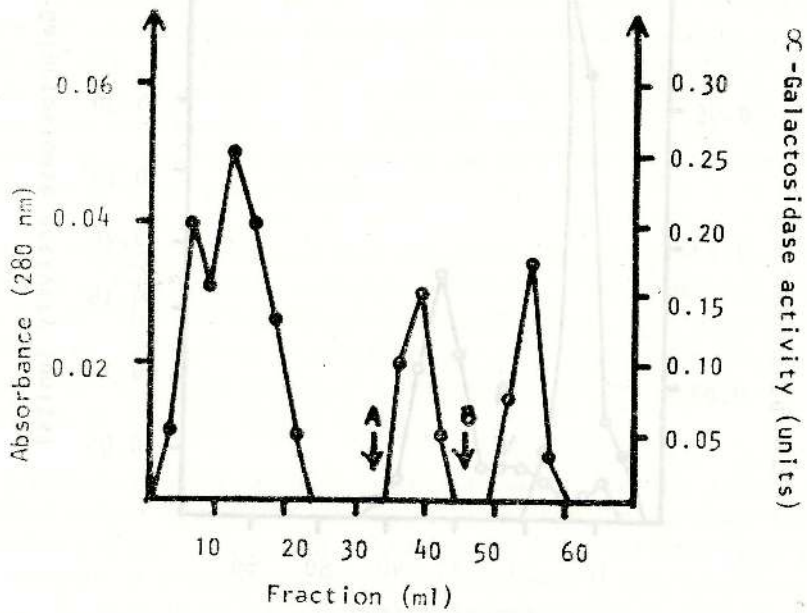

Figure 6: Affinity chromatography using Sepharose-4B-lysino galactose-p-carbozyanilic column (0.5 x 9.0 cm). Applied 2 ml of DEAE-Sephadex A-25 eluted enzyme dualysed against 0.008M McIlvaine buffer (pH 5.0). Eluted with the same buffer and at A, eluted with 0.1M McIlvaine buffer (pH 5.0), at B, eluted with p-nitrophenyl-α-D-galactopyranoside. ●—●, Absorbance at 280 nm; O—O, enzyme activity.

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Food and Feeding of *Siganus lineatus* from Waters around Northern Sri Lanka

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Abstract: *Siganus lineatus* (Cuvier and Valenciennes), is a marine fish which inhabits coastal areas and brackish water bodies in Sri Lanka. This is found in the tropical parts of the Indian and Pacific oceans. Stomach contents of fish ranging from 2.4 cm to 25.5 cm in standard length, collected from twelve stations along the Northern coast, Thondaimannar and Jaffna lagoons were examined. Analysis of stomach contents revealed that *S. lineatus* is purely a herbivore feeding on twelve genera of diatoms, four genera of blue-green algae, six genera of green algae, nine genera of red algae, a brown alga *Dictyota* and an angiosperm - *Thallasia*, of which the diatoms predominated. The major components were *Licmophora, Gomphonema, Navicula, Oscillatoria, Cladophora, Chaetomorpha, Gracilaria* and *Laurencia. Thallasia* predominated all the ot her genera except the diatoms. When the variation in the feeding habits with the size of the fish was analysed by placing the fish in 3 cm length classes, no significant difference in the food was found. The analysis of stomach fullness of the specimens collected during day and night indicated preference to feed during night. An apparent indication of stomach fullness with increase in size of fish has been detected. *Siganus lineatus* is herbivorous in nature.

1. Introduction

Members of the Siganidae, or rabbit fishes, are good food fishes, having flesh which is firm and flaky. They are well liked locally for eating. These economically important group of fishes have gained popularity in recent times because of their suitability for culturing and have been the subject of a number of mariculture studies.[1,5,14] These are small or moderate sized fishes found in the tropical parts of the Indian and Pacific oceans.[1,2,9] They are found in the coastal areas and brackish water bodies in Sri Lanka.[11]

Five species, namely *Siganus lineatus* (Cuvier and Valenciennes) *Siganus javus* (Linnaeus), *Siganus oramin* (= *S. canaliculatus*) (Bloch and Schneder), *Siganus stellatus* (Forskal) and *Siganus virgatus* (Valenciennes) have been recorded along the Northern coasts of Sri Lanka, and in the Thondaimannar and Jaffna lagoons. *Siganus lineatus* is the dominant species in these areas.

Siganus lineatus, commonly referred to as the Golden-line spine foot has an oval and compressed body. The body is light grey, darkest above, with about 12 parallel longitudinal yellow lines as wide as interspaces and broken below into spots. The caudal fin is slaty-grey with a large brown spot slightly larger than the eye-ball, just anterior to the caudal peduncle, changing to bright yellow on death.

S. lineatus frequents coral reefs and rocky localities feeding in shoals. It has a small terminal mouth with a single row of close-set incisor-like teeth on each jaw and feeds by scraping algae from rocks and corals and browsing on seaweeds.

The present paper is a part of a detailed investigation on the biology of *S. lineatus*. In this paper the food and feeding habits of *S. lineatus* are presented. The results of this investigation would have practical value to mari-culturists of *S. lineatus*.

2. Materials and Methods

Materials for the investigation were obtained from Thondaimannar lagoon (80°7'E. to 80° 28' E. long. and 9° 34' N. to 9° 49'N. lat.), Jaffna lagoon, (79° 53' E. to 80°38' E. long. and 9° 26' N. to 9° 46' N. lat.) and Northern coastal areas extending from Thalayaddy to Punakari, both during day and night (Figure 1). Samples were obtained from twelve locations during the period February 1981 to November 1982 using traps, cast nets, set nets, torch and 'sirahu' valai.[12]

The samples were immediately preserved in 4% formalin and brought to the laboratory for detail analyses. Their standard and total lengths were measured to the nearest millimeter using a fish measuring board. After opening the visceral cavity, the gut was removed and its length from the oesophagus to the anus was measured by placing the relaxed alimentary canal on a millimeter ruler. The stomach of each fish was cut longitudinally. The fullness of the stomachs was assessed and categorised as (i) empty (ii) trace to 25% fullness (iii) 25-50% fullness and (iv) more than 50% to total fullness.[10] The content of each stomach was emptied carefully into a specimen tube and diluted four times its volume with formalin. The mixture was shaken until it was as homogeneous as possible. 0.2 ml of the mixture was taken with a suction tube and transferred to a glass slide, covered with a cover slip and examined under a microscope. Each food item was identified and its bulk assessed by the eye taking into account the size of the individual organism as well as their abundance and categorised as either (i) main- those items which formed the bulk of the stomach contents or (ii) considerable- those which still occurring in fair amounts not constituting the bulk of the stomach contents or (iii) rare - those items present in small amounts. Each category was given a number of points - 3 for main, 2 for considerable and 1 for rare.

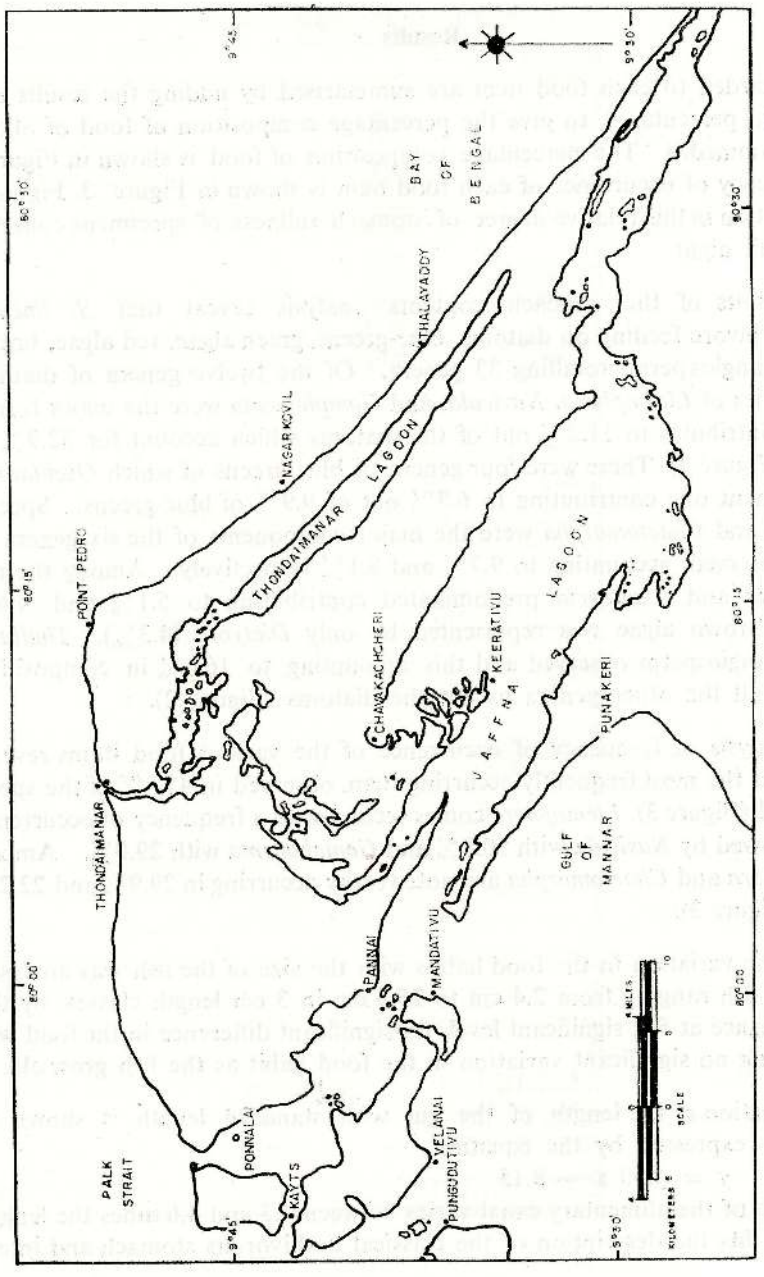

Figure: 1 Map of northern Sri Lanka. (O) Showing location of collecting stations.

This evaluation is essentially an estimate of bulk and the points represents absolute values and not relative ones.[6,6,8,11]

3. Results

All points awarded to each food item are summarised by adding the results and scaled down to percentages, to give the percentage composition of food of all the specimens examined.[13] The percentage composition of food is shown in Figure 2 and the frequency of occurrence of each food item is shown in Figure 3. Figure 4 gives the variation in this relative degree of stomach fullness of specimens collected during day and night.

The results of the stomach contents analysis reveal that *S. lineatus* is purely a herbivore feeding on diatoms, blue-greens, green algae, red algae, brown algae and an angiosperm, totalling 33 genera. Of the twelve genera of diatoms observed, species of *Licmophora*, *Navicula*, and *Gomphonema* were the major forms. *Licmophora* contributes to 11.2% out of the diatoms which account for 32.9% in composition (Figure 2). There were four genera of blue-greens of which *Oscillatoria* was the dominant one contributing to 6.3% out of 9.9% of blue-greens. Species of *Cladophora* and *Chaetomorpha* were the major components of the six genera of green algae observed, accounting to 9.7% and 8.1% respectively. Among the red algae *Gracilaria* and *Laurencia* predominated contributing to 5.1% and 4.6% respectively. Brown algae was represented by only *Dictyota* (4.3%). *Thallasia* was the only angiosperm observed and this amounting to 16.6% in composition predominated all the other genera except the diatoms (Figure 2).

The analysis of frequency of occurrence of the various food items reveals that *Thallasia* is the most frequently occurring item, observed in 45.3% of the specimens examined (Figure 3). *Licmophora* comes second with a frequency of occurrence of 37.6%, followed by *Navicula* with 30.8% and *Gomphonema* with 29.0%. Among others *Cladophora* and *Chaetomorpha* are noteworthy occurring in 29.9% and 22.2% respectively (Figure 3).

When the variation in the food habits with the size of the fish was analysed by placing the fish ranging from 2.4 cm to 25.5 cm in 3 cm length classes, by the analysis of variance at 5% significant level, no significant difference in the food was found, indicating no significant variation in the food habit as the fish grow old.

The variation of the length of the gut with standard length is shown in Figure 5 and is expressed by the equation: —

$$y = 4.60\ x - 8.15$$

The total length of the alimentary canal varies between 4.3 and 4.6 times the length of the fish and fits the description of the classical herbivorous stomach and intestine.[4]

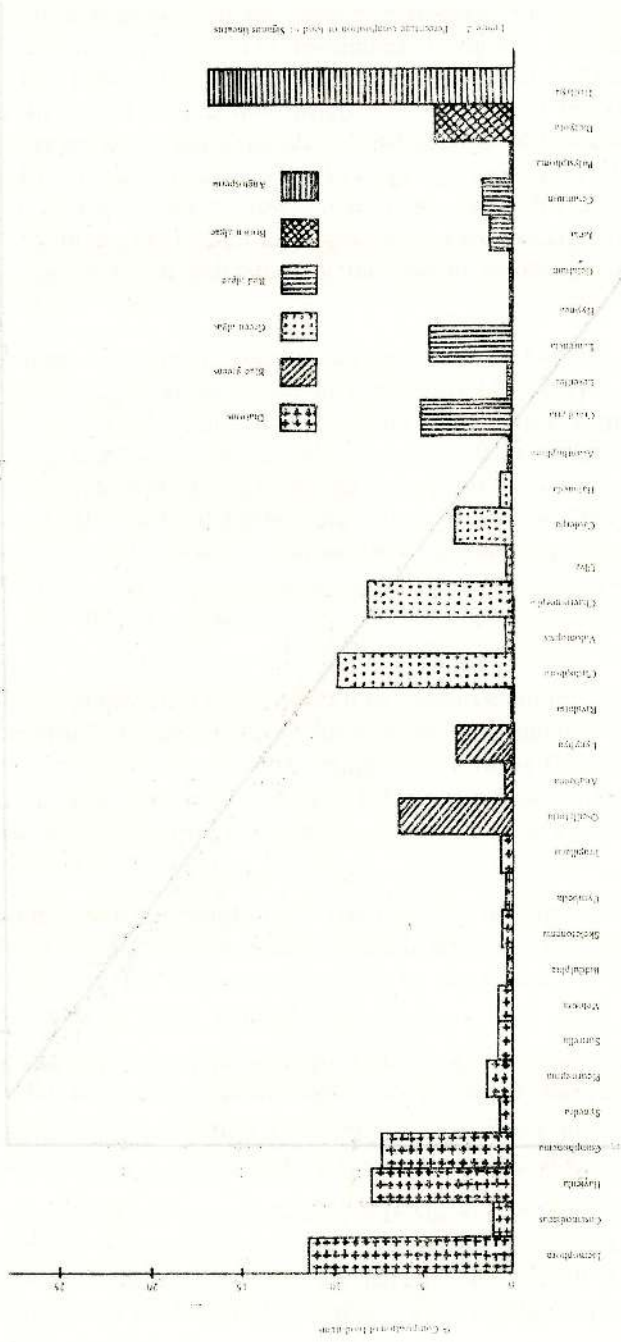

Figure: 3 Percentage composition of food of *Siganus lineatus*.

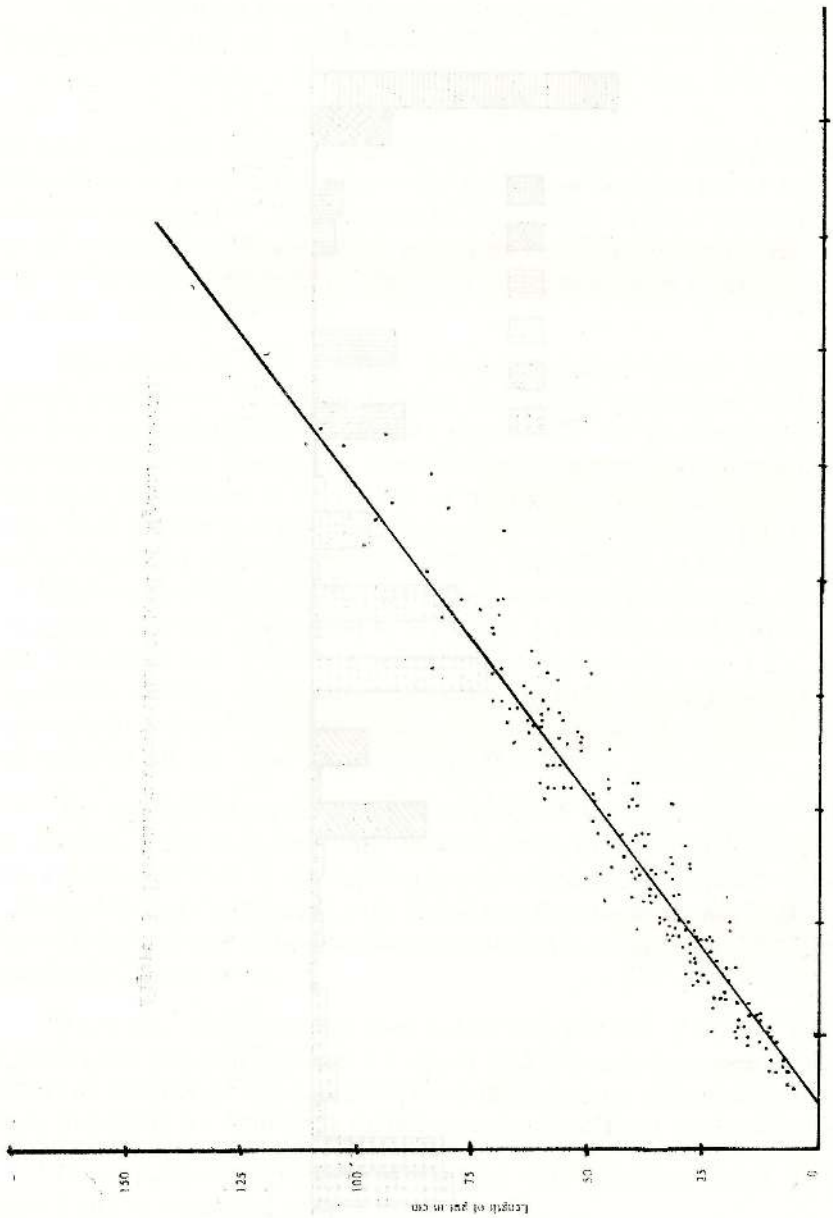

Figure: 5 Variation of the length of gut with standard length in *Siganus lineatus*.

The variation in the relative degree of stomach fullness with length is given in Table 1. From a total of 141 specimens examined, 24 (17.0%) had empty stomachs. The percentage of empty stomachs in the 21 - 50mm length group is 37.5% while in the 141 - 170 mm group it is 4.5%. In the length groups from 21 - 200 mm, there is a gradual increase in percentage of stomachs with 25 - 100% fullness. Data recorded for individuals in length groups 171 - 200 mm, 201 - 230 mm and 231 - 270 mm were less representative than those for other length groups, since fewer specimens, 08, 05 and 08 respectively, were available for analysis. However, there is an apparent indication of increase in stomach fullness with increase in size of fish.

Collections were made during day and night. Out of the 141 specimens analysed, 80 (56.7%) were collected in the nights (Table 1). 15 (24.5%) of the 61 specimens collected during daytime were with empty stomachs and only 09 (11.3%) among those collected in the nights (Figure 4). 62.5% of the specimens with empty stomachs were those collected during day time. 29 (76.3%) of the fish with more than 50% to total fullness were from those collected during night time. The overall picture of stomach fullness does indicate a preference of *S. lineatus* for feeding during night (Table 1 and Figure 4). This is in conformity with the observations reported by Drew.[8]

4. Discussion

The percentage composition of food of all specimens examined derived by summing up points awarded is essentially an approximate volumetric method while frequency of occurrence indicates what organisms are being fed upon, but it gives no information on quantitites and does not take into consideration the accumulation of food organisms resistant to digestion.[13] Both the methods have been adopted in the present investigation.

It is important to couple food studies with the determination of the types and abundance of food present in the environment. However, in the present investigation due to the large area covered in the collection of *S. lineatus*, only contents of stomachs were considered.

Cymbella and *Biddulphia* among diatoms, *Rivularia* among blue-greens *Valoniopsis* and *Ulva* among green algae, *Leveillea*, *Hypnea*, *Gelidium* and *Polysiphonia* among red algae with a frequency of occurrence of 0.8% and percentage composition of 0.1 to 0.4 contributed very little to the diet of *S. lineatus*.

The percentage of occurrence of various food items and composition of stomach contents indicate that among macroscopic algae, *Thallasia*, *Cladophora* and *Chaetomorpha* constitute the major part of the overall diet. These are all attached forms found in the shallow coastal waters and lagoons which are generally inhabited by *S. lineatus*.

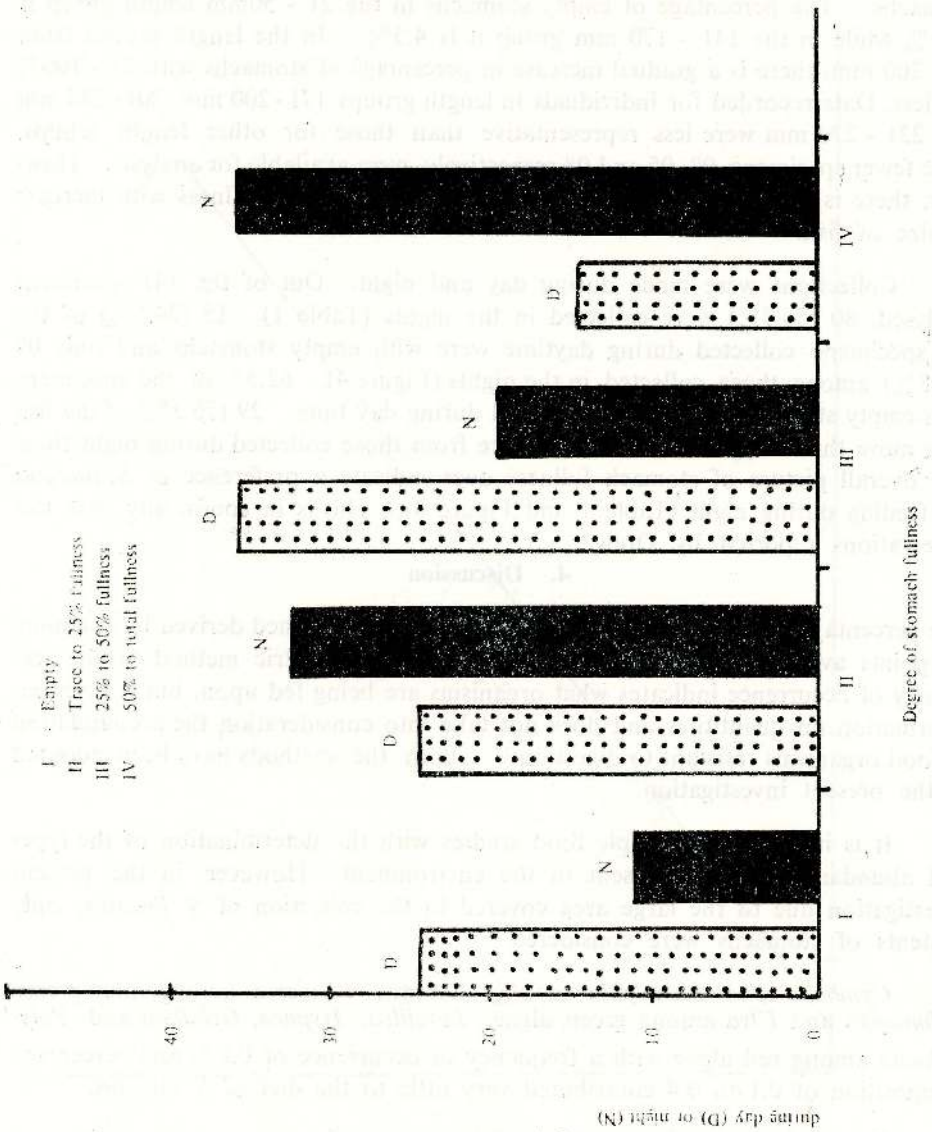

Figure: 4 Variation in degree of stomach fulness in *Siganus lineatus* collected during day and night.

TABLE 1. Variation in relative degree of stomach fullness of different sizes of *Siganus lineatus* collected during Day (O) and (N) Night

Range of Standard length in mm		*21-50*		*51-80*		*81-110*		*111-140*		*141-170*		*171-200*		*201-230*		*231-270*		*Total*	
No. of specimens		*14*		*19*		*41*		*24*		*22*		*08*		*05*		*08*		141	
Degree of fullness of stomach		*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*		
Empty	D	04		01		06		01		01		—		01		01		15	
	N	01		03		02		03		—		—		—		—			09
	D&N	05	37.5	04	21.0	08	19.5	04	16.7	01	4.5	—	—	01	20.0	01	12.5	24	
Trace to 25% fullness	D	04		00		02		03		04		00		00		02			15
	N	02		06		10		01		05		01		00		01		26	
	D&N	06	42.8	06	31.6	12	29.3	04	16.7	09	40.9	01	12.5	00	00	03	37.5		41
25% to 50% fullness	D	02		03		06		07		02		01		00		01		22	
	N	00		01		07		02		04		02		00		00			16
	D&N	02	14.2	04	21.0	13	31.7	09	37.5	06	27.3	03	37.5	00	00	01	12.5	38	
More than 50% to total fullness	D	00		01		03		04		00		00		01		00			09
	N	01		04		05		03		06		04		03		03		29	
	D&N	01	7.3	05	26.4	08	19.5	07	29.1	06	27.3	04	50.0	04	80.0	03	37.5		38
																	Total	D	61
																		N	80

Lam[7] has reported that often large amounts of sponge were found in the stomach and intestine of *S. lineatus* and claimed that siganids are potentially omnivorous even though they may be primarily herbivorous in nature. Drew[4] has also observed some sponges in the stomachs of *S. lineatus*. In this context, three exceptional stomach contents may be mentioned here. Nematodes were found in two specimens of standard lengths 2.7 cm and 15.7 cm, collected in May 1983. Spicules apparently of some sponges were found in two specimens of standard lengths 13.7 cm and 7.7 cm collected in February 1982. *Sertularia sp.* was recorded in one specimen of 4.9 cm collected in July 1982.

Except these, there are no other evidences from the present study to indicate the omnivorous potential of *S. lineatus*. However, the present investigation does indicate that *S. lineatus* is primarily herbivorous in nature.

Acknowledgements

The financial assistance provided by the Natural Resources, Energy and Science Authority of Sri Lanka on Research Grant No. RGB/81/11 to the first author is acknowledged with thanks. Sincere thanks are extended to Dr. E. G. Silas of the Central Marine Fisheries Research Institute, Cochin - 682018, India and to Dr. D. J. Woodland, Department of Zoology, University of New England, Armidale, N.S.W., 2351, Australia for the valuable assistance rendered in the identification of the Siganids.

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SHORT COMMUNICATION

Studies on the Alkaloid Contents of the Bark of Cinchona Found in Sri Lanka

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(*Date of receipt:* 8 *July* 1982)
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Abstract: Studies on *Cinchona* carried out in our laboratory indicated that the extraction of bark with benzene - ethanol (1:1) mixture gave the highest yield of alkaloids. The optimum time of extraction required to obtain the maximum content of alkaloids was found to be 16 hours. The survey of existing *Cinchona* trees in the country indicated that quite a large number of trees are still existing in the jungles of the tea estates in a neglected state. The alkaloid contents of the samples collected from these plants varied very widely, the highest alkaloid contents were found in plants growing in high elevations. The two dimensional thin layer chromatographic technique devised in our laboratory was used to study the distribution of alkaloids in the bark samples.

The genus *Cinchona* belongs to family Rubiaceae and thrives best in tropical climates at altitudes of 1000 to 2000 m. The most common *Cinchona* species (in Sri Lanka) yielding commercially important bark are *Cinchona succirubra* and *Cinchona ledgeriana*. Over twenty alkaloids are reported to be present in *Cinchona* bark out of which quinine and quinidine are the commercially important ones. Quinine had been used as an antimalarial drug while at present it is widely used as a flavouring agent in soft drinks. Quinidine is being used as a cardiac depressant.

Sri Lanka has been associated with *Cinchona* industry since 1858.[2,5] In 1886 this country supplied almost 3/4 of the world bark requirements.[2] From this time onwards the export was on the decline but continued in a small scale until 1976. Though *Cinchona* plantations in Sri Lanka have been completely neglected still there are some trees remaining in tea estates and forests. This study was undertaken as the interest in *Cinchona* has revived during recent times.

Demonstration of distribution of alkaloids

This was performed using two dimensional tlc method which we devised earlier.[9] This technique is capable of separating the *Cinchona* alkaloids into over 14 components.

Improvements in the extraction of alkaloids in the laboratory

The extraction of alkaloids of *Cinchona* bark was carried out according to the method given in Modern Methods of Plant Analysis.[3] In order to attempt to increase the yields of alkaloids the extraction was carried out using several solvents such as ethanol, chloroform, methanol, petroleum ether, ethanol—benzene (1:1) mixture methanol-benzene mixture (1: 1) and ethanol-petroleum ether (1:1) mixture.

20 gms of dried powdered bark are used in each experiment and the averages of three readings were taken. The results of the extractions are given in Table 1.

TABLE 1. Effect of solvent on extraction of quinine from cinchona bark

Solvent	*Quinine as quinine sulphate* $2H_2O$ (%)
Benzene	3.72
Ethanol	4.52
Chloroform	4.20
Methanol	3.80
Petroleum ether	0.68
Ethanol: Benzene	5.25
Methanol: Benzene	4.28
Ethanol: Petroleum etc	3.20

The extraction of alkaloids using benzene-ethanol solution as the solvent was carried out for varying periods of time and the quinine contents of each extract was determined.

Survey of the cinchona trees

This study was carried out at the Tea Research Institute and Department of Minor Exports Crops were interested in the replanting of *cinchona*. The aim of this survey was: (i) to determine the most suitable geographical location for *cinchona* trees, (ii) to select best trees to obtain planting material for future propagation and (iii) to obtain a rough estimate of the number of trees still remaining in the country. In this survey 101 samples of cinchona bark collected from trees in different areas were examined for quinine content and total alkaloid contents. The distribution of alkaloids of each sample was determined by monitoring on tlc plates.[6] The results of the analysis are given in Table 2.

TABLE 2. Summary of quinine and total alkaloid contents of the cinchona bark samples analysed

Location	*No. of samples collected*	*Quinine content estimated as quinine sulphate* $2H_2O$ (%)	*mean*	*Total alkaloid* (%)	*mean*
1. Udagama (524 m)	4	3.5-5.5	4.1		
2. Hunnasgiriya (1656 m)	6	2.6.-8.5	5.1	7.5-11.3	8.6
3. Nuwara Eliya (2000-2330 m)	10	1.2-10.1	6.1	5.1-11.9	9.4
4. Talawakele (1400 m)	35	3.2-9.6	6.0	3.9-12.7	8.9
5. Boralanda (1266 m)	16	5.2-10.5	7.6	6.5-15.8	11.4
6. Dambetenna (1334-2000 m)	4	6.6-10.2	8.5	10.3-17.2	11.5
7. Belihuloya (1000-1830 m)	26	1.1-9.7	6.7	3.3-14	9.6

The experiments that were conducted to improve the yields of extraction of quinine indicated that benzene-ethanol mixture was the best. Ethanol, chloroform and methanol-benzene mixtures gave higher yields than benzene. However ethanol-benzene mixtures cannot be used for large scale extractions due to carcinogenic properties of benzene. For laboratory extractions the benzene-ethanol mixture was selected as it gave the highest yield.

The experiments carried out in order to determine the optimum time required for the extraction of most of the *Cinchona* alkaloids indicated that highest yields were obtained in 16-18 hours of extractions.

These studies showed that considerable care has to be exercised if the correct yield and alkaloid content of a *Cinchona* samples are to be obtained, both solvents and extraction time being important factors.

The survey of the *Cinchona* trees still remaining in Sri Lanka, for their quinine and total alkaloid contents yielded interesting results. The samples collected from Tea Research Institute were obtained from branches of $2\frac{1}{2}$ - 4-year old trees while the other samples were obtained from old trees in the jungles whose ages were not known. Although alkaloid contents cannot be related to the variety of plant due to extensive hybridisation there exists some relationship between the alkaloid contents and elevations. The highest alkaloid contents were observed in trees growing between 1000-2500 m. Although there were marked variations between trees in these locations it was possible to select trees where quinine and total alkaloid contents were more than 9 and $14\frac{1}{2}$% respectively.

The fairly high content of quinine in the samples obtained from the branches of young *Cinchona* trees in Talawakele was another interesting feature.

The study of the distribution of alkaloids in the total alkaloid extract of the samples was carried out employing the thin layer chromatographic technique devised in our laboratory.[9] This study indicated that the major alkaloid in *Ledgeriana* type of trees (this leaf types) was quinine while in broad leaf types of trees cinchonidine was present to the same extent or more than quinine on visual examination.

Our study also indicated that a large number of *Cinchona* trees were remaining scattered and neglected in the jungles of the tea estates. Some of these trees are being used as firewood as few persons in the estates know the identity and the value of this plant. A reasonable income can be obtained if steps are taken to locate these existing plants, maintain infrastructure and harvest the bark carefully. Some attempts should also to be taken under crops diversification scheme to plant *Cinchona* in the vast areas of land that are unsuitable for tea in such estates.

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SHORT COMMUNICATION

Electrical Conductivity of Silver Metavandate

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(*Date of receipt:* 09 *August* 1983)
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Vandates and mixed oxides of vanadium have interesting electrical transport properties. In this note we report our observations on temperature variation of the electrical conductivity of silver metavandate.[3] Silver metavandate ($AgVO_3$) is prepared by the following method.[1] Silver nitrate solution is added to a solution of ammonium metavandate. An impure form of silver metavandate is precipitated. To purify, the precipitate is dissolved in ammonia solution and dilute acetic acid is added, when silver metavandate is reprecipitated. The purified compound, when dried is orange-red in colour and stable up to $\sim$ 250°C.

To measure conductivity the powder is compacted between carbon electrodes in a pyrex tube (diameter $\sim$ 0.5 cm, pellet length $\sim$ 0.3 cm) at a pressure of $\sim 10^8$ Pa and the conductivity at different temperatures is measured with a conductivity meter. Current voltage characteristics are linear and the conductivity is found to vary with temperature (Figure 1) according to the law,

$$\sigma = \sigma_o e^{-E/kT} \qquad (1)$$

with activation energy $E = 0.28\ eV$ and $\sigma o = 0.127\ \Omega^{-1}m^{-1}$.

There is no evidence for ionic conduction[2] in silver metavandate. We have not been able to determine the mobilities of the charge carriers (electrons or holes). The crystal structure of silver metavandate is not reported in literature to the knowledge of the authors.

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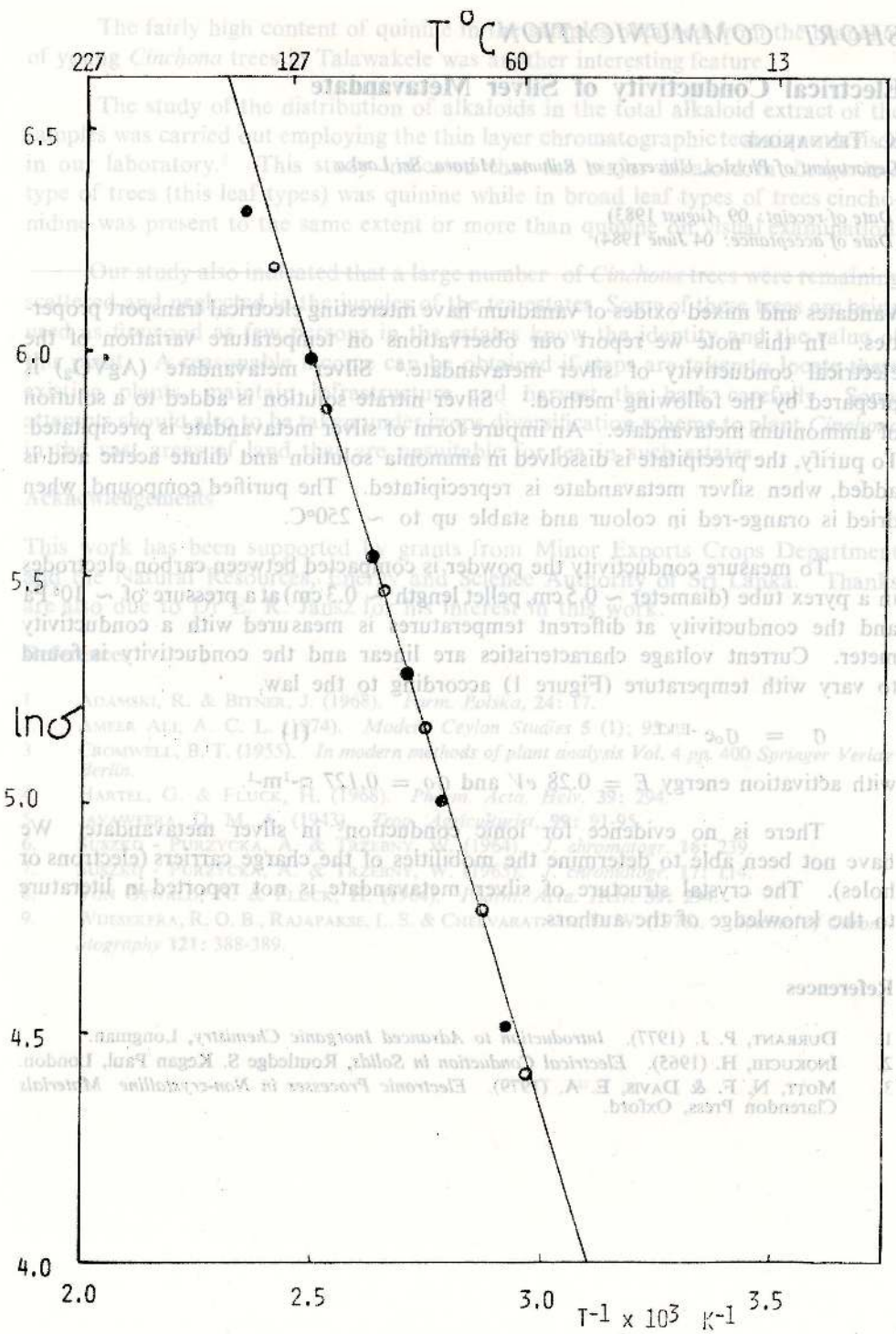

Figure: 1 The plot of ln σ(σ in Ω⁻¹ m⁻¹) vs T⁻¹ (T⁻¹ in °K⁻¹)
o — heating ● — cooling

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භූතල ජල ව්‍යාප්ති ක්‍රම වලට භෝගයන් දක්වන ප්‍රතිචාරය

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1973 – 1974 වර්ෂයේ දී භෝග ප්‍රතිචාරයට අදාලව වාරිමාර්ග ක්‍රම පිළිබඳ සන්සන්දනාත්මක අධ්‍යයනයන් පවත්වන ලදී. අගැයීමට භාජනය කරන ලද වාරිමාර්ග ක්‍රම දෙක අතුරින් සම්මත ඇලි හා සසඳා බැලීමේදී, අක්වක් ඇලි ක්‍රමයෙන් කැපී පෙනෙන අස්වනු ප්‍රති චාරයක් ඇතිවිණ. තෙතමනයට අධික ප්‍රතිචාරයක් දක්වන භෝගයන්ගෙන්, මෙම වාරි මාර්ග ක්‍රමය යටතේ, කැපී පෙනෙනසුළු අස්වනු ලැබිණ. අක්වක් ඇලි සම්බන්ධයෙන් නිරීක්ෂණය කරන ලද තවත් ලක්ෂණයක් නම්, සම්මත ඇලි හා සසඳා බැලීමේදී අක්වක් ඇලි වල විවිධ කොටස් වලින් ලැබෙන අස්වනු වඩා ඒකාකාරී වීමයි.

කොළඹ විශ්ව විද්‍යාලයේ ශිෂ්‍ය ශිෂ්‍යාවන්ගේ පෝෂණ තත්වය පිළිබඳ ඇතැම් දර්ශකයන්හි වූ විචලනතා

රෝස් ජී. එක්ස්. පිරිස්, ඩී. එන්. ප්‍රනාන්දු සහ කේ. අබේවික්‍රම

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1981 වර්ෂයේ දී කොළඹ විශ්ව විද්‍යාලයේ පිය හතරට ප්‍රවේශවූ ශිෂ්‍ය ශිෂ්‍යාවන් 769 දෙනෙකු ගෙන්, ඔවුන්ගේ සමාජ ආර්ථික තත්වයනට අදළ දත්ත සහ පෝෂණය පිළිබඳ ඇතැම් දර්ශක ලබාගන්නා ලදී. අධ්‍යයනයට භාජන කරන ලද පෝෂණ දර්ශක නම්, උස, බර, උසට අනුව බර, හිමෝග්ලොබින් සාන්ද්‍රණය සහ යොවුනුදු වයසයි. විවිධ පියයන්හි ශිෂ්‍ය ශිෂ්‍යාවන්ගේ සමාජ – ආර්ථික පසුතලයද, පෝෂණ තත්වයද, කැපී පෙනෙන අයුරින් වෙනස් විය. වෛද්‍ය පීඨයේ ශිෂ්‍යයින් අතුරින් වැඩි දෙනා සමාජ – ආර්ථික වශයෙන් උසස් කණ්ඩායම් අතුරින් පැමිණි අය වූහ. ඔවුන්ගේ මානවමිතික පරාමිති වඩා යහපත් විය; ඔවුනතර නිරක්ෂිය මඳවූ අතර, අනෙකුත් පීඨයන්හි සිසුන් හා සැසඳීමේ දී ඔවුන්ගේ මධ්‍යන්‍ය යොවුනුදු වයස අවුරිය. මේ සම්බන්ධයෙන් වඩාත්ම අයහපත් තත්වයක් පැවතියේ ශාස්ත්‍ර පීඨයේ සිසුන් අතරෙහිය. පෙනුමෙන් සෞඛ්‍ය සම්පන්න තරුණයින් වූ මොවුනතර අධික නීරක්ෂිය පැවතීම විශේෂ වැදගත් කමෙකින් යුත් කරුණකි.

නඹ සහ කොබෝල්ට් පෙරිසයනයිඩවල විද්‍යුත් පරිවහනය

කේ. තෙන්නකෝන්

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නඹ සහ කොබෝල්ට් පෙරිසයනයිඩ්, විද්‍යුත් සන්නායකයන් වන බැව් පෙනී යයි. ඒවායේ ප්‍රතිරෝධිතාවයන්හි උෂ්ණත්ව විචල්‍යතා අධ්‍යයනයට භාජනය කිරීමෙදී, නියැදිය සෙ.ග්‍රෙ. 118° ට වඩා රත් නොකළහොත්, නඹ පෙරිසයනයිඩවල සක්‍රියන ශක්තිය eV 0.23 වන බැව් පෙනී ගියේය. නියැදිය සෙ.ග්‍රෙ. 118° ට වැඩි උෂ්ණත්වයකට රත්කළහොත් සංයෝගය ආංශික රසායනික භායනයට භාජනය වීමෙන් සක්‍රියන ශක්තිය eV 1.43 ඛවට පත් වෙයි. කොබෝල්ට් පෙරිසයනයිඩ් ද මේ ආකාරයෙන්ම හැසිරෙයි. එහි නියැදිය සෙ.ග්‍රෙ. 132° ඉක්මවා රත්කළහොත්, සක්‍රියන ශක්තිය eV 0.25 සිට eV 0.61 ඛවට පත් වෙයි.

ට්‍රයි ඒරයිල්මිතේන් හේලයිඩ සහ තයෝසයනේට්වල විද්‍යුත් සන්නයනය

කේ. තෙන්නකෝන්, එම්. කහඳ සහ සී. කාසිගේ

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ට්‍රයිඒරයිල් මිතේන් හේලයිඩ සහ තයෝසයනේට් වල සන්නායකතාවයේ උෂ්ණත්ව විචල්‍යතායන් අධ්‍යයනය කරන ලදි. හේලයිඩ්වල ආරෝපණ ප්‍රවාහකයන්ගේ තාප සක්‍රියන ශක්තීන් $I > Br > Cl$ අනුක්‍රමයට වැඩි වෙයි. තයෝසයනේට් ආසන්න වශයෙන් සෙ.ග්‍රෙ. 126° දී සන්නායකතා සංක්‍රමණයක් පෙන්නුම් කරයි.

ශ්‍රී ලංකාවේ ඛනිජ සම්පත් සංවර්ධනය පිළිබඳ වත්මන් තත්වය

ඩී. ජයවර්ධන

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ඛනිජ සම්පත් සංවර්ධනය, ශ්‍රී ලංකාවේ ආර්ථිකයේ සිඝ්‍ර විකාශනය සඳහා වැදගත් පූර්ව අවශ්‍යතාවක් වෙයි. ඉකුත් වසර පහ තුල මැණික් වෙළඳාමත්, ඛනිජ නිෂ්පාදන සහ පිහන් භාණ්ඩ අපනයනයත් පුළුල් වීමෙන් ඛනිජ අංශයේ වැදගත් වර්ධනයක් වාර්තාවී ඇත. මීනිරත්, බර ඛනිජ වැලි වර්ග සහ මයිකා වලින් ද වැඩි අපනයන ආදායම් පෙනෙන්නට තිබිණ. දේශීය ඛනිජමය අමුද්‍රව්‍ය උපයෝගි කර ගනිමින් සිමෙන්ති කර්මාන්තය සිඝ්‍රයෙන් වර්ධනය වීම, මීන් පෙර නොවූ විරූ අයුරින් ඉදිකිරීම් කටයුතු වැඩිවීම හේතුකොටගෙන සිමෙන්ති සඳහා හටගත් ඉල්ලුම සපුරාලීමට ආධාරක විය. ඛනිජ අංශය සිඝ්‍රයෙන් ව්‍යාප්ත කරලීමට ඇති ප්‍රධාන බාධකය දිවයිනෙහි ඛනිජ සම්පත් පිළිබඳ නිසි තක්සේරුවක් කර නොතිබීමයි. භූ විද්‍යා සමීක්ෂණ දෙපාර්තමේන්තුව, නව ඛනිජ නැන්පතු සොයා ගැනීමේ සහ දූනවීමේ

හඳුනාගෙන ඇති ඛනිජ සම්පත් වල තත්වය සහ උපයෝජනය සඳහා ලබාගත හැකි ප්‍රමාණය නක්සේරු කිරීම අරමුණු කරගෙන ඒවා සංවර්ධනය කිරීමේ අභියෝගයට මුහුණ දීමට ඉදිරි පත්වී ඇත. අනාගතයේ වැඩිවන ඉල්ලුම සපුරාලීම සඳහා දේශීය ඛනිජ ආශ්‍රිත කර්මාන්ත පුළුල් කිරීමට නම්, පුනර්ජීවනය නොවන මෙම සම්පත් ක්‍රමානුකූලව උපයෝජනය කරගැනීම වැදගත් සාධකයක් වෙයි. මෙම ලිපියෙන් විවිධ කාර්මික අංශ මගින් දැනට උපයෝගී කරගනු ලබන්නාවූද, ඔයව් ස්වභාවයෙන්ම අපනයනය සඳහා උපයෝජනය කරගන්නාවූද ශ්‍රී ලංකාවේ ඛනිජ සම්පත් සංවර්ධනය පිළිබඳ විස්තරයක් කිරීමට ප්‍රයත්නයක් දරා ඇත. මෑතකදී සොයා ගන්නා ලද රොක් ෆොස්ෆේට් සහ තණ මැග්නටයිට් නිධි වැනි ආර්ථික වශයෙන් වැදගත් ඛනිජ වර්ග පිළිබඳව සහ තව කර්මාන්ත සඳහා ඒවා උපයෝගී කරගැනීම පිළිබඳව මෙහි විස්තර කෙරෙයි. අනාගත ඛනිජ ගවේෂණ වැඩ සටහන් සඳහා ඉලක්ක ප්‍රදේශද මෙම ලිපියෙන් සාකච්ඡා කෙරේ.

දිස්ත්‍රික්ක දෙකක වී අස්වැන්න කෙරෙහි බලපාන සාධක පිළිබඳ විමර්ශනයක්

ඇන් ලික්

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අනුරාධපුර සහ රත්නපුර දිස්ත්‍රික්කයන්හි වී අස්වැන්න කෙරෙහි බලපාන සාධක මෙයින් විමර්ශනයට භාජනය කෙරේ. 1962 - 1978 දක්වාවූ දත්ත භාවිතයෙන් ප්‍රතිපායන විශ්ලේෂණයක් කරනු ලැබේ. මෙහිදී ගොයම් පැලයේ වර්ධන සහ ඒ ඒ අවස්ථාවේදී එහි ජල අවශ්‍යතා කෙරෙහි විශේෂ අවධානය යොමු කෙරේ. වගාකරන ලද මුළු භූමි ප්‍රමාණයත් වැඩිවීමෙන් අක්කරයට ලැබෙන අස්වැන්න කෙරෙහි විශාල බලපෑමක් ඇතිවන බැව් ප්‍රතිඵල වලින් පෙනී යයි. රත්නපුරයේ යල මහ දෙකන්නයේදීමත්, අනුරාධපුරයේ මහ කන්නයේදීත් මේ බැව් දක්නට ලැබිණ. විශේෂයෙන්ම අනුරාධපුරයේ, පැල සිටුවීම, වී වර්ගය, පොහොර වර්ග සහ වාරිමාර්ග වැනි දේශගුණික නොවන, තාක්ෂණික පර්යේෂණයන්ගේ බලපෑම් ලබන, (මෙම ලිපියේ තාක්ෂණික සාධක යනුවෙන් හඳුන්වනු ලබන) සාධක වී නිෂ්පාදනයට විශාල ලෙසින් බලපා ඇති බැවිද අධ්‍යයනයෙන් පෙනී යයි. විශේෂයෙන්ම අනුරාධපුරයේ, දේශ ගුණික විචල්‍යයන්හි වෙනස්කම්, තාක්ෂණික සාධකයන්ගේ වෙනස්කම් තරම් අස්වැන්න කෙරෙහි බලපා නැත. තවද, වැදගත් දේශගුණික විචල්‍යයන්, යොදගනු ලබන තාක්ෂණයන් මත රඳාපවතින බවද ප්‍රතිඵල වලින් පෙනී ගියේය. උදාහරණ වශයෙන්, අනුරාධපුරයේ යල කන්නය, විශාල වාරිමාර්ග යෝජනා ක්‍රම කෙරෙහි වඩා වඩාත් රඳා පවතුණ අතර, උෂ්ණත්වය මෙහිලා වැදගත්වූ බැව් පෙණිණ. එහෙත් මහ කන්නයේ ඇතැම් ගොවිහු තවමත් එක්තරා දුරකට වර්ෂාව කෙරෙහි රැඳී සිටිති. මේ නිසා වර්ෂාපතනය වැදගත් පාරිසරික සාධකයක් වශයෙන් පෙන්නුම් කෙරිණ. මෙම අධ්‍යයනයෙන් සාධකයන්ගේ බලපෑම් සහ ඒවායේ අන්තර් ක්‍රියාකාරිත්වය වර්ධනය කළ යුතු ආකාරය පිළිබඳ පරිපූර්ණ දැනුමක් ලබාගැනීම සඳහා වැඩිදුර කටයුතු කළයුතු ක්ෂේත්‍ර සහ පර්යේෂණ යොමුවිය යුතු අංග ඉස්මතුවී ඇත.

tlc — uv සහන්ව මීතිය ආවිතයෙන් සම විශ්ලේෂණය කිරීමෙන් *Terminalia chebula* ටැනින් සංරචක උකහාගැන්ම පිළිබඳ අධ්‍යයනය

එස්. රත්නායක, ඊ. ඊ. ජූන්ස් සහ කේ. ටී. ඩී. ද සිල්වා

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Tlc - uv සහන්ව මීතිය මඟින් *Terminalia chebula* ටැනින් වර්ග වෙන්කර ගැනීමේ සහ ප්‍රමාණාත්මක වශයෙන් විශ්ලේෂණය කිරීමේ ක්‍රමයක් මෙහි විස්තර කෙරේ. Tlc ලපයකට μg 0.5 සිට 2.5 දක්වා වූ පරාසයක් සඳහා මෙම ක්‍රමය යොදගත හැකිවන අතර, එක් එක් ටැනින් වර්ග සඳහා එහි 4 – 6% දක්වා වූ විචල්‍යතා සංගුණකයක් වේ. තනි ටැනින් සංරචක සංයෝග සහ මිරබලන් නිස්සාරක සඳහා මෙම ක්‍රමය යොද ගැනීමෙන්, 0.5% ක සාන්ද්‍රතා මට්ටමකදී, සම්වලට වෙබියුලැනික් අම්ලය සහ වෙබියුලැජික් අම්ලය සිදුයෙන් උකහාගනු ලබන බව පෙනී ගොස් ඇත. ඒවා උකහා ගැනීමේ වේගය, වෙබියුලනික් අම්ලය (ජලීය ද්‍රාවනයකට නාපය යෙදීමෙන්) වියෝජනය වීමෙන් ලැබෙන ඵල උකහාගැනීමේ වේගයට වැඩි බවද පෙනී ගොස් ඇත. සරළ තත්වයන් යටතේ මිරබලන් ටැනින් වර්ග නිස්සාරණය කරගැනීමේ වාසිදායක බවක් මෙයින් පෙන්නුම් කෙරේ. සම්වලට වෙබියුලැනික් අම්ලය උකහාගැනීම සඳහා ප්‍රශස්ත P^H අගය 4.1 බව අධ්‍යයනයේදී හෙලිවිය. මෙම සංයෝගයෙන් සම පදම් කිරීම කෙරෙහි, කාබොක්සිලික් අම්ල කාණ්ඩයේ අයනීකරණය බලපෑ හැකි බැවි මෙයින් පෙන්නුම් කෙරේ.

ශ්‍රී ලාංකිකයින් අතර ආහාර පිළිබඳව පැවතෙන විශ්වාස සහ පිළිවෙත් 3. වතු අංශය

වන්දානි ලියනගේ සහ ටී. ඩබ්ලිව්. චික්‍රමනායක

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මහනුවර සහ නුවරඑළිය දිස්ත්‍රික්කයන්හි වතුකරයේ මව්වරුන් 300 දෙනෙකු මේ සම්බන්ධව අධ්‍යයනයට භාජනය කර ඇත. මෙම මව්වරුන් අතර ගර්භනී සහ කිරිමව් අවස්ථාවන්ද, සමහර අවස්ථාවන්හිදී යම් යම් ආහාර වලින් වැළකීම පිළිබඳවද, ළදරුවන්ට සහ ආහාර දීම පිළිබඳ පිළිවෙත්ද සලකා බලන ලදී. මෙම මව්වරුන්ගේ සහ දකුණු ඉන්දියාවේ මව්වරුන්ගේ පිළිවෙත් අතර සමානකාවයන් ඇතත් ශ්‍රී ලංකාවේ වතුකම්කරුවන්ගේ ආහාරය කෙරෙහි දකුණු ඉන්දියාවේ කම්කරුවන්ගේ ආහාරය කෙරෙහි තරම් ආහාර විරෝධතා බලපෑමක් නොපෙනේ. වතුකරයේ සායන සහ ආරෝග්‍යශාලා පහසුකම් ලඟින්ම තිබීම මෙයට හේතුවිය හැකිය. යම් යම් ආහාර විරෝධතා බලපාන්නේ ඒවායේ ඇති 'ශීත උෂ්ණ' ගති මත බව විශ්වාස කරයි. මෙම ශීත උෂ්ණ ස්වභාවය ගර්භනී අවස්ථාවන්හිදී, දරු ප්‍රසූතියෙන් පසු දැතිවන සූතිකාභාරය පිටවීම කෙරෙහිත් කිරිවල ප්‍රමාණය සහ තත්ත්වය කෙරෙහිද බලපෑමක් ඇතිබව විශ්වාස කෙරේ. මෙම මව්වරුන්ගෙන් වැඩි ප්‍රමාණය දරු ප්‍රසූතියෙන් පැය 48 ක් ඇතුලත මව්කිරි දීම අරඹති. මව්වරුන්ගෙන් තුනෙන් එකක් පමණ, දෙවන වර්ෂයෙන් පසුවද වෙනත් ආහාරයන්ට අතිරේකව තවදුරටත් මව්කිරි දෙති. බුලින්ම දෙනු ලබන සහ ආහාර වන්නේ පාන් සහ බිස්කෝතුය. ළදරුවන් වැඩි ප්‍රමාණයකට පළමු වසර අවසන්වන ආසන්නයේදී බත් කවනු ලැබේ.

උතුරු ශ්‍රී ලංකාව අවට ජලයේ *Siganus lineatus* වර්ගයාගේ ආහාර සහ අහාර ගැනීම

කේ. චිත්‍රවඩිවේලු සහ ඒ. සිවපාලන්

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Siganus lineatus (Cuvier සහ Valenciennes) යනු, ශ්‍රී ලංකාවේ වෙරළබඩ ප්‍රදේශවල සහ කිවුල් ජලාශයන්හි වෙසෙන මුහුදු මත්ස්‍ය වර්ගයකි. මොවුන් ඉන්දීය සහ ශාන්තිකර සාගරයන්හි නිවර්තනික කොටස්වල දක්නට ලැබේ. උතුරු වෙරළේ, කොන්ඩෙයිමන්නාර් සහ යාපන කලපුවේ මධ්‍යස්ථාන දෙළහකින් ලබාගත් සෙ.මී. 2.4 සිට සෙ.මී. 25.5 අතර සම්මත දිගින් යුත් මෙම මසුන්ගේ ආමාශීය ද්‍රව්‍ය පරීක්ෂණයට භාජනය කරන ලදී. ආමාශීය ද්‍රව්‍ය විශ්ලේෂණයේදී *S. lineatus* වර්ගය, ගණ දෙළහකට අයත් ඩයටම්ද, ගණ හතරකට අයත් නීලහරිත ඇල්ගී ද, ගණ හයකට අයත් හරිත ඇල්ගීද ගණ නවයකට අයත් රතුවන් ඇල්ගීද, *Dictyota* නම් දුඹුරු ඇල්ගාවක්ද, ඩයටෝම ප්‍රධාන කොටගත් *Thallasia* නම් ආවෘතබීජකයක්ද, ආහාරයට ගන්නා පූර්ණ ශාක භක්ෂකයකු වන බැව් පෙනී ගියේය.

මේවායේ ප්‍රධාන සංරචකයන් වූයේ *Licmophora, Gomphonema, Navicula, Oscillatoria Cladosphora Chaetomorpha, Gracilaria* සහ *Laurencia* ය. ඩයටම් හැරුණු කොට සෙසු ගණ සියල්ලම අතිබහා ප්‍රමුඛත්වය දැරුවේ *Thallasia* හ. මසුන් සෙ. මී. 3 දිග කාණ්ඩ වශයෙන් වෙන්කර, මසුන්ගේ ප්‍රමාණය අනුව ඔවුන්ගේ ආහාර පිළිබඳ පුරුදුවල විචලනා විශ්ලේෂණය කළ විට ආහාරයෙහි සැළකිය යුතු වෙනස්කමක් දක්නට නොලැබිණ. දිව කාලයේ සහ රාත්‍රී කාලයේ එක් රැස් කරගන්නා ලද නිදර්ශකවල, ආමාශයේ පිරුණු බව විශ්ලේෂණය කිරීමේදී රාත්‍රී කාලයේ ආහාර ගැනීමේ වැඩි කැමැත්තක් පෙන්නුම් කෙරිණ. මත්ස්‍යයා ප්‍රමාණයෙන් විශාලවත්ම, මසුන්ගේ ආමාශයේ පිරුණු බවක්ද පෙනී ගියේය. *Siganus lineatus* ස්වභාවයෙන්ම ශාක භක්ෂකයෙකි.

පොල් ග්‍රැණුපෝෂයෙන් ලබාගත් - ගැලැක්ටොසිඩේස් ආකර්ශණ වර්ණලේඛ ශිල්ප ක්‍රමයෙන් පවිත්‍රනය කිරීම

කේ. බාලසුබ්‍රමනියම් සහ සී. ඩී. මැතිව්

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පොල් හැන පෝෂයෙන් ලබාගත් ගැලැක්ටොසිඩේස් (α – ඩි – ගැලැක්ටොසයිඩ් ගැලැක්ටොහයිඩ්‍රොලේස් EC 3.2 1.22). පවිත්‍රනය සඳහා නිශ්චිත අධිශෝෂකයන් හතරක් පිළිගෙළ කරන ලදී. සෙෆ්පැරෝස් – 4 බී – ලයිසින් – ගැලැක්ටියුරොනේට්, සෙෆ්පැරෝස් 4 බී ලයිසින් ගැලැක්ටොසැමයින්, සෙෆ්පරෝස් – 4 බී – ලයිසින් – ගැලැක්ටෝස් – පී – කාබොක්සිඇනිලයිඩ් සහ සී එච් – සෙෆ්පැරෝස් – 4 බී – ගැලැක්ටොසැමයින් මෙසේ පිළිගෙළ කරන ලද ආකර්ෂණ ජෙලයන් විය. පොල් ග්‍රැණුපෝෂ නිස්සාරණයෙන් ලබාගත් — ගැලැක්ටොසිඩේස්, ඇමෝනියම් සල්ෆේට් විභාජනයෙන් සහ DEAE සෙෆ්පැඩෙක්ස් වර්ණලේඛ ශිල්

ලේෂණයෙන් අඩ වශයෙන් පවිත්‍රනය කරන ලදී. මෙම අඩ වශයෙන් පවිත්‍රනය කළ ද්‍රව්‍යය, මෙකී නිශ්චිත අධිශෝශකයන් භාවිතයෙන් තවදුරටත් පවිත්‍රනය කරන ලදී. අධිශෝෂණය වූ ඇ ගැලැක්ටොසිඩෙස්, රේඛීය අනුක්‍රමයකට වැඩිවන ස්වාරක්ෂක සාන්ද්‍රණයක් හෝ නිශ්චිත නිරයිශේෂකයක් වන පී – නයිට්‍රොෆිනයිල් – ඇ – ඩී – ගැලැක්ටොපයිරනොසයිඩ් යොද සෝදා හරිනු ලැබේ. උපස්තරය වශයෙන් පි – නයිට්‍රොෆිනයිල් – ඇ ඩී – ගැලැක්ටොපයිරනොසයිඩ් යොද ගනිමින් පරීක්ෂණයට භාජනය කළ පවිත්‍ර කල එන්සයිමයේ නිශ්චිත ක්‍රියාකාරිත්වය, ප්‍රෝටීන් මී.ග්‍රෑ. 1 ට ඒකක 20 ක් විය. මුල් දළ නිස්සාරිතයේ පවිත්‍රනයේ 900-ගුණයක වැඩිවීමක් මෙයින් පෙන්නුම් කෙරෙන අතර ලැබුණු පලදාව 67% ක් විය. පවිත්‍ර නය කළ එන්සයිමය, සම්ජාතිය බව පොලිඇක්‍රිල් එමයිඩ ජෙල් විද්‍යුත්ගාමනයෙන් පෙන්වන් ලදී.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

மேல் மட்ட நீர் பரம்பல் முறைகளுக்கான பயிர் தூண்டப்பேறு

என். சேனநாயக்கா

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சில நீர்ப்பாசன முறைகளுடன் தொடர்பு கொண்ட பயிர் தூண்டப்பேறுகள் மீதான ஒப்பியல் ஆய்வுகள் *1973-1974* ஆண்டுகளில் மேற்கொள்ளப்பெற்றன. இதற்கெனப் பயன்படுத்தப்பெற்ற இரண்டு முறைகளுள் நெளிசால் முறையானது சாதாரண சால் முறையோடு ஒப்புநோக்கப்பெற்றபின் சிறப்பு மிக்க பயிர் தூண்டப்பேறுகளை வழங்கும் வல்லமை கொண்டதெனப் புலனுகியது. இந்நீர்ப் பாசன முறையின் கீழ் செய்கைபண்ணப்பெற்ற அதி ஈரலிப்பு தூண்டப்பேறுடைய பயிர்வகைகள் மிகச் சிறந்த விளைச்சலைத் தரும் வல்லமைகொண்டிருந்தன. சாதாரண சால் முறையோடு ஒப்பு நோக்குகையில் நெளி சால் முறையின் கீழ் செய்கை பண்ணப்பெற்ற வெவ்வேறு பகுதிகளிலிருந்து பெறப்பெற்ற விளைச்சலானது ஒரு சீரான முறையில் அறுவடை செய்ய முடிந்தமை இன்னெரு சிறப்பம்சமாகும்.

கொழும்பு பல்கலைக்கழக மாணுக்கர்களில் காணப்பெற்ற ஊட்டச்சத்து நிலைச் சுட்டிகள் சார்ந்த மாறல்கள்

ரேஸ் ஜீ. எக்ஸ். பிரிஸ், துலிதா என். பர்ணந்து, கே. அபேவிக்கிரமா

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1981 இல் கொழும்பு பல்கலைக்கழகத்தின் நான்கு பீடங்களுக்கு அனுமதிக்கப் பெற்ற *769* மாணுக்கரின் ஊட்டச்சத்து நிலை சார்ந்த சில சுட்டிகளும் சமூகப் பொருளாதார நிலை சார்ந்த தரவுகளும் சேகரிக்கப்பட்டன. மாணுக்கரின் உயரம், எடை, உயரத்துக்கான எடை, ஈமோகுளோபின் செறிவு, தலைப்பூப்பு ஏற்படும் வயது ஆகிய ஊட்டச்சத்துச் சுட்டிகள் ஆய்வுசெய்யப்பெற்றன.

வெவ்வேறு பீடங்களைச் சேர்ந்த மாணுக்கர்கள் அவர்தம் சமூகப் பொருளாதாரப் பின்னணி என்ற வகையிலும் ஊட்டச்சத்து நிலையிலும் மிகுந்த வித்தியாசம் கொண்டவர்களாய் காணப்பெற்றனர். கலைத்துறைப் பீடத்தைச் சேர்ந்த மாணுக்கர்கள் மிகவும் தாழ்வான சுட்டிகளைக்கொண்டிருந்தனர். ஏனைய பீடங்களைச் சேர்ந்த மாணுக்கர்களுடன் ஒப்புநோக்குகையில் மருத்துவ பீடத்தைச் சேர்ந்த மாணுக்கர்கள் — இவர்களுட் பலர் உயர் சமூகப் பொருளாதார வகுப்பைச் சேர்ந்தவர்களே — சிறந்த மனித உடல் அளவைப் பரமானங்களைக் கொண்டவர்களாயும் குறைவான குருதிச் சோகை அறிகுறிகள் கொண்டவர்களாயும் தலைப்பூப்பு ஏற்படும்போது குறைவான இடை வயது கொண்டவர்களாயும் காணப்பெற்றனர்.

மேலீடாகப் பார்க்குமிடத்து உடல் நலமிக்க வாலிபப் பருவத்தினர் எனக் காட்சி அளிக்கும் இம்மாணாக்கர்களுட் பலர் குருதிச் சோகையால் தாக்கப்பெற்றவர்கள் என்ற உண்மை விசேட கவனத்திற்குரியது.

செம்பு, கோபாற்றுப் பெரிசயனேட்டுக்களின் மின் பெயர்வு

கே. தென்னகோன்

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செம்பு, கோபாற்றுப் பெரிசயனேட்டுக்கள் மின் கடத்திகளாகக் காணப்படுகின்றன. இவற்றின் தடைத்திறன் சார் வெப்பநிலை மாறல் இங்கு ஆராயப்பெற்றுள்ளது. 118 °Cக்கு மேல் சூடாக்கப்படாவிடின் செம்புப் பெரிசயனேட்டின் ஏவப்படுகை சக்தி 0.23 eV எனக் கண்டுபிடிக்கப்பட்டுள்ளது. சோதனை மாதிரி 118°Cக்கு மேல் சூடாக்கப்பெறின் கலவையின் இரசாயன படியிறக்கம் காரணமாக ஏவப் படுகை சக்தி 1.43 eV வரை மாற்றமடையும். கோபாற்றுப் பெரிசயனேட்டும் அதே பண்பு நடத்தைகொண்டது. அதன் சோதனை மாதிரி 132 °C க்கு மேல் சூடாக்கப்பெறின் அதன் ஏவப்படுகை சக்தி 0.25 eV இலிருந்து 0.61 வரை மாற்றமடைகிறது.

திரியரில்மீதேன் ஏலீட்டுக்கள், தியோசயனேற்றுக்களின் மின் கடத்தல்

கே. தென்னகோன், மகேந்திரா, கஹந்தா, சிறில் காரிகே

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திரியரில்மீதேன் ஏலீட்டுக்கள், தியோசயனேற்றுக்கள் என்பவற்றின் கடத்து திறன் வெப்பநிலை மாறல் ஆராயப் பட்டுள்ளது, ஏலீட்டுக்கள் பொறுத்தவரை ஏற்றச்சுமைகாவிகளின் வெப்ப ஏவப்படுகை கள்திகச் சக் I> Br> Cl என்ற தொடர்பினைபு முறைப்படி அதிகரிக்குமென்பது கண்டறியப்பட்டுள்ளது. தியோசயனேற்றுக்கள் பொறுத்தவரை கடத்து திறன் நிலைமாறல் ~ 126 °C இல் ஏற்படுகிறது.

இலங்கையில் கனிப்பொருள் வள வளர்ச்சியின் இன்றைய நிலை

டீ. ஜயவர்த்தனை

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இலங்கையின் பொருளாதாரம் விரைவாகச் செழித்து வளரக் கனிப்பொருள் வளங்களை அபிவிருத்தி செய்தல் இன்றியமையாததாகும். கடந்த ஐந்தாண்டுக் காலப்பகுதியில் இரத்தினக்கல் வியாபாரம், பெற்றோலியப் பொருள் மற்றும் மட்பாண்ட ஏற்றுமதி ஆகியவற்றைக் கொண்டு கனிப்பொருள்துறை குறிப்பிடத்

தக்க வளர்ச்சியுற்றுள்ளது. பெனசிற் கரி, பாரிய கனிப்பொருள் மணல், மைகா ஏற்றுமதி செய்வதனூல் கிடைத்த வருமானமும் அதிகரித்துள்ளது. என்றும் கண்டி ராத வகையில் கட்டுமானத் தொழில் பெருகியதன் விளைவாக சீமெந்துக்கு ஏற் பட்ட பெரும் கிராக்கிக்கு ஈடு கொடுக்கத்தக்கவாறு உள்ளூர் மூலப் பொருள்களைப் பயன் படுத்தி சீமெந்து கைத்தொழிலும் வேகமுடன் வளர்ச்சி அடைந்தது.

இந்நாட்டினுள்ள கனிப்பொருள் வளங்களைத் தக்க முறையில் மதிப்பீடு செய்யத் தவறியமை கனிப்பொருள் துறை விரைவாக வளர்ச்சியுறப் பெரும் தடையாக இருக்கிறது. பயன்படுத்தத்தகு கனிப்பொருள் வளங்களின் பண்பினையும் அளவினையும் மதிப்பீடு செய்யும் பெரு நோக்கத்துடன் முன்னெடுத்த புவிச்சரிதவியல் அளவைத் திணைக்களம் புதிய கனிப்பொருட் படிவுகளைக் கண்டுபிடிக்கவும் இது வரை கண்டுபிடிக்கப்பெற்ற கனிப்பொருள் வளங்களை அபிவிருத்தி செய்யவும் அயராது உழைத்து வருகிறது. பயன்பாட்டுக்குப் பின் வற்றுப்போகின்ற இவ் வளங்களைக் கிரமமாகப் பயன்படுத்தவில்லையெனின் வருங்காலத்தில் உள்ளூர் கனிப்பொருள் மூலக் கைத்தொழில்களின் தேவையினைப் பூர்த்திசெய்தல் அரிதா கும். அக்கைத்தொழில்களின் வளர்ச்சியும் தடைப்படும்.

இலங்கையில் பல்வேறு கைத்தொழிற் துறைகளில் இன்று உபயோகிக்கப்பெற்று வருகின்ற கனிப்பொருள் வளங்களினதும் மூலப் பொருளாக ஏற்றுமதி செய்யப் பெறுகின்ற கனிப்பொருள்களினதும் அபிவிருத்தி எங்ஙனம் அமைய வேண்டு மென்பது இந்தக் கட்டுரையில் விளக்கப்பட்டுள்ளது. கற்பாறைப் பொசுபேற்று, செம்பு-மாக்கனேற்றுத்தாது போன்ற அண்மையில் கண்டுபிடிக்கப்பட்ட கனிப் பொருள்களின் பொருளியல் முக்கியத்துவம், புதிய கைத் தொழில்களைத் தாபிப் போருக்கு இவை உபயோகமாகும் முறை ஆகியனவும் விளக்கப்பட்டுள்ளன. வருங்கால கனிப்பொருள் தேடும் நிகழ்ச்சித் திட்டங்களுக்கு அமையும் குறியிலக்கு களும் இக்கட்டுரையில் ஆராயப்பெற்றுள்ளன.

இரண்டு மாவட்டங்களில் நெல் விளைச்சலைப் பாதிக்கும் காரணிகளின் ஆய்வு

ஆன் லீக்கர்

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அனுராதபுரம், இரத்தினபுரி ஆகிய மாவட்டங்களில் நெல் விளைச்சலினைப் பாதிக்கும் காரணிகள் ஆய்வுசெய்யப்பெற்றுள்ளன. 1962 - 1978 வரையுள்ள தரவுகளைப் பயன்படுத்திப் பின்னிறக்கப் பகுப்பாய்வுகள் மேற்கொள்ளப்பெற்றுள் ளன. நெற்பயிரின் ஒவ்வொரு வளர்ச்சிப் பருவங்களிலும் தேவைப்படும் நீரின் அளவினை ஆராய்ந்து அதன் வளர்ச்சிப் பருவங்களின் மீது விசேட கவனம் செலுத் தப்பட்டுள்ளது. செய்கை பண்ணப்படுகின்ற மொத்த நிலப்பரப்பு அதிகரிக்கும் பட்சத்தில் அஃது ஓர் ஏக்கருக்குரிய விளைச்சலின் மீது பெரிய தாக்கம் ஏற்படுத்த வல்லதெனப் பெறுபேறுகள் காட்டுகின்றன. இரத்தினபுரி மாவட்டத்து இரண்டு போகங்களிலும் அனுராதபுர மாவட்டத்து பெரும் போகத்திலும் இது நிரூபண மாயிற்று.

மறு நடுகை, நெல்லின் இனம், உர வகைகள், நீர்ப்பாசனம் போன்ற தொழினுட்பவியல் ஆராய்ச்சிமுறை (இந்தக் கட்டுரையில் தொழினுட்பவியற் காரணிகள் எனக் கூறப்பட்டது) சார்ந்த, காலநிலையோடு தொடர்பற்ற காரணிகள், விசேடமாக அனுராதபுர மாவட்டத்தில், நெல் உற்பத்திக்கான முக்கிய பங்கினை வகித்து வருகின்றனவென்பதை இந்த ஆய்வு மூலம் அறியலாம். குறிப்பாக அனுராதபுர மாவட்டத்தில் காலநிலை மாறிகளின் மாற்றங்கள் தொழினுட்பக் காரணிகள் பாதிக்கும் அளவிற்கு விளைச்சல் மாற்றங்களைப் பாதிக்கவில்லை. முக்கியத்துவம் வாய்ந்த காலநிலை மாறிகள் பயன்படுத்தப்பெற்ற தொழிநுட்ப முறையினை நம்பியிருந்தனவென்பதையும் பெறுபேறுகள் சுட்டிக்காட்டின. உதாரணமாக, அனுராதபுரத்தில் சிறு போக வேளாண்மை பெரும்பாலும் பெரிய நீர்ப்பாசனத் திட்டங்களையும் வெப்பநிலையினையும் நம்பியிருந்தது. ஆனால் பெரும் போகம் செய்யும் விவசாயிகள் இன்றும் ஓரளவிற்கு மழை நீரை நம்பி இருக்கின்றபடியால் மழைவீழ்ச்சியும் ஒரு முக்கியமான காலநிலைக் காரணியாக அமையும் என்பது கண்டறியப்பெற்றது.

மேல் ஆராய்ச்சிகள் எத்திசை நோக்கிச் செல்லவேண்டும் என்பதையும் இக் காரணிகளின் விளைவும் அவற்றின் செயல், எதிர்ச் செயல் எங்ஙனம் அமைந்து முழு நிறைவான அறிவினைப் பெற உதவவேண்டுமென்பதையும் இந்த ஆய்வு தெட்டத் தெளிவாகக் காட்டியுள்ளது.

தோல் பருப்பு மூலம் தேர்மினுலியா செபுலா தனின் கூறுகளின் உள்ளெடுப்பு — tlc-uv செறிவுமானம் பயன்படுத்தப்பட்டுள்ளது

எஸ். இரத்தினுயக்கா, இ. இ. ஜான்ஸ், கே. ரீ. த. கில்லா

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tlc-uv செறிவுமானத்தைப் பயன்படுத்தித் தேர்மினுலியா செபுலா தனின் பதார்த்தங்களை வேருக்கும் முறையும் அவற்றின் கணியப் பகுப்பும் விளக்கப் பட்டுள்ளன. இம்முறை 0.5 முதல் 2.5 வரை uv/tlc சரி நுண்ணிட வீச்செல்லைக் குள் பிரயோகிக்கப்பட முடிவதுடன் ஒவ்வொரு தனின் வகைக்கும் 4-6 வரையான மாறல் குணகமும் கொண்டுள்ளது. தனிநிலைத் தனின் கூறுகள் மீதும் அக்கூறுகளும் மைருபாலான் பிழிசாறுகளும் கலந்த சேர்வைகளின் மீதும் இம்முறையினைப் பயன்படுத்திய தன் பின்னர் 0.5 செறிவு மட்டத்தில் செபூலினிக்கமிலமும் செபூலாகிக்கமிலமும் விரைவாக தோலுள் எடுக்கப்படுகின்றனவென்பது கண்டு அறியப்பட்டுள்ளது. இவற்றின் உள்ளெடுப்பு விகிதம் செபூலினிக்கமில (நீர்மக் கரைசலில் வெப்பத்தைக் கொண்டு)ப் பிரிகை உற்பத்திகளை விட வேகம் கொண்டு இயங்குகிறதென்பதும் கண்டுபிடிக்கப்பட்டுள்ளது. பின்னையது மைருபாலான் தனின் வகைகளை மென்னயமுள்ள சூழலில் பிரித்தெடுப்பதன் அனுகூலத்தைச் சுட்டிக்காட்டுகிறது. தோலால் செபூலினிக்கமிலத்தை உள் எடுப்பதற்கு மிகப் பொருத்தமுடைய pHபெறுமானம் 4.1 ஆக இருப்பதும் இவ் ஆய்வால் புலனுகியது. அஃதாவது இச்சேர்வையின் மூலம் தோல் பதனீடு ஏற்படும்போது காபொட்சில் அமிலவினத்தின் அயனுக்கம் முக்கிய பங்கு வகிக்கின்றதென்பது வெளிப்படை.

இலங்கையர்களின் உணவுக் கோட்பாடுகளும் பழக்க வழக்கங்களும்

3. பெருந்தோட்டத் துறை

சந்திராணி லியனகே, ரீ. டபிள்யூ. விக்கிரமநாயக்கா

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கண்டி, நுவரேலியா மாவட்டங்களைச் சேர்ந்த தோட்டங்களில் 300 தாய்மார்கள் கருப்ப காலம், பால்கொடுக்கும் காலம், பால்மறத்தற் காலம் ஆகிய பொழுது களில் உட்கொள்ளாத உணவுவகைகள் பற்றியும் சில பழக்க வழக்கங்கள் பற்றியும் இங்கு ஆய்வு செய்யப்பட்டுள்ளது. இத்தாய்மார்கள் கடைப்பிடிக்கும் பழக்க வழக்கங்களுக்கும் தென்னிந்தியத் தாய்மார்கள் அனுசரிக்கும் முறைகளுக்கும் இடையில் ஓரளவான ஒப்புமை இருப்பதெனினும் தமிழ் நாட்டுத் தாய்மார்களை விட இலங்கைத் தோட்டத் தொழிலாளிப் பெண்களிடையில் உணவு அருந்தல் பற்றிய தடைக்கட்டுகள் அவ்வளவு இல்லை எனலாம். இது தோட்டங்களில் கூடு தலான மருத்துவமனைகளும் கிளினிக்குகளும் இருப்பதனால் ஏற்பட்ட விளைவு ஆகலாம். உணவுத் தவிர்ப்புக்கெனக் கொடுக்கப்படும் காரணங்கள் பல. உணவு களின் ''குளிர்-சூடான'' தன்மை, கருப்பநிலைக் காலத்தின் மீதும், பிள்ளைப் பேற் றுக்குப் பின் பேற்றுநீர் இழிவின் மீதும், சுரக்கப்பெறும் தாய்ப்பாலின் அளவு, பண்பின் மீதும் அவ்வுணவுகள் கொண்டுள்ள தாக்கம் ஆகியவை அவற்றுட் சில.

தாய்மார்களுட் பலர் பிள்ளைப் பேற்றுக்குப் பின் 48 மணித்தியாலங்களுக்குள் முலைப்பால் கொடுக்கத் தொடங்குகின்றனர். இத்தாய்மார்களுள் மூன்றில் ஒரு பங்கு வீதத்தினர் இரண்டு வருடங்களைக் கடந்தும் பிள்ளைகளுக்கு முலைப் பால் ஊட்டுகின்றனர், பாண், விசுக்கோத்துக்கள் முதன்முதல் ஊட்டப்படும் திண்ணிய உணவுகளாகும். குழந்தைகள் பலருக்கு முதல் வருடத்தின் இறுதியில் சோறு ஊட்டப்படுகின்றது.

வட இலங்கையைச் சூழ்ந்துள்ள நீர்நிலைகளில் வாழும் சிகானுசு லினேதுசு (Siganus Lineatus) மீனின் உணவும் உணவுப் பழக்கங்களும்

கே. சித்திரவடிவேலு, ஏ. சிவபாலன்

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சிகானுசு லினேதுசு **(Cuvier and Valenciennes)** என்பது இலங்கையின் கட லோரப் பகுதிகளிலும் சவரான நீர் நிலைகளிலும் வாழும் ஒரு கடல் மீன் இனமா கும். இது இந்தியப் பெருங்கடலிலும் பசுபிக் பெருங்கடலிலும் அயன மண்டலப் பகுதிகளில் உயிர் வாழ்கிற மீன் ஆகும்.

வட கடலோரத்தைச் சேர்ந்த தொண்டமானாறு, யாழ்ப்பாணக் கடலேரிகளின் பன்னிரண்டு இடங்களிலிருந்து சேகரிக்கப்பெற்ற 2.4. cm முதல் 25.5 cm வரையான மீன்களின் உதர உள்ளடக்கங்கள் சோதனைக்கு எடுக்கப்பட்டன.

உதர உள்ளடக்கங்களைப் பகுப்பு செய்த பின்னர், சி. லினேயசு முற்றுகவே இலைகளை உண்டு வாழும் மீன் என்பது தெளிவாகியது. இம்மீனினம் பன்னிரண்டு சாதி தயற்றங்களையும் நான்கு சாதி நீலப்பச்சை அல்காக்களையும் ஆறு சாதி பச்சை அல்காக்களையும் ஒன்பது சாதி சிவப்பு அல்காக்களையும் திக்கியோதா எனும் கபில நிற அல்காவினையும் தயற்றங்கள் விஞ்சி மேம்பட்டிருக்கும் தல்லாசியா எனும் வித்துமூடியுளியினையும் உணவாகக் கொள்ளுகின்றது. இவற்றுள் இலிகொம்போரு, கொம்போனேமா, நாவிகூலா, ஒசில்லாதொறியா, இளாடோருபோரு, சேற்றேமோர்பா, கிருசிலாரியா, லோறென்சியா ஆகியவை பெருவாரியாக உட்கொள்ளப்பட்டிருந்தன. தயற்றங்களைத் தவிர, இவ்வெல்லா சாதிகளிலும் தல்லாசியா விஞ்சி மேம்பட்டிருந்தது.

உடல் நீளம் 3 சென்றி மீற்றர் அளவு கொண்ட வகுப்புகளில் இட்டு மீன்களின் உணவு உட்கொள்ளும் பழக்கங்களை மாற்றுவதற்கு வழிகோலிய பின்னரும் அவை உட்கொண்ட உணவு வித்தியாசப்படவில்லை. இராப் பகல் உதரத்தின் நிறைவினைப் பகுப்பு செய்வதற்கு மேற்கொண்ட சோதனையின் பிரகாரம் இரவு நேரங்களில் உணவு உட்கொள்ள இம் மீன்கள் விருப்பம் காட்டுகின்றன என்பது புலனுகியது. வயிறு பெருகப் பெருக மீனின் அளவும் பெருகும் ஓர் இயல்பும் காணப்பட்டது. சிகானுசு லினேதுசு இயல்பாகவே இலையுண்ணி எனலாம்.

இணைப்பீர்ப்புச் சேர்மானப் பிரிப்பின் மூலம்
தெங்கு வித்தகவிழையத்து ∝ — கலற்ரோ சிடேசு தூய்தாக்கம்

கே. பாலசுப்பிரமணியம், சி. டீ. மத்தியூ

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (1): 113—127

தெங்கு வித்தக விழையத்து ∝ - கலற்ரோ சிடேசு (∝-D-க லற்ரோசிடே கலற்ரோ ஜதரோலேசு EC 3.2 1.22)) தூய்தாக்கத்துக்கென நான்கு தனிநீலை புறத்து உறிஞ்சிகள் தயாரிக்கப்பட்டன, தயாரிக்கப்பெற்ற இணைப்பீர்ப்பு அரைதிண்மக் கரைசல்கள் வருமாறு: செப்பாரோசே — 4B — இலைசின்- கலற்றுரோனேற்று; செப்பாரோசே - 4B - கலற்ரோசாமைன்; செப்பாரோசே - 4B - இலைசின் - கலற்ரோசே - P - காபொட்சியனலைட்டு; CH - செப்பாரோசே - 4B - கலற்ரோசாமைன் - ஆகியனவாகும். தெங்கு வித்தக விழையப் பிழிசாற்று ∝ கலற்ரோசிடேசு DEAE செப்பாடெக்சு ஈர்ப்புச் சேர்மானப் பிரிப்பு வழியாக அமோனியச் சல்பேற்றுப் பகுதிபடுத்தல் மூலம் அரைகுறையாகத் தூய்தாக்கப் பெற்றது. அடுத்ததாக இப்பாதியாகத் தூய்தாக்கப்பெற்ற தயாரிப்பு மேற்கூறிய தனிநிலைப் புறத்து உறிஞ்சிகளைப் பயன்படுத்தி இணைப்பீர்ப்புச் சேர்மானப் பிரிப்பு மூலம் மேலும் தூய்தாக்கப்பட்டது. தாங்கற் செறிவு அதிகரிப்பு சார் நீட்டல் படித்திறனுற்றலைப் பயன்படுத்தி அல்லது P - நைற்ரோபினில் ∝ - D - கலற்ரோபைரனோசைட்டுத் தனி நிலை உறிஞ்சனீக்கியைப் பயன்படுத்தி புறத்துறிஞ்சப் பெற்ற ∝ - கலற்ரோசிடேசு கழுவி நீக்கப்பெற்றது. அடிப்படைப் பொருள் 20 அலகுகள் / மி.கி. புரதம் என்ற அளவினதாக இருந்தபடியால் தூய்தாக்கப்பெற்ற நொதியத்தின் தனி

நீலத் தொழிற்பாடு P - நைற்ரேபினில் - ∝ - D - கலற்ரே பைரனைசைட்டு உபயோகிக்கப்பெற்று பரீட்சிக்கப்பட்டது. இதன்வழி மூல செப்பமாக்கப்படாத பிழிசாற்றின் தூய்தாக்கம் 900 மடங்கு அதிகரித்தது. அத்துடன் விளைச்சலும் 67%. ஆகவும் இருந்தது. பொலிசுக்கிரிலமைட்டு அரை திண்மக் கரைசல் மின்னயனத்தின் வழி தூய்தாக்கப் பெற்ற நொதியம் ஏகவினமாய் அமைந் திருந்தது.

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