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TEN SCIENTISTS HONOURED

Address by His Excellency,

President J. R. Jayewardene

at the ceremony honouring achievements of ten Sri Lankan Scientists

All over the world, scientists, comparatively speaking, form a very small group; firstly, because before they attain eminence in the fields that they have adopted, they have to spend years of study. Also, the fields in which they work are limited as far as numbers are concerned. I've read through the biography of some of those who are receiving awards today, and I see the amount of work that they must have done; the places they must have gone to, to do their research, the competition they must have faced; and the awards have been given to them.

Sri Lanka should be proud that we have men and women of your calibre, though it is a small country, though its population is also comparatively small. Within this small compass, I think we have in the past produced, are producing today and can in the future also produce, men and women who can hold their own in the academies of the world.

Unfortunately we cannot afford to give all of you the opportunities that bigger countries afford; it is so in every part of the world, even in the big countries such as India. Some learned men have to go abroad to complete their studies, or to find an avenue for the use of their work and the attainments they have reached.

In our country, too, you find men of science of Sri Lanka who are contributing their quota to the advancement of world knowledge. This is something that I have personally thought of, and have now been given the opportunity of giving science a proper place in our development. I remember it was a commission appointed by me, under the Chairmanship of Sir Sydney Cain that recommended the establishment of the Institute of Scientific Research. I think soon after the UNP lost in 1956 or just before, that recommendation was implemented.

Since I assumed office as President and had greater opportunity of carrying out my intentions, we have created several Institutes dealing with scientific knowledge.

The Science Council has now been absorbed in the body dealing with Natural Resources, Energy and Science. It has got off the ground, and I hope it will make its contribution to our knowledge. The Fundamental Research Institute, also recommended in the 1950s, lay hidden in the report of a commission. We got it out, published it, and the Fundamental Research Institute has just started work. An Institute to deal with environmental pollution has also been created. The National Aquatic Resources Authority is now functioning. The Pali Buddhist University, for the first time in the world, has been inaugurated.

There are many more similar institutions that are necessary, that we intend to establish. That shows the interest that my Ministers and I take in scientists and the opportunities given to them to do research, either here or abroad, and in the implementation of their recommendations.

I find that of the several distinguished men who are receiving awards, five of them have been chosen as a team for the Presidential awards and they have helped us in rice production: in producing a variety which has helped to increase our production of rice so enormously in the past few years. The other scientists, I find have also interested themselves in agriculture, some in rubber, some in coconut and some in the soil and what is pertinent to agriculture.

Only Dr. Gnanalingam has ventured into outer space. I hope his researches will help us, and help the world to find out what is out there.

These men – I am sorry there is no woman among them - are people of great attainment. I am sure in the time to come, too, they would give of their knowledge and devote themselves to scientific advance. These men who are receiving awards for the first time, as the Minister says, have been recognised by the State.

I have had various complaints that the salaries they get are not enough. That's a complaint which even Ministers make. I am afraid I cannot talk about that just now, but I do feel that those who devote themselves to science are those who should be adequately rewarded, not only by getting President's Awards and other awards, but in the emoluments that they get.

I think, in the last few years, we have been able to help them to some extent. They must understand that they form part of a bigger complex, and theirs is a complaint that is universal. But I do feel we must try and keep them in our country, either by paying them adequately for the work they do, providing them necessary research facilities and further scope for them to give expression to what they have learnt and are learning for the betterment of our people.

Because we are a small country we cannot provide the facilities that big countries provide. But I am sure that particularly India close to us, has promised in any way to help our students, and scientists, to learn in their great institutes. I am sure countries such as the United States of America and England particularly, where our men and women are studying and working, have stretched out the hand of friendship to us and have agreed to exchange scholars to help us with necessary equipment and finance and also to come here and work together with us. We must take advantage of those offers because Sri Lanka is small and cannot afford to provide the facilities that these big countries provide. It is not we alone who are in this difficulty. You possibly know that the great scientist Rutherford, had to leave New Zealand and go to Cambridge to do the research which ended in the splitting of the atom.

It is not only Sri Lanka that's in this difficulty. Practically every country in the world except the few that are developed, the few that have all the wealth, the money and the resources to give scientists scope for the use of their talents, have this problem.

I am happy that I am able to give these awards today – the President's Award and the other awards, firstly, to the team that did research in rice and to the other scientists, for their individual attainments.

Address by the Secretary-General, National Science Council of Sri Lanka,
Dr. R. P. Jayewardene

Your Excellency, Honourable Minister of Industries and Scientific Affairs, Honourable Minister of Agriculture, Ladies and Gentlemen,

We are fortunate to be present on this historic occasion when, for the first time in the history of our Country, the Government and Head of State recognise and reward distinguished Scientists.

In initiating the awards scheme we have introduced into the field of Science the spirit of competition. Competition is an important feature in another field of human endeavour — the field of sport where individual achievement is highly praised. Where many are called and few are chosen. Where there are winners and losers and the winners become the heroes and idols of the public. In the field of science, individual achievement is based on the accumulated knowledge gathered by many scientists over many years and in many parts of the world. It is a community effort and the community benefits. Hence we are all winners. It is therefore fit and proper that the State recognize and reward the achievements of the scientists.

Your Excellency, the Scientists of Sri Lanka and the National Science Council thank you for accepting the awards scheme and consenting to name the first prize as the President's Award for the keen interest you take in the development of Science and for arranging this ceremony in the President's House. We also thank the Minister of Industries and Scientific Affairs and the staff of this Ministry for their kind help in all scientific matters and all of you for being present this morning to grace this occasion.

PRESIDENTIAL AWARDS FOR SCIENTIFIC ACHIEVEMENTS
(1981—1982)

Left to right

Back row : Prof. S. N. Arseculeratne, Mr. M. Nadarajah, Dr. O. S. Peries, Dr. S. Gnanalingam

Front row : Mr. C. Kudagamage, Dr. D. Senadhira, His Excellency President J. R. Jayewardene, Mr. C. A. Sandanayake, Mr. M. P. Dhanapala

NATIONAL AWARDS FOR SCIENTIFIC ACHIEVEMENTS
(1981-82)

PRESIDENT'S AWARD

The President's Award for Scientific Achievement has been won by the following team of scientists: Dr. H. Weeraratne, Dr. D. Senadhira, Mr. M. P. Dhanapala, Mr. C. Kudagamage and Mr. C. A. Sandanayake.

This team of scientists was responsible for the breeding of the BG varieties of rice the use of which has contributed enormously to the increase in rice production in Sri Lanka.

The breeding programme carried out by this team has produced varieties which are non-lodging, high yielding and resistant to Leaf blast and Bacterial leaf Blight. The breeding programme also produced $3\frac{1}{2}$ month varieties that could replace the traditional varieties of this age class which are low-yielding. Varieties resistant to the Gall Midge and the Brown Hopper have also been produced.

It is hoped that this Award would serve as an incentive to agricultural scientists and to scientists of other disciplines to increase the pace of national development through the application of science and technology.

HECTOR WEERARATNE — Bachelor of the Science of Agriculture, University of the Philippines; Doctor of Philosophy (Agronomy), North Dakota State University, USA; Rice Breeder, *Centro Internacional de Agricultura Tropical*, Cali, Colombia; Formerly Senior Rice Breeder, Central Rice Breeding Station, Batalagoda.

DHARMAWANSE SENADHIRA — Bachelor of the Science of Agriculture, Sri Lanka; Doctor of Philosophy, University of California; Ford Foundation Scholar 1969; Rockfeller Foundation Fellow 1972; Senior Rice Breeder and Deputy Director, Agriculture, Central Rice Breeding Station, Batalagoda.

MADDUMA PATHIRANNEHELAGE DHANAPALA — Bachelor of the Science of Agriculture, Sri Lanka; Master of Science, Saga University, Japan; Rice Breeder, Central Rice Breeding Station, Batalagoda.

CHANDRASIRI KUDAGAMAGE — Bachelor of the Science of Agriculture, Sri Lanka; Master of Science, Purdue University, USA; Entomologist, Central Rice Breeding Station, Batalagoda.

CHANDRADEWA ASHOKA SANDANAYAKE —Bachelor of the Science of Agriculture, Sri Lanka; Rice Breeder, Central Rice Breeding Station, Batalagoda.

NATIONAL SCIENCE COUNCIL AWARDS

The National Science Council Award has been won by five scientists for outstanding research carried out over a period of several years.

SARATH NANDA ARSECULERATNE – Bachelor of Medicine and of Surgery, Sri Lanka; Doctor of Philosophy, University of Oxford; Visiting (Fulbright) Professor of Microbiology, Harvard University (1972/73); Professor of Microbiology, University of Peradeniya.

Professor S. N. Arseculeratne has won the Award for his research work on hepatotoxins. His work includes a survey of contamination of coconut and other food products by aflatoxins, recommendations regarding control of contamination, studies on the decontamination of coconut oil, work on assay techniques, and research on liver diseases caused by aflatoxins. Prof. Arseculeratne has also trained a number of research scientists who, working under his supervision, have obtained high post-graduate qualifications.

SUNTHARALINGAM GNANALINGAM–Bachelor of Science, First Class Honours, Sri Lanka; Bachelor of Arts, Engineering Tripos, First Class Honours, University of Cambridge; Doctor of Philosophy, University of Cambridge; Former Fellow, Trinity College, Cambridge (1952–1956), Fellow of the Institution of Electrical Engineers, London; Senior Member of the Institute of Electrical and Electronics Engineers, New York; Senior Post-doctoral Resident Research Associate of the US National Academy of Sciences at the NASA Goddard Space Flight Centre (1971-1972); President-Elect of the Sri Lanka Association for the Advancement of Science (1982); Head, Section of Applied Physics and Electronics, Ceylon Institute of Scientific and Industrial Research.

Dr. S. Gnanalingam has won the Award for his research work on the ionosphere. While attached to the Ceylon Institute of Scientific and Industrial Research, he pioneered and carried out a sustained programme of research on the ionosphere. Sri Lanka being situated near the equator is an important link in the programme of ionospheric research being carried out in different parts of the world. Ionospheric research is of importance in communication technology and it also helps to elucidate the basic chemical and physical processes taking place in the upper atmosphere.

MURUGESU NADARAJAH – Bachelor of Science, Sri Lanka; Master of Science, University of Birmingham; Winner of the gold medal awarded by the Institute of Chemistry in 1979 for research and development on new types of natural rubber latex; Retired Head of the Rubber Chemistry Department, Rubber Research Institute, Sri Lanka.

Mr. M. Nadarajah has won the Award for his many important contributions to the development of rubber technology in Sri Lanka. Mr. Nadarajah's work includes investigations on the deleterious effects of the presence of copper in latex, factors causing the growth of mould in rubber, the improvement of the quality of latex crepe, the use of papain as a coagulant of latex, and the use of natural rubber as an adhesive and as an additive to bitumen.

OSMUND STANLEY PERIES – Bachelor of the Science of Agriculture, University of Melbourne; Doctor of Philosophy, University of Bristol; General President of the Sri Lanka Association for the Advancement of Science (1981); Director, Rubber Research Institute, Sri Lanka.

Dr. O.S. Peries has won the Award for his extensive research work on fungal diseases on rubber and methods of disease control. Dr. Peries has carried out extensive research work over a period of several years on a number of fungal diseases of the leaves, bark and root of the rubber tree. His research work extended to the investigation of control measures. The adoption of the control measures recommended by him has resulted in a significant improvement in the economics of rubber production. Dr. Peries has also played an important role in training post-graduate research scientists.

CHRISTOPHER RAJENDRA PANABOKKE – Bachelor of Science, Sri Lanka; Doctor of Philosophy, University of Adelaide; Retired Director of Agriculture. Senior Research Fellow, International Service for National Agricultural Research, The Hague, Netherlands.

Dr. C. R. Panabokke has won the Award for his studies on the soils of Sri Lanka and their agricultural potential. Dr. Panabokke's studies on the soils of Sri Lanka have made an extremely valuable contribution to our understanding of the physical and chemical characteristics of Sri Lanka's soils and their suitability for different agricultural crops. He was responsible for the development of soil survey and land classification criteria for major irrigation development projects in this country. His work on soil survey and land classification has played an important part in the agricultural development programme of the country.

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On the use of Complete and Incomplete Information in Regression Analysis

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Abstract : Theil's Theory of restricted least squares is extended to the case of mixed linear and quadratic constraints on the parameters of the multiple regression model which is, for instance, the case arising in estimating a class of nonlinear models. The 'mixed estimation problem' of Theil and Goldberger (1961) and Theil (1963) is also considered when the estimates of the parameters are required to satisfy any exact linear restriction, and explicit formulae for 'restricted least squares estimates in mixed estimation' are established.

1. Introduction

Suppose the statistician has some prior knowledge on the Parameters of a regression in addition to the sample observations. He may have knowledge of the sum of some coefficients, of the values of some coefficients, of the certain relationships between the coefficients, or of merely the signs of some coefficients. The statistician may have derived this information from economic theory or perhaps from previous statistical work. Such knowledge that the statistician might have in addition to the prevailing sample information is refered to as extraneous information. The advantage of incorporating this extraneous information is clear: it is intuitive that a gain in efficiency will result provided that the available information is utilised properly and efficiently. This extraneous information may be used to improve the estimates of the unknown parameters.

The first three sections of this paper will be devoted to discuss the restricted least squares. The estimation results of the restricted least squares under exact linear restrictions is reproduced in Section 2. The purpose of the third section is to establish an estimation procedure when the coefficients are related by a quadratic equation whereas in the fourth section the same is done under restrictions on the coefficients up to an equation of second order. A numerical example is given in each of these two sections to illustrate the procedure. The last two sections are concerned with the mixed estimation. The results of the classical mixed estimation are reproduced in Section 4. As an extension, in section 5, similar results are obtained for mixed estimation under linear restrictions on the coefficients.

Throughout this paper we shall make the usual assumptions on the regression model $y = X\beta + \varepsilon$, that the disturbances are uncorrelated, homoscedastic, and each has Zero means.

$$E(\varepsilon) = O$$
$$E(\varepsilon\varepsilon') = \sigma^2 I$$

with the N x K matrix of X of rank K fixed in repeated samples where y and E are N x I vectors and β is the KxI parameter vector.

2. Exact Linear Restrictions, Restricted Least Squares

Suppose we know a set of linear relationships between the parameters. Situations of this kind arise often in Economic theory, for example, the sum of the exponents in a Cobb-Douglas production function is known to be one, sum of the money income and price elasticities in a demand function is known to be zero. One way of dealing with this kind of a problem is to incorporate the restriction in the fitting process in such a way that the restriction is exactly satisfied by the estimated coefficients. A general formula for the least squares estimators of the parameters subject to exact linear restrictions was first developed by Theil (1) in 1961. The following is an outline of that proof.

The given set of linear restrictions on the parameters may be expressed compactly as,

$$\mathbf{r} = \mathbf{R}\beta$$

where r is a known column vector of $g<k$ elements, g being the number of restrictions, and R is a $g \times k$ known matrix. In order to find b, the desired "restricted least squares estimator" of β, the sum of squared residuals $(\mathbf{y} - \mathbf{Xb})\,(\mathbf{y} - \mathbf{Xb})$ is minimized subject to $(\mathbf{Rb} - \mathbf{r})$. Using the Lagrangian minimization it is shown that this occurs when,

$$\mathbf{b} = \hat{\beta} + (\mathbf{X'X})^{-1}\mathbf{R'}\,[\mathbf{R}(\mathbf{X'X})^{-1}\mathbf{R'}]^{-1}(\mathbf{r} - \mathbf{R}\hat{\beta})$$

where $\hat{\beta} = (\mathbf{X'X})^{-1}\mathbf{X'y}$ is the ordinary (unrestricted) least squares estimator. It can be easily shown comparing the variances of the estimates b and $\hat{\beta}$ that there has been a gain in efficiency in using the extraneous information which consists of exact linear restrictions on the parameters.

3. Least Squares Under Quadratic Constraints

It is of mathematical interest now to find the restricted least squares estimators when the extraneous information consists of exact quadratic restrictions on the coefficients, because of its simplicity. Such a treatment is useful, in particular, in estimating the parameters of nonlinear models such as $Y = \theta + (\alpha X_1 + \beta X_2)(\gamma + X_3)$ which is equivalent to the linear model $\lambda = 0 + \alpha X_1 X_3 + \beta X_2 \times_3 + \lambda_1 X_1 + \lambda_2 X_2$ with the restriction $\alpha\lambda_1 - \beta\lambda_2 = 0$. First we consider the case where only a single constraint on the coefficients of the classical regression model is present.

Let the single quadratic relationship between the coefficients of the linear regression model $\mathbf{y} = \mathbf{X}\beta + \varepsilon$, be

$$C = \beta'\mathbf{R}\beta$$

where C is a known scaler and R is a known symmetric matrix of order k. For example, if we wish to incorporate the restriction $\beta^2 + 4\beta\beta_2 + 2\beta\beta_3 + 3\beta_3^2 = 3$ we would set,

$$C = 3 \quad \text{and} \quad R = \begin{pmatrix} 1 & 2 & 1 & 0 & 0 & . & . & 0 \\ 2 & 0 & 0 & 0 & 0 & . & . & 0 \\ 1 & 0 & 3 & 0 & 0 & . & . & 0 \\ 0 & 0 & 0 & 0 & 0 & . & . & 0 \end{pmatrix}$$

It should be pointed out that it is not always possible to find the restricted least squares subject to a quadratic constraint on the parameters by direct substitution, unlike in linear constraints. However we can make use of the Lagrange minimization to do this. The estimates of the parameters obtained by restricted least squares in this case, will not be unbiased. Nevertheless, these estimates possess smaller mean square error over the unrestricted least square estimates.

We seek for the estimated coefficient vector, b, to satisfy the restrictions, so we must find b that minimizes $(y - Xb)'(y - Xb)$ subject to the restriction $C = b'R\,b$. therefore we minimize,

$$F(b,\lambda) = (y - Xb)'(y - Xb) - \lambda\,(c - b\,R\,b)$$

where λ is a Lagrange multiplier which is a scalar. The points at which a local minimum . a local maximum or a saddle point may occur, can be evaluated by setting the respective derivatives of $F(b, \lambda)$ with respect to b and λ equal to zero;

$$\frac{\partial F}{\partial b} = -2X'y + 2(X'X)b + 2\lambda\,Rb = 0$$

$$\frac{\partial F}{\partial b} = -C + b'Rb = 0$$

Hence the required values of b and λ are given by the quadratic equations,

$$\left.\begin{aligned} (X'X + \lambda R)b &= X'y \\ b'Rb &= C \end{aligned}\right\} \qquad (3.1)$$

or equivalently by

$$\left.\begin{aligned} (I_k + \lambda(X'X)^{-1}R)b &= \hat{\beta} \\ \text{with} \quad \lambda &= 1/C\,(b'X'Xb - y'Xb) \end{aligned}\right\} \qquad (3.2)$$

where $\hat{\beta}$ is the unrestricted least squares estimator of β .

These equations cannot be solved explicitly for b, however, they can be solved numerically for a given problem, under certain conditions on R. To illustrate this fact, a numerical example will be discussed at the end of this section.

In order to choose the value of b which indeed minimizes the Lagrangian function $F(b,\lambda)$ the following second order condition is used.

In order to minimize the sum of squares of residuals subject to the quadratic constraints we must choose the values of λ for which the matrix

$$\frac{\partial^2 F}{\partial b\, \partial b'} = 2\,(X'X + \lambda\, R) \text{ is positive definite.}$$

In case where there are more than one local minima of $F(b,\lambda)$ occur the one which gives the least value of F is to be chosen. The restricted least squares estimate of β is the value of b that satisfies the equation 3.1 with this particular value of λ.

To see the biasedness of b rewrite 3.1 as

$$b = \hat{\beta} - \lambda\,(X'X)^{-1}\, R\, b$$

Therefore $E(b) = \beta - E\,(\lambda(X'X)^{-1}\, R\, b)$

Therefore the direction of the bias is determined by the term $E\,(\lambda\,(X'X)^{-1}\, Rb)$.

These results can be generalized when there are more than one quadratic relationship between the parameters. Suppose that the extraneous information consists of the quadratic constraints:

$$C_i = \beta'\, R_1\, \beta, \quad i = 1,2, \ldots\ldots l$$

with l is less than k

where C_i 's are known scalars and R_i 's are k x k symmetrical matrices such that

$$\begin{pmatrix} R_i & b \\ \cdot & \cdot \\ \cdot & \cdot \\ R_l & b \end{pmatrix} \text{ is of full rank.}$$

Again we wish to minimize $(y - Xb)'(y - Xb)$ subject to $C_i = \beta\, R_i\, \beta$ $i = 1, 2, \ldots\ldots l$. Define

$$F\,(b,\, \lambda_i;\, i=1,\, 2, \ldots l) = (y - Xb)\;\; (y - Xb) - \sum_{i=1}^{l} \lambda_i\,(C_i - b'R_1\, b)$$

Setting the derivatives of F with respect to b and λ_i's equal to zero gives for the points of inflection,

$$\frac{\partial F}{\partial b} = -2X'y + 2X'Xb' + 2\sum_{i=1}^{l} \lambda_i R_i b$$

$$\frac{\partial F}{\partial \lambda_i} = -C_i + b'R_i b = 0$$

Hence the restricted least squares estimator of β in this case is given by

$$(X'X + \sum_{i=1}^{l} \lambda_i^{\circ} R_i)\, b = X'y \qquad (3.3)$$

and $$b'R_i b = C_i, \quad i = 1, 2, \ldots\ldots l \qquad (3.4)$$

where λ_1° ' s are chosen so that the matrix $(X'X + \Sigma \lambda_i^{\circ} R_i)$ is positive definite.

A numerical illustration;

As an illustration, consider a two variable relationship

$$y = \alpha + \beta x$$

and suppose we wish to incorporate the quadratic constraint[1] $2\alpha\beta = 5$, which can be written as, $C = \beta R. \beta$

where $R = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$, $C = 5$.

Let us suppose that 20 sample observations yield

$$X'X = \begin{pmatrix} 20 & 10 \\ 10 & 3.2 \end{pmatrix} \text{ and } X'y = \begin{pmatrix} 20 \\ 8 \end{pmatrix}$$

Therefore we require to compute $\hat{\alpha}$, $\hat{\beta}$ and λ such that

$$(X'X+\lambda R)\, b = \begin{pmatrix} 20 & 10+\lambda \\ 10+\lambda & 3.2 \end{pmatrix} \begin{pmatrix} \hat{\alpha} \\ \hat{\beta} \end{pmatrix} = \begin{pmatrix} 20 \\ 8 \end{pmatrix}$$

$$2\hat{\alpha}\hat{\beta} = 5$$

$$20 + \hat{\alpha}(10 + \lambda)\hat{\beta} = 20$$

$$(10 + \lambda)\hat{\alpha} + 3.2\hat{\beta} = 8$$

1. This constraint may have arisen in the estimation of the model $2\alpha(Y - \alpha) = 5X$

Then we may obtain $(\hat{\alpha}^2 + \hat{\alpha} + 1)(\hat{\alpha} - 1)^2 = 0$,

whose only real solution is $\hat{\alpha} = 1$.

Thus the corresponding values of $\hat{\beta}$ and λ which satisfy the Constraint equations are,

$$\hat{\beta} = \frac{5}{2}, \lambda = -10$$

Now observing that, this particular value of λ makes the matrix,

$$(X'X - \lambda R) = \begin{pmatrix} 20 & 0 \\ 0 & 3.2 \end{pmatrix} \text{ positive definite,}$$

we conclude that

$\left.\begin{matrix} \hat{\alpha} = 1 \\ \hat{\beta} = 5/2 \end{matrix}\right\}$ minimize the sum of the squared residuals subject to the constraint $(\hat{\alpha}\ \hat{\beta})\ R\ (\hat{\alpha}\ \hat{\beta})' = C$.

Thus the restricted least square estimators of α and β are $\hat{\alpha} = 1$ and $\hat{\beta} = 5/2$ respectively.

4. Least Squares Under Mixed Linear and Quadratic Constraints

In this section we consider a more general situation where the parameters of the classical regression model are known to be related by second order equations such as the two equations $2\beta_1 + \beta_1^2 + \beta_1\beta_3 + \beta_3 = 0$ and $2\beta_1 = \beta_4^2$. We will establish a general formula to determine the restricted least squares estimates when the constraint on the parameters consists of only a single equation of this type. The generalization to the case where there are more than one equation of that type is straightforward but will not be undertaken here.

The mixed linear and quadratic constraint under consideration may be expressed in the form,

$$C = \beta' R \beta + r'\beta$$

where C is a known scalar, R is a known symmetric matrix of order k and r is a column vector of k coefficients.

To incorporate this information the method of restricted least squares is proposed. Therefore we require the estimated coefficient vector b, that minimizes $(y - Xb)'(y - Xb)$ subject to $C = b'Rb + r'b$. Thus the appropiate Lagrangian function becomes,

$$F(b, \lambda) = (y - Xb)'(y - Xb)\lambda - (C - b'Rb - r'b)$$

where λ is a Lagrange multiplier. The stationary points of this function are found by setting the derivatives of F with respect to b and λ equal to zero.

$$\frac{\partial F}{\partial b} = -2X'y + (2X'X)b + \lambda(2Rb + r) = 0$$

$$\frac{\partial F}{\partial \lambda} = -(C - b'Rb - r'b) = 0$$

The second order condition for a minimum is satisfied if

$$\frac{\partial^2 F}{\partial b \partial b^1} = 2(X'X - \lambda R) \text{ is positive definite.}$$

Hence the restricted least squares estimator of the parameter vector β is given by the equations,

$$(X'X + \lambda^* R)b = X'y - \frac{\lambda^*}{2} r$$

$$C - b'Rb + \lambda^* r'b$$

where λ^* is chosen so that the matrix $(X'X + \lambda^* R)$ is positive definite. In case where there are more than one local minima the one which gives the least value of $F(b,\lambda)$ should be chosen.

A numerical Illustration

Suppose we want to find the restricted least squares estimators of α and β appearing in the two variable linear regression model,

$y = \alpha + \beta x + u$, given the extraneous information that $\alpha + \beta^2 = 3$. Let us also suppose that 20 sample observations yield,

$$X'X = \begin{pmatrix} 20 & 40\frac{2}{3} \\ 40\frac{2}{3} & 163 \end{pmatrix}, \quad X'y = \begin{pmatrix} 68\frac{1}{2} \\ 284 \end{pmatrix}$$

using the usual notation we have,

$$R = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}, \text{ and } r = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

therefore the above two implies that,

$$\begin{pmatrix} 20 & 40\frac{2}{3} \\ 40\frac{2}{3} & 63 + \lambda \end{pmatrix} \begin{pmatrix} \hat{\alpha} \\ \hat{\beta} \end{pmatrix} = \begin{pmatrix} 68\frac{1}{2} - \frac{\lambda}{2} \\ 284 \end{pmatrix}$$

and $\hat{\alpha} + \hat{\beta}^2 = 3$

Eliminating λ and $\hat{\alpha}$ from these equations we have

$$(5\hat{\beta} - 9)\ (4\hat{\beta}^2 - 5\hat{\beta} + 9) = 0.$$

The only real solution of this equation is $\hat{\beta} = 1.8$

The corresponding values of $\hat{\alpha}$ and $\hat{\lambda}$ are $\hat{\alpha} = -0.24$ and $\lambda = 0.2$

Now

$$(X'X + \lambda R) = \begin{pmatrix} 20 & 40\frac{2}{3} \\ 40\frac{2}{3} & 163 + \lambda \end{pmatrix}$$

is positive definite when $\lambda = 0.2$

Therefore we conclude that $\hat{\beta} = 1.8$, $\hat{\alpha} = -0.24$, $\lambda = 0.1$ minimizes the Lagrangian function F (b, λ). Hence the restricted least squares estimators of α and β are $\hat{\alpha} = -0.24$, $\hat{\beta} = 1.8$ respectively.

5 Mixed Estimation

When unbiased estimates of some of the parameters of a linear regression is available from outside of the sample, a technique to use this information so as to obtain more efficient estimates was suggested by Durbin[1] in 1953. In fact this approach can be extended further to tackle various problems concerning extraneous information. This procedure of "mixed estimation" was developed by Theil and Goldberger[4] in 1961 and it was extended by Theil[5] in 1963. One may make prior expectations on the results of a regression on the basis of extraneous information. The expectations that we derived from theoretical considerations are called prior information, the positivity of the marginal productivities in a production function being an example. The kind of expectations which were derived from previous statistical work, for example some unbiased estimates of certain parameters, are called statistical prior information. The estimation process that combines the prior information together with the sample data is called mixed estimation.

The prior knowledge is formulated in terms of prior estimates of the parameters which are assumed to be unbiased, namely $r = R\beta + v$, where v is the error of the prior information with $E(v) = 0$ and the g-element vector r estimates $R\beta$, R being a known gxk matrix. Particularly if r is an unbiased estimate of β, a vector formed by g coefficients of β, we would set $R = (I_g\ 0)$ because $r = \beta_1 + v$, where 0 is $g \times (k\text{-}g)$ matrix containing only zeros. Let us assume that $E(vv') = \psi$ is known and that $E(v\epsilon') = 0$. We combine sample observations and the prior information to write

$$\begin{pmatrix} y \\ r \end{pmatrix} = \begin{pmatrix} X \\ R \end{pmatrix} \beta + \begin{pmatrix} \epsilon \\ v \end{pmatrix}$$

where

$$E \begin{pmatrix} \epsilon \\ v \end{pmatrix} = 0 \text{ and } E \begin{pmatrix} \epsilon \\ v \end{pmatrix} (\epsilon'\ v') = \begin{pmatrix} \sigma^2 I_n & 0 \\ 0 & \psi \end{pmatrix}$$

It can be shown that the application of Generalized Least Squares to the above linear regression model yields

$$b = \left(\frac{1}{\sigma^2} X'X + R' \psi^{-1} R \right)^{-1} \left(\frac{1}{\sigma^2} X'y + R'\psi^{-1} r \right) \text{ and that}$$

$$\text{Var } (b) = \left(\frac{1}{\sigma} X'X + R'\psi^{-1}R \right)^{-1}$$

This estimator b is a best linear unbiased estimator of β, where "best" refers to the sample and prior information taken together.

6. Mixed Estimation Under Linear Constraints

Now suppose that two kinds of extraneous information are available to the statistician, some exact linear relationships between the coefficients are known and on the other hand a prior information, for instance some unbiased estimates of some of the coefficients, is available. The statistician wishes to incorporate his knowledge on the parameters in order to improve the estimate of the coefficient vector. Let the known linear restrictions on the coefficients be $S = L\beta$, where S is a known vector of h elements and L is a $h \times k$ known matrix of rank $h < k$. Assume that the prior knowledge can be formulated as,

$$r = R\beta + v$$

with $E(v) = O$, where v is the error of the prior information, r is a known gxl vector and R is a known g x k matrix. Let us assume that $E(v\epsilon') = O$ and that $E(vv') = \psi$ is known. In order to apply generalized least squares we write the prior and sample information together as,

$$\begin{pmatrix} y \\ r \end{pmatrix} = \begin{pmatrix} \lambda \\ R \end{pmatrix} \beta + \begin{pmatrix} \epsilon \\ v \end{pmatrix}$$

which can be rewritten as,

$y_1 = X_1 \beta + u$, where y_1 is a (n + g) XI vector X_1 is a (n + g) x k matrix and $u = \begin{pmatrix} e \\ v \end{pmatrix}$. We have for the covariance matrix of the extended "disturbance",

$$E(uu') = \begin{pmatrix} \sigma^2 I_n & 0 \\ 0 & \psi \end{pmatrix} = \Omega$$

The symmetric positive definite matrix Ω can be expressed in the form,

$\Omega = PP'$, where P is non-singular.

Now premultiply the model,

$$y_1' = X_1' \beta + u \text{ by } P^{-1} \text{ to give}$$
$$y^* = X^* \beta + u^* \quad \ldots\ldots\ldots\ldots \quad (6.1)$$

where $y^* = P^{-1} y$ $X^* = P^{-1} X_1$ and $u^* = P^{-1} u$. It is easily seen that,

$E(u^*) = 0$, and that
$E(u^* u^{*\prime}) = \sigma^2 I$ because

$P^{-1} \Omega P^{-1\prime} = I_{(n \times g)}$ so that (6.1) satisfies all the assumptions of a classical least squares model. Now it follows from section (2) that the restricted least squares estimator of β under $S = L\beta$ is,

$$b = \hat{\beta} + (X^{*\prime} X^*)^{-1} L [L (X^{*\prime} X^*)^{-1} L']^{-1} (S - L\hat{\beta}) \text{ and that}$$

$V(b) = V - VL' (LVL')^{-1} LV$, where $V = \sigma^2 (X^{*\prime} X^*)^{-1}$

and $\hat{\beta} = (X^{*\prime} X^*)^{-1} X^* y$. Moreover we know that b is the BLUE of β in the sense that its elements have the minimum variance within the class of all unbiased estimators which are linear functions of y and S, where "best" refers to the sample and prior information taken together. The b and var (b) can be expressed in terms of X as follows,

Since $X^* = P^{-1} X_1$ and $y^* = P^{-1} y_1$,
we have, $X^{*\prime} X^* = X_1' \Omega^{-1} X_1$ and $X^{*1} y^* = X_1' \Omega^{-1} y_1$

and in turn we have,

$$X^{*\prime} X^* = \left(\frac{1}{\sigma^2} X' X + R' \psi^{-1} R\right)$$

$$\text{and } X^{*\prime} y = \left(\frac{1}{\sigma^2} X' y + R' \psi^{-1} r\right).$$

Hence $\hat{\beta} = \left(\frac{1}{\sigma^2} X' X + R' \psi R\right)^{-1} \left(\frac{1}{\sigma^2} X' y + R' \psi^{-1} r\right)$

and

$$b = \hat{\beta} + \left(\frac{1}{\sigma^2} X' X + R' \psi^{-1} R\right)^{-1} L' \left[L \left(\frac{1}{\sigma^2} X' X + R' \psi^{-1} R\right)^{-1} L'\right]^{-1} (S - L \hat{B}).$$

The variance of b also reduces to.

$$V(b) = V(\hat{\beta}) - V(\hat{\beta}) L' (L V(\hat{\beta}) L')^{-1} L V(\hat{\beta})$$

where

$$V(\hat{\beta}) = \sigma^2 \left(\frac{1}{\sigma^2} X' X + R' \psi^{-1} R\right)^{-1}.$$

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The Geology and Geochemistry of the Uda Walawe Serpentinite, Sri Lanka

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Abstract : Although two-thirds of the present nickel production is derived from nickel sulphides, lateritic nickel reserves are estimated to be around three times as those of sulphides. These vast reserves of lateritic nickel are expected in humid tropical terrains of the world where very little exploration work has been carried out. A lateritized serpentine body from Uda Walawe, Sri Lanka, has been studied for its geology and geochemistry. The nickel content shows a range of 0.05%-2% and occurs partly in the iron-oxide phase. Cobalt correlates well with manganese but there does not appear to be a significant correlation of nickel with magnesium and silicon. The chromium content ranged from 300-3100 ppm and was found mainly in the chrome spinels found in abundance in the serpentine body. Geologically, the Uda Walawe serpentinite body is located at a possible plate margin at the boundary of the Highland Group and the eastern Vijayan Complex and may well represent the more mobile part of an ophiolitic sequence.

1. Introduction

Nickeliferous laterites, serpentinites and other ultramafic bodies have recently been the subject of intensive study. The economic importance of laterites have been discussed at length[21] and special emphasis is now being laid on nickel bearing laterites.[14,22] Even a cursory glance at a map showing the distribution of tropical rain forests of the world where most laterites are expected to occur shows that the majority of them lie in developing countries. The utilization of lateritic nickel reserves is of particular importance to such developing countries in the tropical and sub-tropical regions where the largest reserves and resources of lateritic nickel occur. Although 62% of the present world production is derived from nickel sulphides,[15] the world nickel reserves in the laterites are considered to be three times as large as those of sulphides.[2] Even though the nickeliferous laterites are rather low grade resources, the large scale occurrences and possible complex utilization including the by-product recovery of Co, Cr, and Fe have triggered intense research work in many laboratories.[14] It is thus appropriate to term nickeliferous laterite as a resource of the future.

Lateritized serpentinites have been discovered in Sri Lanka recently[6,7] and they lie in the eastern sector of the island along the boundary of the Highland Group and the Vijayan Complex[17] (Figure 1). At present the mineral wealth of Sri Lanka consists mainly of non-metallic deposits[4,13] and in view of the many serpentine bodies found in Sri Lanka, exploration for nickel in these bodies is worthwhile.

2. Geologic setting

Geologically the greater part (about 92%) of Sri Lanka consists of rocks of Precambrian age, the island having remained stable over a long period of time. The Precambrian rocks have been classified into a Highland Group consisting mainly of rocks belonging to granulite facies, a Vijayan Complex of granites, granitic gneisses and migmatites of the amphibolite facies and a Southwestern Group, a complex of cordierite gneisses and charnockites (figure 1). For a detailed account of the geology of Sri Lanka, the reader is referred to Cooray.[3]

The serpentine bodies so far found in Sri Lanka all lie along the boundary of the Highland Group and the eastern Vijayan Complex. This boundary is now considered to represent the geosuture of an ancient plate margin and a potential mineralized belt.[16,17,18,19] Of these the Uda Walawe serpentine body is the best known and has been studied for its petrology and geochemistry[6,7] on a preliminary investigation. The serpentine body itself is approximately 7 km^2 in extent (Figure 2) and is surrounded by charnockites, calc-gneisses, migmatites and cordierite bearing gneisses. Along the northern contact of the body, diopside bearing gneisses and calciphyres could be recognized. In the eastern part of the area are hornblende-biotite gneisses and migmatites characteristic of the Vijayan Complex rocks.

Figure 3 illustrates the generalized cross-section of the lateritic serpentinite of Uda Walawe, Sri Lanka. The lateritic iron-ore cap is present at the top and is generally devoid of vegetation. This lack of vegetation in places where the lateritic cap is thick is very obvious and can easily be recognized in the aerial photographs covering such lateritic terrains. Below the lateritic cap are the remnants of the highly weathered serpentinized ultramafic rock which retains in most cases the original reticulate or banded structure. A conspicuous feature in this zone is the occurrence of small black grains of magnetite and chrome spinels. In a number of case histories,— India,[24] Thailand[20] and Cuba[11] this feature has been observed. It is also common to find the weathered ultramafic rock assuming varying shades of green. It is of interest to note that Brindley and Pham Thi Hang[1] observed a close correlation of the nickel content of serpentinite with the intensity of the green colour as determined by the Munsell colour chart. This feature is worthy of consideration during prospecting for nickel. Even the secondary silica minerals such as chert, agate, chalcedony, opal, etc., occasionally display shades of green colour which in some cases could be used as a guideline during exploration for nickeliferous laterites over serpentine bodies.

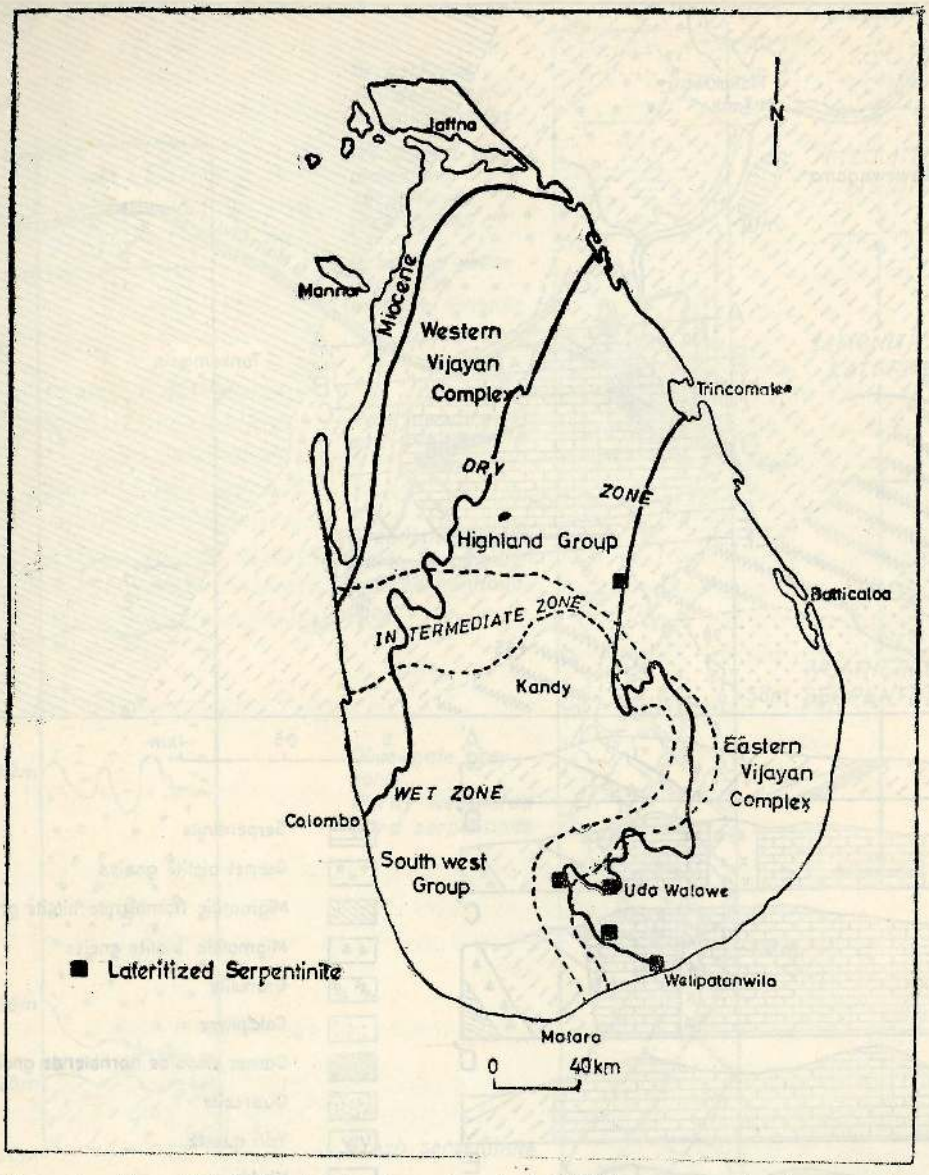

Figure 1. Map of Sri Lanka showing the main geological divisions and the climatic boundaries.

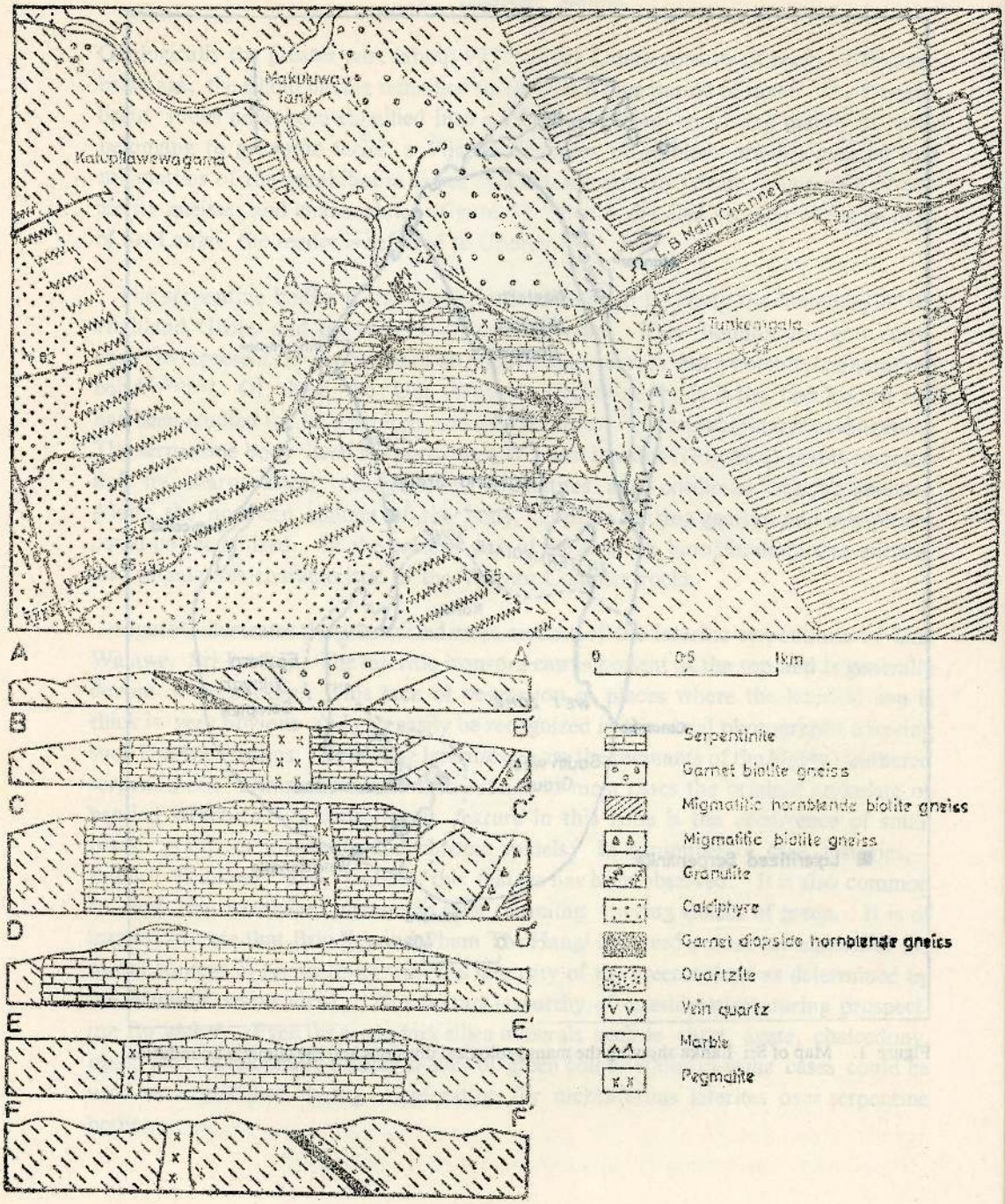

Figure 2. Geological map of the Uda Walawe serpentine body of Sri Lanka.

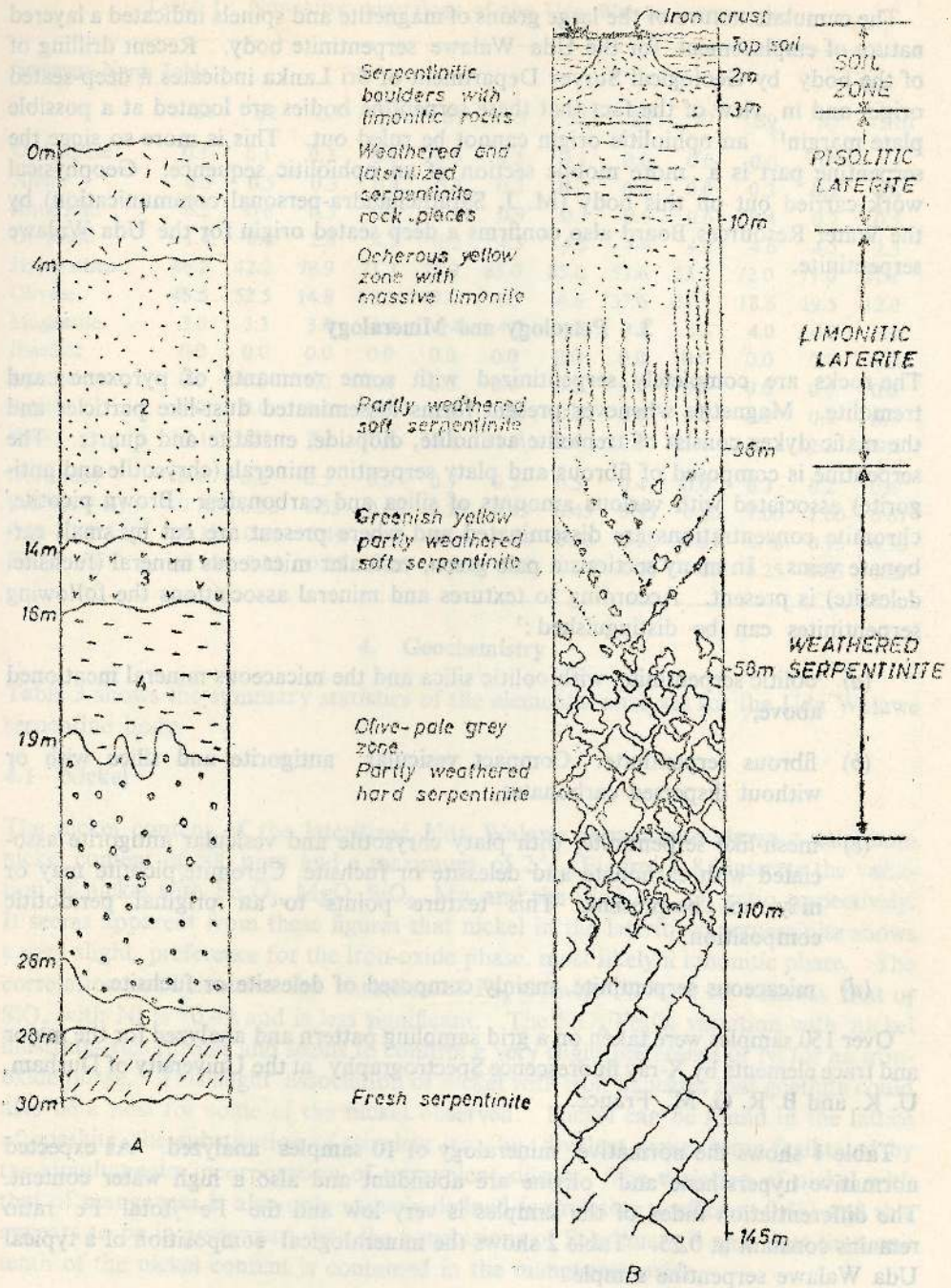

Figure 3A. Specimen geological section of a laterite in Sri Lanka

1 = Humus rich soil material with iron concretions
2 = Coarse grained yellowish-brown soil material
3 = Fine textured grey soil material (gibbsite abundant)
4 = Iron-rich pebbly layer
5 = bauxitic material
6 = reliefs of parent rock
7 = fresh bed rock

Figure 3B. Generalized profile of the Uda Walawe serpentinite of Sri Lanka.

The cumulate nature of the large grains of magnetite and spinels indicated a layered nature of emplacement for the Uda Walawe serpentinite body. Recent drilling of of the body by Geological Survey Department of Sri Lanka indicates a deep-seated origin and in view of the fact that these serpentine bodies are located at a possible plate margin[17] an ophiolitic origin cannot be ruled out. This is more so since the serpentine part is a more mobile section of an ophiolitic sequence. Geophysical work carried out on this body (M. J. Sarathchandra-personal communication) by the Water Resources Board also confirms a deep seated origin for the Uda Walawe serpentinite.

3. Petrology and Mineralogy

The rocks are completely serpentinized with some remnants of pyroxene and tremolite. Magnetite whenever present forms disseminated dust-like particles and the mafic dykes consist of tremolite/actinolite, diopside, enstatite and quartz. The serpentine is composed of fibrous and platy serpentine minerals (chrysotile and antigorite) associated with various amounts of silica and carbonates. Brown picotite/chromite concentrations are disseminated and where present are cut by small carbonate veins. In many sections a pale green, vesicular micaceous mineral (fuchsite, delessite) is present. According to textures and mineral associations the following serpentinites can be distinguished :[7]

(*a*) oolitic serpentinite, with oolitic silica and the micaceous mineral mentioned above,

(*b*) fibrous serpentinite. Compact vesicular antigorite and silica with or without dispersed carbonates,

(*c*) mesh-like serpentinite, with platy chrysotile and vesicular antigorite associated with carbonate and delessite or fuchsite. Chromite/picotite may or may not be present. This texture points to an original peridotitic composition,

(*d*) micaceous serpentinite, mainly composed of delessite or fuchsite.

Over 150 samples were taken on a grid sampling pattern and analyzed for the major and trace elements by X-ray fluorescence Spectrography at the University of Durham, U. K. and B. R. G. M., France.

Table 1 shows the normative mineralogy of 10 samples analyzed. As expected normative hypersthene and olivine are abundant and also a high water content. The differentiation index of the samples is very low and the Fe^{3+}/total Fe ratio remains constant at 0.25. Table 2 shows the mineralogical composition of a typical Uda Walawe serpentine sample.

TABLE 1. Normative mineralogy of the Uda Walawe serpentinite.

Summary Norm Table												
	S1	S2	S3	S4	S4	S5	S5	S7	S7	S9	S?	S10
Orthoolase	0.1	0.1	0.3	0.5	0.5	0.3	0.3	0.0	0.0	0.0	0.0	0.2
Albite	0.3	0.5	0.3	0.4	0.2	0.2	0.2	0.4	0.0	0.3	0.2	0.4
Anorthite	0.5	0.6	0.3	0.5	1.0	0.9	0.3	0.6	0.6	0.4	0.7	0.5
Diopside	1.4	0.8	2.4	4.7	4.2	4.3	4.5	4.4	4.6	4.6	4.5	2.3
Hypersthene	46.2	42.2	78.9	71.3	71.9	85.0	85.0	53.6	53.7	72.0	71.0	81.1
Olivine	48.5	52.5	14.8	18.1	17.8	4.5	4.6	37.6	37.7	18.6	19.5	12.0
Magnetite	3.0	3.3	3.0	4.4	4·4	4.7	4.7	3.3	3.3	4.0	4.0	3.4
Ilmenite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apatite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	12.1	12.1	8.3	10.8	10.6	11.0	11.0	11.3	11.4	12.7	12.3	9.1
Diff.Index	0.4	0.6	0.5	0.9	0.7	0.5	0.5	0.4	0.0	0.3	0.2	0.6
VA(NA+K)	0.70	0.38	0.53	0.46	0.30	0.43	0.43	0.95	0.60	1.00	1.00	0.67
(NA+K)/AL	0.32	0.31	0.49	0.46	0.26	0.20	0.23	0.28	0.01	0.26	0.13	0.36
F3(F2 + F3)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

4. Geochemistry

Table 3 shows the summary statistics of the elemental analyses for the Uda Walawe serpentine body.

4.1 Nickel

The nickel content of the lateritized Uda Walawe serpentinite shows a minimum nickel content of 500 ppm and a maximum of 2%. Figures 4–8 illustrate the variation of nickel with Fe_2O_3, MgO, SiO_2, Mn and the SiO_2/Fe_2O_3 ratio respectively. It seems apparent from these figures that nickel in the lateritized serpentinite shows a very slight preference for the iron-oxide phase, most likely a limonitic phase. The correlation coefficient for the variation of Fe_2O_3 with Ni is +0.60 whereas that of SiO_2 with Ni is +0.49 and is less significant. The SiO_2/Fe_2O_3 variation with nickel illustrates this further and seems to confirm a very slight preference of Ni for an iron-oxide phase. This slight association of nickel with iron indicates that goethite could also be a host for some of the nickel observed. Nickel can be found in the lattice of goethite, the substitution of trivalent iron by divalent nickel being facilitated by the simultaneous incorporation of tetravalent silicon. The variation of nickel with that of manganese is also only vaguely defined (correlation coefficient-0.48) and this appears to be in agreement with the conclusions of Schellmann[22] that less than one tenth of the nickel content is contained in the manganese oxide.

TABLE 2. Mineralogical composition of a typical Uda Walawe serpentine sample.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	TiO_2	P_2O_5	S	F	MnO	O-Excess
43.27	0.18	1.44	4.00	38.98	0.67	0.03	0.00	11.24	0.00	0.01	0.00	0.01	0.00	0.16	0.00

Table of cation atomic percentages

Si	40.46	Al	0.20	Fe^3	1.02	Fe^2	3.13	Mg	54.31	Ca	0.68	Na	0.05	K	0.00	Ti	0.01	P.	0.00	S	0.22
Mn	0.13	Zr	0.00	Cr	0.00	Li	0.00	Ba	0.00	Nb	0.00	Ni	0.00								

Table of normative mineral percentages

quartz	0.00	0.00	kaliophylite	0.00	0.00	wollastonite	0.00	0.00	titanite	0.00	0.00
corundum	0.00	0.00	halite	0.00	0.00	hypersthene	43.82	42.89	perovskite	0.00	0.00
zircon	0.00	0.00	thenardite	0.00	0.00	olivine	50.45	52.51	rutile	0.00	0.00
orthoclase	0.00	0.00	sod. carb.	0.00	0.00	cal. orthosil	0.00	0.00	apatite	0.00	0.00
albite	0.29	0.27	acmite	0.00	0.00	magnetite	2.35	1.52	fluorite	0.00	0.00
anorthite	0.43	0.36	sod. metasil	0.00	0.00	chromite	0.00	0.00	pyrite	0.02	0.00
leucite	0.00	0.00	pot. metasil	0.00	0.00	hematite	0.00	0.00	calcite	0.00	0.00
nepheline	0.00	0.00	diopside	2.64	2.41	ilmenite	0.02	0.01	water	11.24	35.09

Other petrochemical functions

Ratio (mol.prop.) of MgO over total (MgO + Fe) in ferromagnesian minerals = 0.95
Wt. % K metal = 67.59
Per alkalinity index = 0.27
Ratio (Na+) / (Na+) + (K+) = 1.00
Differentiation index = 0.29
Colour index = 99.29
Coordinates in SiO_2 - Al_2O_3 - (Na_2O + K_2O) (mol.prop.) . Silica = 99.69 alumina = 0.25 alkales = 0.07
Total olivine = 50.45 consisting of Fe 47.02 plus Fe 3.43
Total orthopyrosene = 43.82 consisting of En 41.10 plus Fs 2.72
Composition of clinopyroxene by Wt . wollastonite = 1.40 Enstatite = 1.16 Ferrosilite = 0.08
Composition of feldspar by Wt : orthoclase = 0.00 albite = 41.59 anorthite = 58.41
Molecular composition of feldspar : orthoclase = 0.00 albite = 43. 04 anorthite = 5.6964 3E + 01
Iron oxidation ratio $Fe_2O_3/(FeO + Fe_3O_3)$ = 26.51%
Ratio $K_2O/(Na_2O + K_2O)$ = 0.00%

CO-ORDINATES IN THE SYSTEM PLAGIOCLASE – QUARTZ – OLIVINE – DIOPSIDE : Wt. % REPRESENTED BY THIS SYSTEM = 97.60%

	Component Wt.%	Mol. Prop.%	Mol. Cat.%
Plagioclase	0.71	0.25	0.65
Quartz	18.24	27.04	10.89
Olivine	83.35	71.19	89.01
Diopside	2.70	1.52	2.45
Diopside projection			
Plagioclase	0.73	0.26	0.66
Quartz	13.60	27.46	11.17
Olivine	85.67	72.28	88.17
Olivine projection			
Plagioclase	4.25	0.87	4.62
Quartz	79.52	93.85	77.87
Diopside	16.22	5.28	17.51
Quartz projection			
Plagioclase	0.82	0.34	0.72
Olivine	96.07	97.57	96.53
Diopside	3.11	2.08	2.75
Plagioclase projection			
Quartz	13.33	27.11	10.96
Olivine	83.95	71.36	86.57
Diopside	2.72	1.52	2.47

TABLE 3. Summary statistics of the elemental analyses for the Uda Walawe serpentine body.

	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	P
MEAN	44.960	0.220	8.483	34.301	1.390	0.030	0.018	0.020	0.222	0.003
VAR	16.610	0.023	1.724	14.654	14.025	0.000	0.000	0.004	0.009	0.000
SDEV	4.075	0.150	1.313	3.828	3.745	0.014	0.019	0.064	0.096	0.005
MAX	63.710	1.110	11.560	40.210	35.580	0.070	0.130	0.600	0.637	0.020
MIN	24.100	0.040	5.360	15.360	0.002	0.001	0.000	0.000	0.071	0.0.00
	S	Fe_2	H_2O	Ba	Nb	Zr	Y	Sr	Rb	Zn
MEAN	0.017	5.768	10.389	10.700	2.600	1.420	1.160	6.070	1.350	78.930
VAR	0.000	0.798	2.561	276.730	1.520	3.224	0.734	79.645	0.727	1454.765
SDEV	0.009	0.893	1.600	16.635	1.233	1.795	0.857	8.924	0.853	38.141
MAX	0.000	7.860	14.350	100.000	5.000	10.000	4.000	80.000	4.000	246.000
MIN	0.000	3.640	4.140	0.000	0.000	0.000	0.000	1.000	0.000	34.000
	Cu	Ni*	Pb	Th	Cr	Ga	La	Ce		
MEAN	4.190	4831.420	3.100	2.250	1819.340	1.620	4.880	19.200		
VAR	17.054	5780.424	3.450	4.647	3794.484	1.756	4.006	30.120		
SDEV	4.130	2786.715	1.857	2.156	666.179	1.325	2.016	5.488		
MAX	23.000	24067.000	7.000	9.000	3146.000	5.000	16.000	46.000		
MIN	0.000	555.000	0.000	0.000	373.000	0.000	0.000	1.000		

*Ranges for nickel concentrations.

number of samples	Ni ppm
20	500—1000
105	1000—4000
20	4000—10,000
10	10,000—20,000

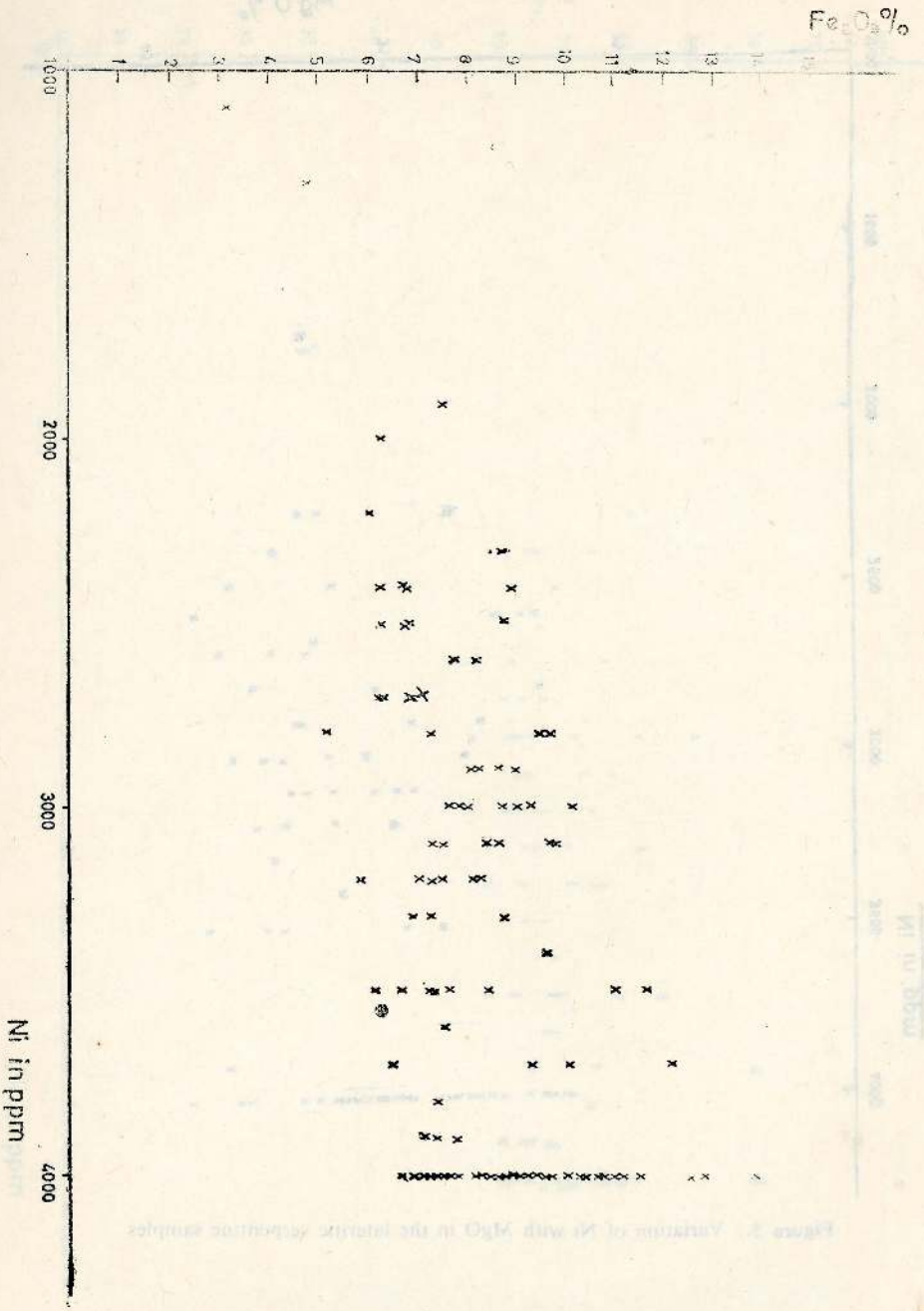

Figure 4. Variation of Ni with Fe_2O_3 in the lateritic serpentine samples

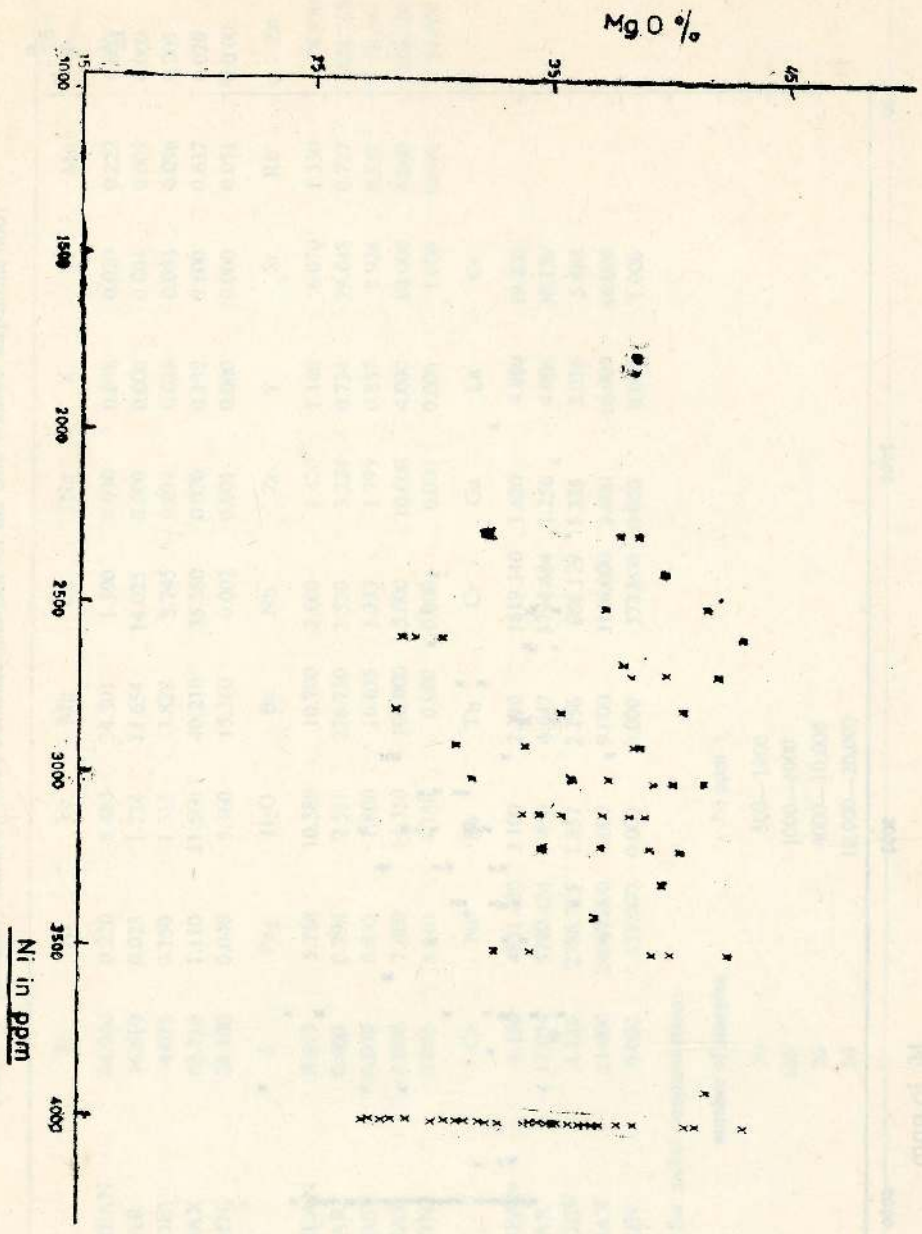

Figure 5. Variation of Ni with MgO in the lateritic serpentine samples

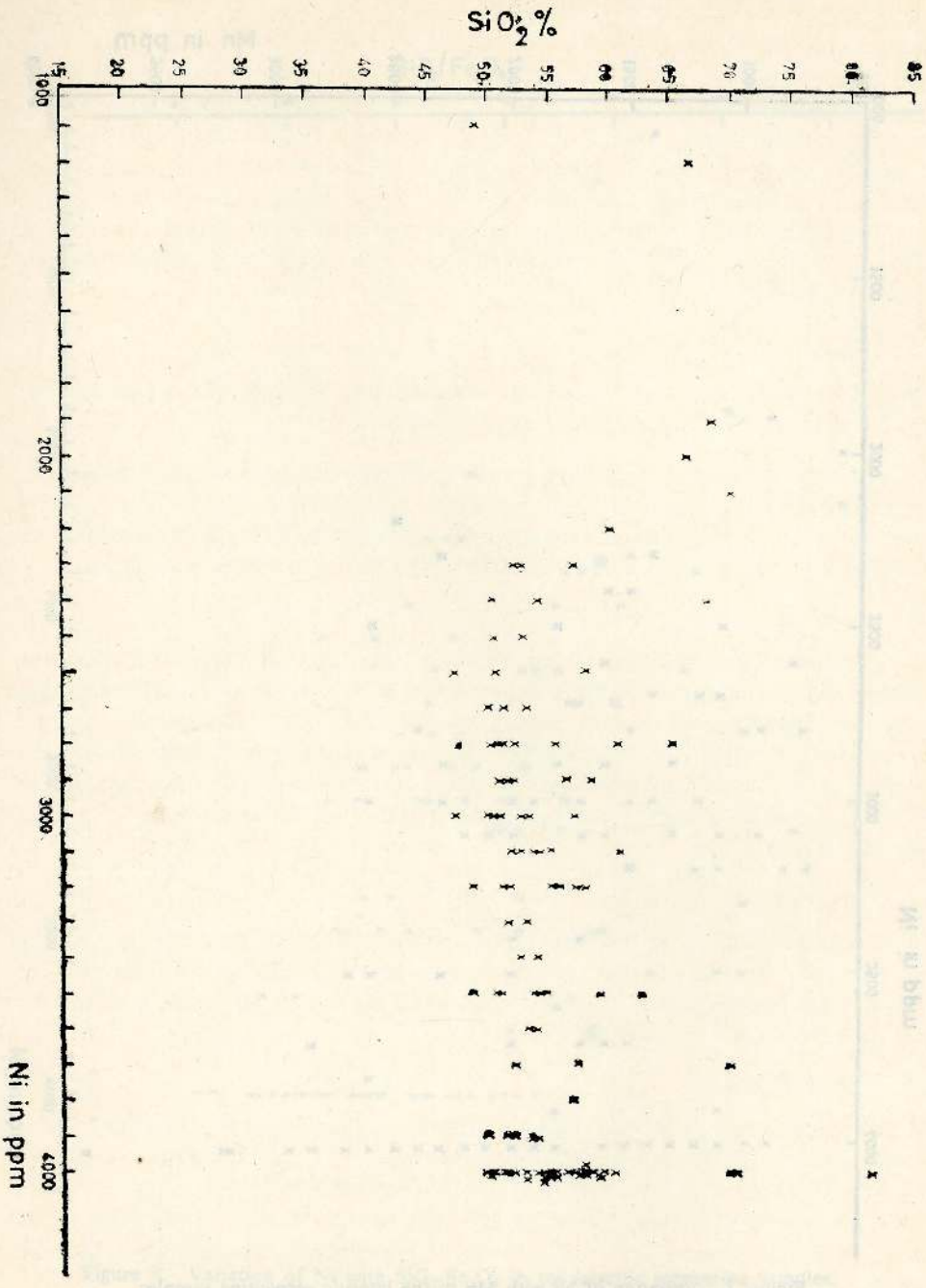

Figure 6. Variation of Ni with SiO_2 in the lateritic serpentine samples.

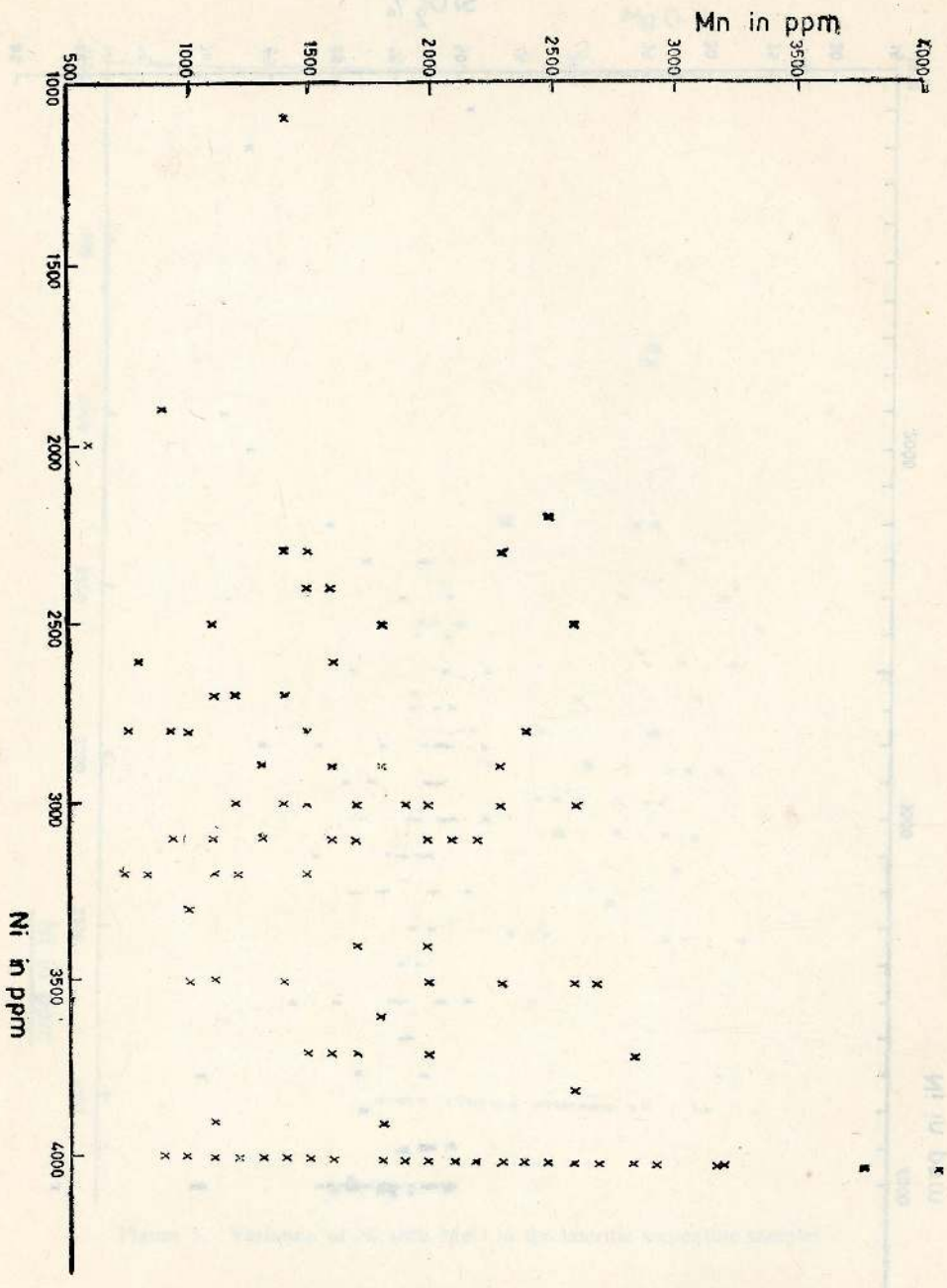

Figure 7. Variation of Ni with Mn in the lateritic serpentine samples.

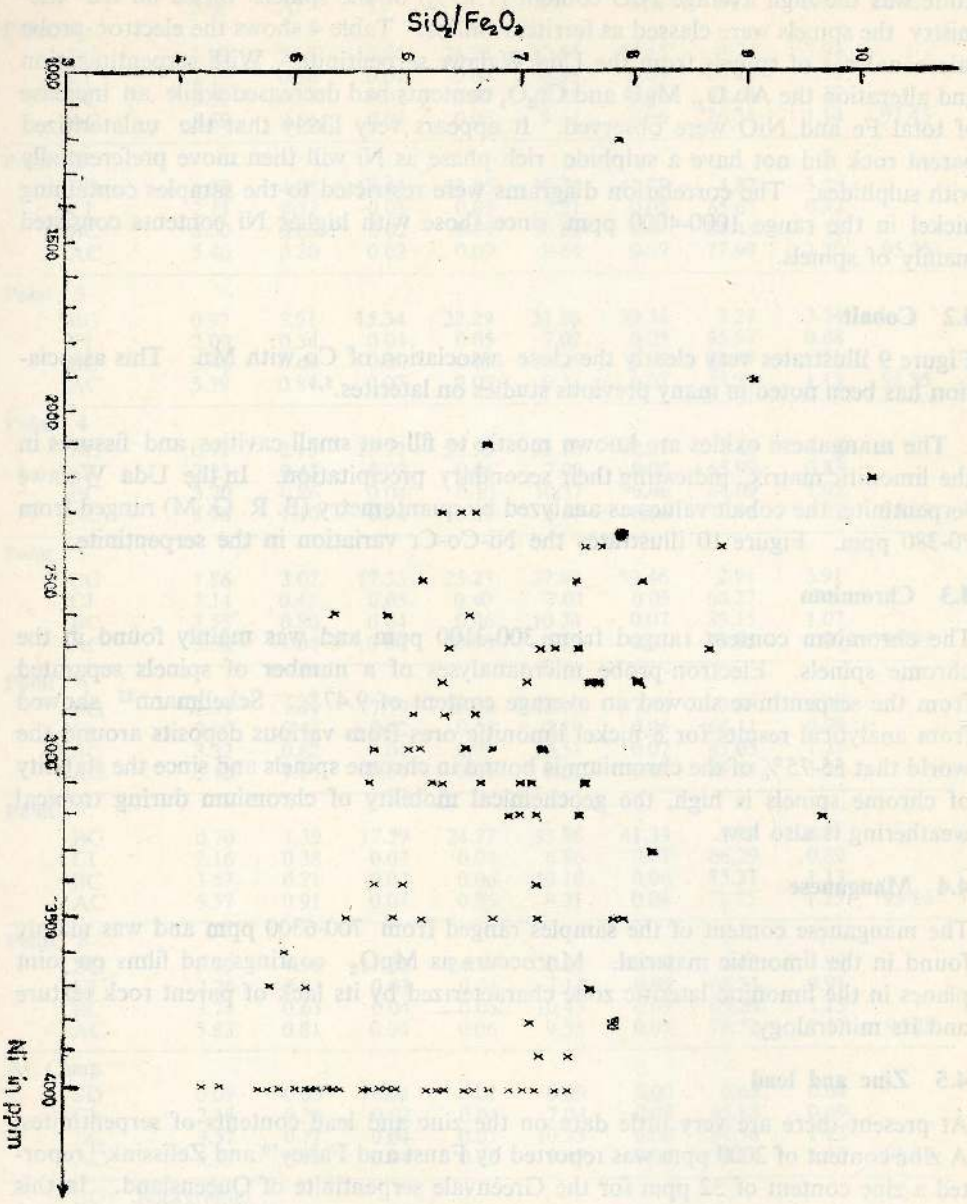

Figure 8. Variation of Ni with SiO_2/Fe_2O_3 in the lateritic serpentine samples.

A further noteworthy feature observed in the distribution of nickel in the serpentinite was the high average NiO content (1.15%) of the spinels. Based on the chemistry the spinels were classed as ferritchromites. Table 4 shows the electron-probe microanalyses of spinels from the Uda Walawe serpentinite. With serpentinization and alteration the Al_2O_3, MgO and Cr_2O_3 contents had decreased while an increase of total Fe and NiO were observed. It appears very likely that the unlateritized parent rock did not have a sulphide rich phase as Ni will then move preferentially with sulphides. The correlation diagrams were restricted to the samples containing nickel in the range 1000-4000 ppm, since those with higher Ni contents consisted mainly of spinels.

4.2 Cobalt

Figure 9 illustrates very clearly the close association of Co with Mn. This association has been noted in many previous studies on laterites.[5,9]

The manganese oxides are known mostly to fill out small cavities and fissures in the limonitic matrix, indicating their secondary precipitation. In the Uda Walawe serpentinite, the cobalt values as analyzed by quantometry (B. R. G. M) ranged from 70-380 ppm. Figure 10 illustrates the Ni-Co-Cr variation in the serpentinite.

4.3 Chromium

The chromium content ranged from 300-3100 ppm and was mainly found in the chrome spinels. Electron-probe microanalyses of a number of spinels separated from the serpentinite showed an average content of 9.47%. Schellmann[22] showed from analytical results for 8 nickel limonitic ores from various deposits around the world that 55-75% of the chromium is bound in chrome spinels and since the stability of chrome spinels is high, the geochemical mobility of chromium during tropical weathering is also low.

4.4 Manganese

The manganese content of the samples ranged from 700-6300 ppm and was mainly found in the limonitic material. Mn occurs as MnO_2 coatings and films on joint planes in the limonitic lateritic zone characterized by its lack of parent rock texture and its mineralogy.

4.5 Zinc and lead

At present there are very little data on the zinc and lead contents of serpentinites. A zinc content of 2000 ppm was reported by Faust and Fahey[10] and Zelissink[23] reported a zinc content of 32 ppm for the Greenvale serpentinite of Queensland. In this study the zinc content ranged from 30-250 ppm in the samples investigated. Zinc on account of its tendency to enter into 4 fold co-ordination in minerals[8] prefers the the spinels and other iron-oxide minerals.

TABLE 4A. Electron-probe microanalyses of spinels from the Uda Walawe serpentinite.

		Mg	Al	Ti	V	Cr	Mn	Fe	Ni	Total
Point	**1**									
	BG	1.02	2.88	18.84	24.23	32.66	40.45	3.74	3.94	
	CI	2.16	0.36	0.01	0.04	6.98	0.05	64.23	0.88	
	BC	3.59	0.67	0.02	0.07	10.21	0.06	82.64	1.12	
	AC	5.59	0.86	0.02	0.06	9.34	0.06	76.35	1.14	93.43
Point	**2**									
	BG	1.38	4.85	18.45	23.55	30.84	41.79	4.82	3.38	
	CI	2.11	0.33	0.01	0.05	7.21	0.05	65.63	0.92	
	BC	3.50	0.63	0.02	0.09	10.53	0.07	84.43	1.17	
	AC	5.46	0.80	0.02	0.09	9.64	0.07	77.99	1.20	95.26
Point	**3**									
	BG	0.92	3.91	15.34	22.29	31.88	39.34	3.27	3.74	
	CI	2.09	0.34	0.04	0.05	7.02	0.05	65.97	0.88	
	BC	3.46	0.65	0.06	0.09	10.25	0.07	84.87	1.11	
	AC	5.39	0.84	0.07	0.09	9.38	0.07	78.38	1.13	95.35
Point	**4**									
	BG	0.92	2.15	17.72	23.93	31.16	42.27	5.23	4.18	
	CI	2.23	0.45	0.03	0.06	7.09	0.05	65.99	0.83	
	BC	3.70	0.86	0.04	0.10	10.37	0.06	84.89	1.05	
	AC	5.76	1.10	0.04	0.09	9.50	0.06	78.46	1.07	96.09
Point	**5**									
	BG	1.86	3.02	17.33	25.23	37.99	39.46	2.91	3.91	
	CI	2.14	0.43	0.03	0.40	7.01	0.05	66.27	0.84	
	BC	3.55	0.80	0.04	0.06	10.24	0.07	85.15	1.07	
	AC	5.54	1.04	0.04	0.06	9.37	0.07	78.75	1.09	95.95
Point	**6**									
	BG	1.39	1.39	17.79	25.58	35.13	37.98	3.68	4.05	
	CI	2.00	0.43	0.02	0.03	7.19	0.05	66.11	0.95	
	BC	3.32	0.82	0.04	0.05	10.51	0.07	85.05	1.21	
	AC	5.18	1.05	0.04	0.04	9.61	0.07	78.54	1.23	
Point	**7**									
	BG	0.70	1.39	17.29	24.77	35.86	41.33	5.03	4.71	
	CI	2.16	0.38	0.03	0.04	6.96	0.05	66.29	0.89	
	BC	3.57	0.71	0.04	0.06	10.18	0.06	85.27	1.13	
	AC	5.57	0.91	0.04	0.06	9.31	0.06	78.75	1.15	95.86
Point	**8**									
	BG	1.39	4.18	17.22	24.89	30.27	43.04	4.45	3.99	
	CI	2.26	0.33	0.03	0.04	7.14	0.05	66.23	0.91	
	BC	3.74	0.63	0.04	0.06	10.43	0.07	85.20	1.15	
	AC	5.83	0.81	0.04	0.06	9.55	0.07	78.72	1.17	96.25
Av. Comp.										
	SD	0.09	0.05	0.01	0.01	0.09	0.00	0.65	0.04	
	CI	2.16	0.38	0.02	0.04	7.03	0.05	65.88	0.89	
	BC	3.57	0.71	0.04	0.07	10.35	0.06	84.76	1.13	
	AC	5.57	0.91	0.04	0.06	9.47	0.06	78.30	1.15	95.55

BG: Background
CI: Metal%
BC: as oxide
AC: Oxide % with all correlations
SD: Standard deviation

TABLE 4B. Structural parameters for the spinels from the Uda Walawe serpentinite.

Uda Walawe Spinel Recalculation N = 8 Sum = 95.5 V = 00.06

Spinel analysis Wt. %

SiO_2 : 0.0 TiO_2: 0.040 Al_2O_3: 0.910 Cr_2O_3: 9.470 Fe_2O_3: 0.0 MnO : 0.060 MgO : 5.570 Na_2O : 0.0 K_2O : 0.0
NiO : 1.150 FeO : 78.300 CaO : 0.00

Cation proportions Si : 0.0 Ti : 0.036 Al : 1.287 Cr : 8.968 Fe^3 0.0 Fe^2 78.577 Mn : 0.061 Mg : 9.96 Ca : 0.0 Na : 0.0 K : 0.0
Ni : 1.110

Sum of cations to 32 oxygens : 30.429

Oxidation ration : 0.0

Differentiation index, cation proportions : 11.250

Chrome spinel parameters after Irvine : $Mg/Mg + Fe^2 = 0.113$ $Fe^3/Cr + Al + Fe^3 = 0.00$ $Cr/Cr + Al = 0.874$

Structural formula Si : 0.0 Ti : 0.011 Al : 0.392 Cr : 2.729 Fe^3 : 0.0 Fe^2 : 23.910 Mn : 0.019 Mg : 3.031 Ca : 0.0 Ni : 0.338

	Excess Fe^2 or Fe^3 iron in Irvine end- member recalculation scheme, Fe_2O_3 : 0.0 FeO : 74.082 calculated to 32 oxygens	Fe^2 and Fe^3 iron have been redistributed to give no residual recalculation of magnetite oxidation ratio thus produced = 62.804	Fe^2 and Fe^3 iron have been redistributed to give sum cations = 24.00 Residual FeO = 0.006 Fe_2O_3 = 0.0
End-member proportions			
Ulvospinel $Fe^2{}_2TiO_4$	0.699	0.121	0.108
Chromite $Fe^2Cr_2O_4$	86.836	15.018	13.453
Magnesiochromite $MgCr_2O_4$	0.0	0.0	0.0
Spinel $MgAl_2O_4$	12.465	2.156	1.931
Hercynite $Fe_2Al_2O_4$	0.0	0.0	0.0
Magnesioferite $MgFe_2{}^3O_4$	0.0	0.0	31.283
Magnetite $Fe^2Fe_2{}^3O_4$	0.0	82.705	53.225

Analysis of spinel with sum of cations : 24.00

SiO_2: 0.0 TiO_2 : 0.40 Al_2O_3: 0.910 Cr_2O_3 : 9.470 Fe_2O_3: 62.383 FeO: 22.163 MnO: 0.060 MgO: 5.510 CaO: 0.0 Na_2O : 0.0
K_2O : 0.0 NiO : 1.150

Cation Proportions

Si : 0.0 Ti : 0.036 Al : 1.287 Cr : 8.968 Fe^3 : 56.335 Fe^2 : 22.241 Mn : 0.061 Mg : 9.961 Ca : 0.0 Na 0.0 K : 0.0 Ni : 1.110

Sum of cations to 32 oxygens : 24.000 Oxidation ratio; 71.695

Chrome spinel parameters after Irvine : $Mg/Mg + Fe^2 = 0.009$ $Fe^3/Cr + Al + Fe^3 = 0.846$ $Cr/Cr + Al + 0.874$

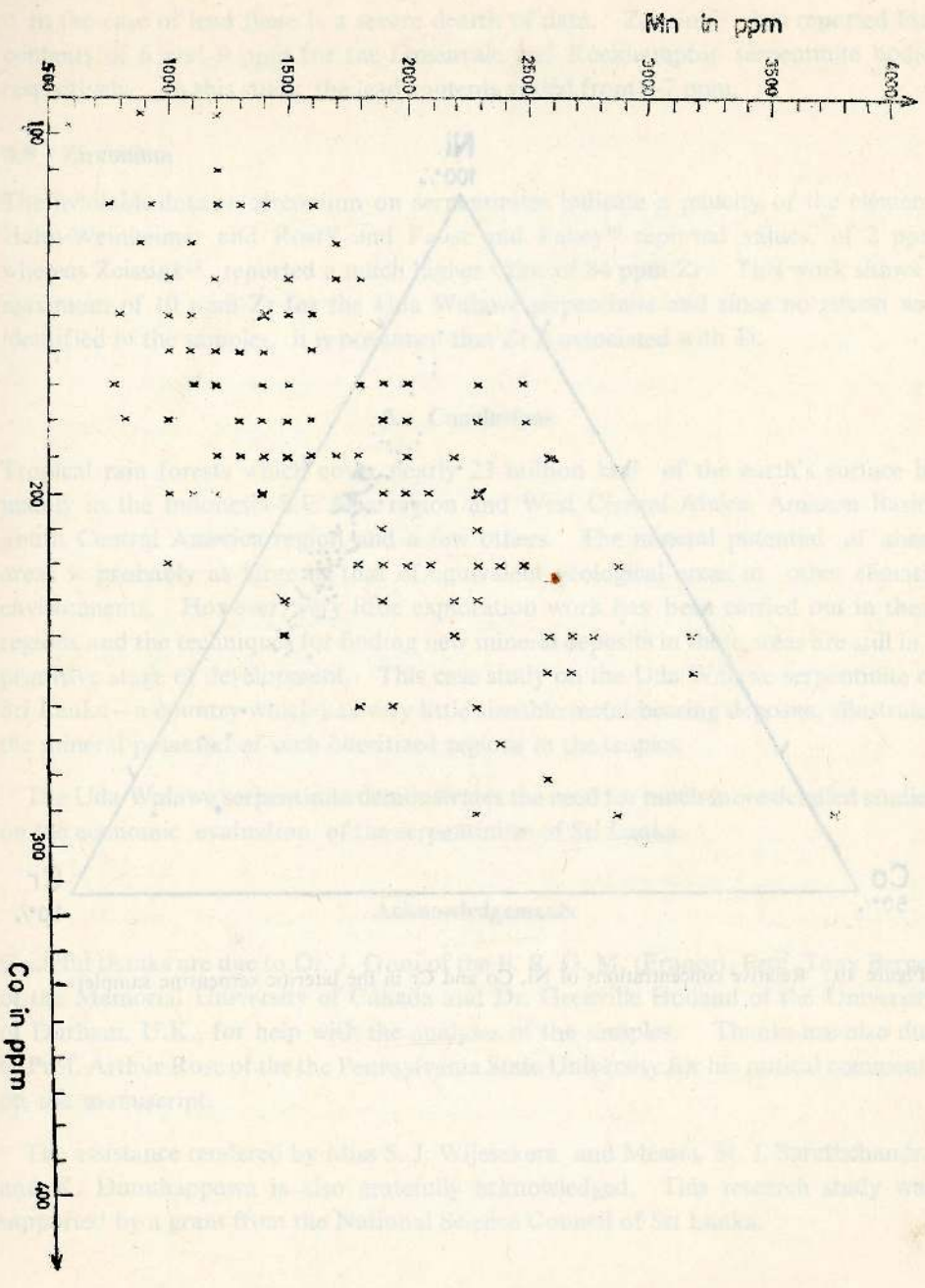

Figure 9. Variation of Co with Mn in the lateritic serpentine samples.

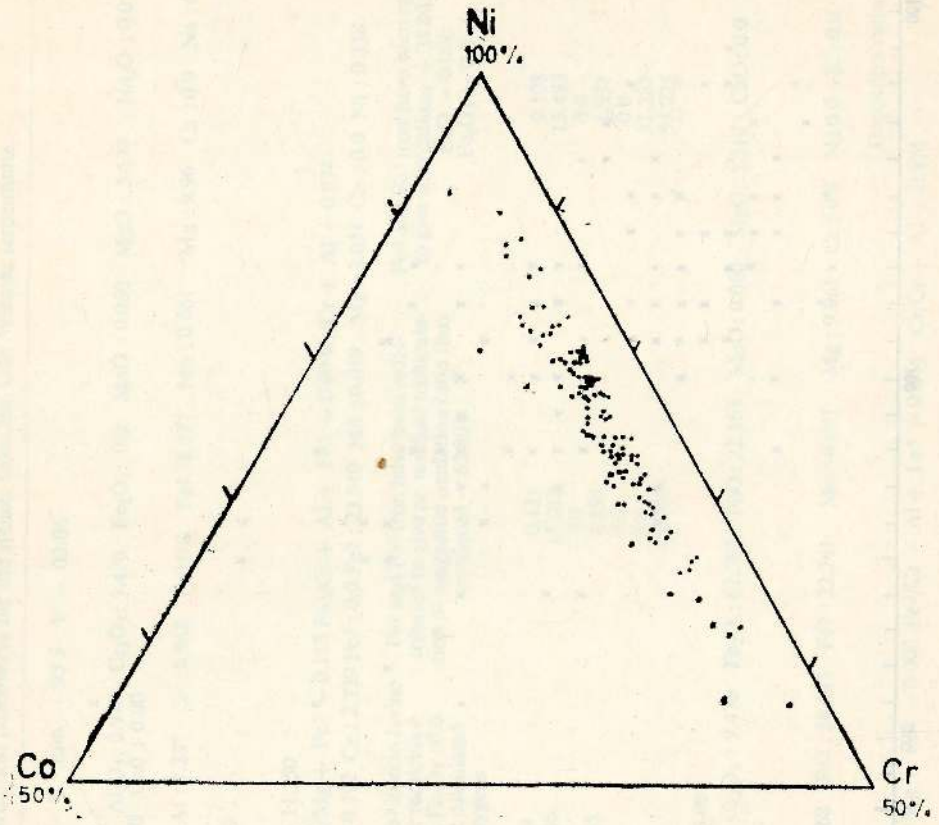

Figure 10. Relative concentrations of Ni, Co and Cr in the lateritic serpentine samples.

In the case of lead there is a severe dearth of data. Zeissink[23] has reported lead contents of 6 and 9 ppm for the Greenvale and Rockhampton serpentinite bodies respectively. In this study, the lead contents varied from 0-7 ppm.

4.6 Zirconium

The available data on zirconium on serpentinites indicate a paucity of the element. Hahn-Weinheimer and Rost[12] and Faust and Fahey[10] reported values of 2 ppm whereas Zeissink[23] reported a much higher value of 84 ppm Zr. This work shows a maximum of 10 ppm Zr for the Uda Walawe serpentinite and since no zircon was identified in the samples, it is presumed that Zr is associated with Ti.

5. Conclusions

Tropical rain forests which cover nearly 23 million km^2 of the earth's surface lie mainly in the Indonesia-S.E Asia region and West Central Africa, Amazon Basin, South Central America region and a few others. The mineral potential of these areas is probably as large as that of equivalent geological areas in other climatic environments. However, very little exploration work has been carried out in these regions and the techniques for finding new mineral deposits in these areas are still in a primitive stage of development. This case study on the Uda Walawe serpentinite of Sri Lanka—a country which has very little sizeable metal bearing deposits, illustrates the mineral potential of such lateritized regions in the tropics.

The Uda Walawe serpentinite demonstrates the need for much more detailed studies on the economic evaluation of the serpentinites of Sri Lanka.

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The Genetics of Inherited Abnormalities in Livestock

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1. Introduction

During the last thirty years there has been much knowledge accumulated and published in the science of genetics. The older definition of a gene as a basic unit of inheritance has now been modified. One of the most significant discoveries in recent times, that led to a re-definition of the gene was that of Watson and Crick in 1953. These authors defined a gene in terms of DNA (deoxyribonucleic acid) and DNA has today been universally accepted as the biochemical unit through which inheritance is accomplished.

A phenotype is dependent on two or possibly three major factors namely, the genotype consisting of a wide variety of genes, the environment in which the genes are expressed and interactions between the genotype and the environment. Heredity provides the basic specifications, the environment both internal and external provides the wherewithal for fulfilling these specifications.[69]

2. Abnormalities in general

Abnormalities appear in various forms, different degrees of expression, combinations with other abnormalities through different pathways and modes of origin. If one follows the development stages of an organism from the zygote to maturity, defects or death could occur at any stage of development such as during fertilization or shortly thereafter, during embryonic growth, birth or during postnatal development. If at any stage the animal dies, the abnormality could be termed a lethal abnormality.

Abnormalities and consequently death could occur due to the action of genes when they are referred to as lethal genetic abnormalities. On the other hand abnormalities that result in death may arise due to injury, poor nutrition, climate or the ingestion of poisons when they may be called lethal environmental abnormalities. Similarly, an abnormality where the animal is at some disadvantage but survives, could be called a non-lethal abnormality (taillessness, dwarfism, etc.), and if the abnormality has a genetic component, the genes may be termed non-lethal genes.

3. Whether heredity or environment

It is important to ascertain whether an abnormality that arises for the first time is genetic or non-genetic. If it is genetic it would be eventually necessary to identify its exact mode of inheritance and find out what types of genes are involved. This however is sometimes a very difficult exercise that may take time, and still provide inconclusive results. Even when the abnormality is non-genetic, pinpointing the exact reason for the abnormality is difficult. The difficulty of correct identification of the abnormality is increased further when the environment mimics a genetic abnormality. In case of arthrogryposis for example, the ingestion of toxins, such as those found in lupines[7,72] have resulted in abnormalities similar to the arthrogryposis condition

which is genetic.[29] A type of hereditary congenital flexed pasterns was reported in an inbred herd of Jersey cattle by Mead *et al.*[57] These authors suggested a genetic and a non-genetic mode of inheritance for the same defect, both types having similar phenotypic manifestations.

The classification of an abnormality into genetic or non-genetic is further complicated by genotype x environment interactions. Magee[69] reported one such instance involving scrotal hernia in swine, where the interaction was between the genotype and maternal effect.[69] Among Hereford cattle, cancer eye is common whereas in other breeds such as Charolais and Charbray which have white faces the defect is uncommon.[48]

When a defect occurs in a commercial or a breeding flock for the first time, one is often interested in finding out whether it is genetic or non-genetic. Although one cannot ascertain its exact origin with a very great deal of certainty, some preliminary observations are useful in shedding some light on the problem. In general, a genetic or hereditary basis is indicated, under the following conditions:

1. The defect occurs independent of environment. This may be taken as a case where genotype x environment interactions are minimal and similar defects are seen to occur everywhere.
2. When similar phenotypes have been identified in the literature and large enough samples have indicated a genetic basis.
3. If the defect is confined to one breeding group, usually a sire or dam and their progeny. This observation is a fairly reliable measure as to whether the abnormality is genetic.
4. If inbreeding tends to increase the frequency of occurence, a genetic basis is suspected. Inbreeding does not create genetic abnormalities but just helps to show them up.

On the other hand an environmental basis is indicated under the following circumstances.

1. The defect occurs in relation to a particular environmental factor, and when it could be corrected by providing the necessary conditions.
2. If it occurred following a period of stress and corrected itself when the stress period was over.
3. If it had been previously demonstrated or reported as being due to a toxin, injury, disease, nutrition or any other non-genetic component.
4. If it was not responsive to inbreeding and did not conform only to certain breeding groups or lines.

Abnormalities whether they are genetic or non-genetic, may go completely undetected and never investigated when defective animals are born dead. Often in commercial herds neither is the dead foetus examined, nor is it subject to a post mortem, instead it is buried or burnt as the dead animal is an economic liability. No effort is made to look through breeding records and come to some conclusion about its cause unless the condition recurs.

3.1. The origin of genetic defects

Any genetic defect must come into a population initially through a mutation. Mutations occur at the level of the gene- 'gene or point mutations', or at the level of the chromosomes- 'chromosomal aberrations'. After the re-discovery of the gene by Watson and Crick,[70] it is now believed that the hereditary information is contained in the base sequences along the DNA chains. Changes that occur in the molecular structure of the DNA (like a loss or gain of a base) base pairing sequences that lead to new metabolic actions compared to the original action, is a gene mutation. Jacob and Monod[39] put forward their theory of the operon in which a regulator, operator, promoter and structural genes, consisting of DNA base pairs were recognised. A change in any of these gene base pairs would also be a mutation in the present context. Mutations change genes defined by their physiological action; for the most part these would be changes in the cistrons and operons of molecular genetics.[68] Similarly entire chromosomes or parts thereof may be subject to changes, in structure or arrangement. These are referred to as chromosomal mutations.

Mutation rates are dependent on the kinds of alleles, external and genic environmental factors and in natural environments the rate is about 10^{-5} or 1/1,000,00.[58] Sinnott *et al*[63] refer to the work of Dobzhansky and Spassky who estimated the lethal mutation rate in *Drosophila melanogaster* to be 10^{-5} per gene per generation. Haldane[31] reported that the mutation frequency for haemophilia was between $1x10^{-5}$ and $5x10^{-5}$ per generation. Higher rates of mutation have been reported for certain other characters such as neurofibromatosis in man, 10^{-4}.[58] Table 1 gives a summary extracted from Sinnott *et al*[63] for some characters and their mutation rates in man.

3.2. Genes and their involvement

There are many kinds of genes that affect a phenotype. This paper is written with a particular emphasis on qualitative genes, or genes affecting those traits that can be characterized rather than measured. Qualitative traits are also traits that are influenced by a few genes or that are simply inherited. Genes affecting qualitative traits generally show dominance, recessiveness or incomplete dominance in the phenotype. Genes could conveniently be divided into 3 groups (*a*) major genes which determine to a large extent the expression of the phenotype (*b*) contributing minor genes, which have less significant effects on the phenotype and (*c*) modifiers which could collectively modify the phenotype.

TABLE 1. Approximate rates of mutation per million gametes of some genes in man (After Neel and Schull).

	Disease or abnormality	Rate
Autosomal dominants	Epiloia	10
	Achondroplasia	42
	Pelger's anomaly	80
	Aniridia	5
	Retinoblastoma II	23
Autosomal recessives	Micropthalamos	15
	Albinism	28
	Colour blindness (total)	28
	Infantile amaurotic idiocy	11
	Ichthyosis	11
Sex-linked recessives	Haemophilia	35

Source—Sinnott *et al* (1958).

Genetic defects are more often of a recessive type.[48] In such a situation theoretically the individual showing the abnormality in the phenotype must show a double recessive genotype (bb). The heterozygotes (Bb) and homozygous dominant (BB) types will not usually show the defect. Whenever a defective offspring is born and an autosomal recessive inheritance is established, both parents are automatically identified as carriers. However, even in a carrier (heterozygote) by carrier mating a defective offspring will result only 25% of the time.

Dominance in some instances may be responsible for genetic defects, and the phenotype is usually expressed both in the heterozygote and homozygote. These defects are often semi-lethal and gene frequencies can be quickly lowered, through selection.

Appendix 1 shows a partial listing of genetic abnormalities in Cattle, Sheep, Goats and Swine from the literature.

3.3. Gene Penetrance

When a gene fails to manifest its expected effect in the phenotype it is referred to as being incompletely penetrant.[48] The term penetrance applied to an individual can take on values of either 0 when the defect is not shown, or 1 where the defect is shown. However, when penetrance is applied to a population, it can take on values ranging from 0 to 1. It follows from this discussion that whether a genetic defect is of a dominant or recessive type its expression in the phenotype is again dependent on the level of gene penetrance. Modifier genes as well as other genes in the background genotype are important regulators of penetrance.[28]

Another word often used conjointly with penetrance is expressivity. Expressivity applies only to a gene system that shows penetrance and relates to the degree of expression of a character. For example, Shupe *et al.*[62] reported an investigation of a skeletal congenital malformation which showed variable expressivity, believed to be hereditary in origin, among Hereford cattle. In arthrogryposis affecting Charolais cattle the limb defect is often associated with a cleft palate, which then refers to the expressivity of the defect.[5,6,49,53]

4. Characterization of genetic defects

Gene defects could be categorised differently from the normal approach of classification taking into account, the type of qualitative gene involved, and factors that make elimination of the deleterious gene more difficult. Using these bases, the following classification was developed.

1. Genetic defects that are recessive, autosomal and show complete penetrance.
2. Genetic defects that are recessive, autosomal and show incomplete penetrance.
3. Genetic defects that are recessive, autosomal, show incomplete penetrance and heterozygote advantage.
4. Genetic defects that are dominant in effect with complete penetrance.
5. Genetic defects that are dominant in effect with incomplete penetrance.
6. Sex linked recessive or dominant defects.
7. Defects incompletely dominant that show some expression in the heterozygote.

This report will consider only the first three kinds as a majority of genetic abnormalities are of a recessive type. The methods by which the frequency of the defective gene could be reduced which are discussed in this report will in general apply to recessive inheritance.

4.1 Selection against a recessive gene

Complete selection against a recessive gene which is responsible for a genetic abnormality is difficult to achieve as recessives are usually hidden in the heterozygote. Falconer[17] showed that (1) selection was most effective at intermediate frequencies of the defective recessive gene and became least effective when the gene frequency was large or small and (2) selection was ineffective when the recessive allele was rare. Lasley[48] stated that discarding or culling all homozygous recessive individuals in a population reduces the recessive gene frequency but does not eliminate it.

It becomes necessary at this point to digress from a purely qualitative basis into population genetics, which relate to gene frequencies. The theoretical basis for the study of populations arises from the Hardy-Weinberg law, and Falconer[17] defined it as follows: in a large random mating population both gene frequencies and genotype frequencies are constant from generation to generation in the absence of migration, mutation and selection, and the genotype frequencies are defined by the gene frequency. Assuming that the Hardy-Weinberg law operates and q is the frequency of the recessive gene in a population then (1-q) = p = frequency of the dominant allele in the population. The genotypes in the next generation will be as, $p^2 + 2pq + q^2$, where,

p^2 = Dominant homozygotes (AA)
$2pq$ = Heterozygotes (Aa)
q^2 = Recessive homozygotes (aa)

Table 2 which is presented subsequently, demonstrates that even though the frequency of a lethal recessive gene is very low in a population, there are sufficient numbers of heterozygotes (Carriers) still carrying the deleterious gene. Table 2 was constructed assuming that the Hardy-Weinberg equilibrium operates.

TABLE 2. Relationship between gene frequency and % carriers.

Frequency of the recessive gene (q)	%Heterozygotes or carriers (2pq)
0.5	50%
0.3	42%
0.2	32%
0.1	18%
0.05	9.5%
0.01	1.98%
0.005	0.995%

Table 2 demonstrates that when 1 out of every 100 or 0.01 is abormal 18% of all animals are carriers. Similarly, when 1 out of every 10,000 is abnormal, 2% are carriers.

Now let us assume that the frequency of arthrogryposis in Charolais cattle was such that every 1 in 100 was crippled. Assuming that penetrance is complete, the frequency of occurrence was $q^2 = 0{\cdot}01$, therefore $q = \sqrt{0.01} = 0.1$ Thus the frequency of the normal allele p = (1-q) = 0.9. At equilibrium, the heterozygotes in the population will have a frequency of $2pq = 2\ (0.9 \times 0.1) = 0.18$. Thus the ratio of heterozygotes: recessive homozygotes is 0.18: 0.01 or 18:1. In other words, heterozygotes are 18 times more frequent than the defectives. As the frequency of the defective gene becomes smaller the frequency of the carriers relative to the frequency of those showing the defect will increase.[63]

Thus far in the discussion we have considered situations where selection is 100% effective against a recessive homozygote or where S = 1. Falconer[17] stated that "S" the selection coefficient denotes the strength of the selection or the proportionate reduction of the genetic contribution of a particular genotype, compared with a standard genotype usually the most favoured. The selection coefficient S = Q, when all individuals and genotypes concerned survive and reproduce.

Opposed to the selection coefficient is the fitness or the adaptive value 'W' (Sinnott *et al*[63]) given as 1 - S. Now when a genotype is lethal or sterile and selection is is 100% effective, then S = 1 and W = (1—1)=0. Thus depending on the strength of selection, 'S' can take on values from 0 to 1.

Table 3 has been obtained from Sinnott *et al*[63] and shows the effect of complete selection against recessive trait.

Assuming that the frequency of a recessive gene in a population is 0.5, S = 1, there is a complete selection against the recessive defect, the Hardy-Weinberg equilibrium is valid and heterozygotes are twice as numerous as the recessive homozygotes, the original recessive gene frequency of 0.5 is halved in 3 generations but the carrier (heterozygotes) are 6 times more frequent as the homozygous recessives. After 9 generations of selection the original recessive gene frequency is reduced to 0.1 at which time heterozygotes are 18 times more frequent than the recessive homozygotes. The values demonstrate that as the frequency of a defective gene decreases, the heterozygotes (carriers) become more frequent, selection is less effective, and it takes a long while to reduce the frequencies.

TABLE 3. Effects of complete selection against a recessive trait.

Generations	Gene frequency (q^1) 1,2	%Recessive Homozygotes (q^2)	%Heterozygotes (2pq)	%Dominant Homozygotes (p^2)
1	0.500	25.00	50.00	25.00
2	0.333	11.11	44.44	44.44
3	0.250	6.25	37.50	56.25
4	0.200	4.00	32.00	64.00
5	0.167	2.78	27.78	69.44
9	0.100	1.00	18.00	81.00
10	0.091	0.83	16.53	82.64
20	0.048	0.23	9.07	90.70
30	0.032	0.10	6.24	93.65
40	0.024	0.06	4.76	95.18
50	0.020	0.04	3.84	96.12
100	0.010	0.01	1.96	98.03

Source—Sinnott *et al*[63]

1. Formula used to calculate q_1,[17]

$$q_1 = \frac{q^2(1-S) + P_q}{1-Sq^2}$$

When S = 1,

$$q_1 = \frac{P_q}{1-q^2}$$

Where, q_1 = new gene frequency
q = original recessive gene frequency
p = original dominant gene frequency
S = Selection coefficient

2. Formula used to calculate q_1,[48]

$$q_1 = \frac{q}{1-(n \times q)}$$

Where n = number of generations

4.2 Selection against a recessive with incomplete gene penetrance

Thus far we have dealt with theoretical descriptions in populations where selection for a recessive defect is complete, due to possibly lethality and complete penetrance of the defective gene. For the purpose of our discussion the selection coefficient 'S' could be equated to penetrance (P) and if S = 0.1 the level of penetrance would be 10%. We have also seen the difficulties that arise in reducing recessive gene frequencies when, P = S = 1. The difficulty in controlling gene frequencies is further aggravated when penetrance of the defective gene is incomplete. The effectiveness of selection in large breeding groups is proportional to the level of penetrance; if penetrance is low selection against a recessive defect would naturally be less effective than if the intensity of selection or penetrance approached unity.

Sinnott *et al*[63] showed results which demonstrated some of the additional difficulties that may arise due to partial selection or incomplete penetrance (table 4).

TABLE 4. Effects of partial selection (due to incomplete gene penetrance) against a recessive trait on the frequency in %, of the individuals homozygous for the recessive gene.[1]

Generations	S = P = 1	S = P = 0.5	S = P = 0.1	S = P = 0.01
1	1.00	1.00	1.00	1.00
10	0.25	0.46	0.84	0.98
20	0.11	0.26	0.71	0.97

Source—Sinnott *et al*[63]

1. Table values calculated assuming 1% homozygous recessive individuals or q = 0.01.

When penetrance was complete 10 generations were needed to reduce the gene frequency to a quarter of the original value. When penetrance was 50%, 20 generations were needed to reduce the the original gene frequency to a quarter of its original value and selection was very ineffective in bringing about a change in gene frequency in 20 generations, when penetrance was 10% and 1%.

Incomplete penetrance may also be associated with heterozygote advantage[5] and if it be the case, selection for the heterozygote is obvious and this will help to maintain the frequency of the recessive defective gene, stationary in a population under natural selection. If heterozygote advantage is observed in economic and production characters the defective gene frequency will again be maintained at above normal levels in commercial populations, due to the advantage gained through artificial selection.

One aspect that we have assumed in the discussion so far is the idea of a large random breeding population, a prerequisite for the Hardy-Weinberg law to be operative. However, in commercial herds random mating is not practiced instead, specific breeding plans are carried out and animals selectively bred. Furthermore, the breeding populations we would deal with are usually small. These two factors are therefore confounded in this discussion and looking at selection with the element of random breeding removed would be a more exact approach, although it is difficult to accomplish.

5. Methods of identification of recessive defects

There are many methods available for the detection of recessive abnormal inheritance in domestic livestock. Some of these methods are restrictive in the sense that certain previous records such as pedigrees, are needed, while others involve planned breeding and whether or not it should be practiced to identify a carrier of a genetic defect depends on factors, such as the attitude of the breeder, the severity of the defect and the frequency of occurrence.

5.1 Pedigree analysis

A pedigree is a record of an animal's ancestors that are related to it through its parents. A pedigree to be useful in detecting an inherited defect must contain all necessary information, such as numbers identifying the animals, the condition of all progeny born and detailed descriptions of any abnormalities encountered. A pedigree is particularly useful in tracing the sire (s), dam (s), animal (s), or breed (s) that may have introduced the defective gene into the population. In the study of recessive

gene inheritance through a pedigree the following should be borne in mind, (1) a recessive gene must be independently introduced to the maternal and paternal sides of a pedigree if ever a defective offspring results. (2) Common ancestors appearing on both the sire's and dams' side of the pedigree are often responsible for the introduction of the recessive gene (3) whenever a defective offspring is both parents automatically become carriers.

The pedigree presented in chart 1 is taken from a population of Charolais and Angus cross bred cattle from the University of Alberta herds in Kinsella, Alberta. A pedigree record in this instance was used to determine how the defective arthrogryposis gene was introduced into this pedigree. Assuming that the defective gene must be introduced independently to the sires' side and the dams' side in the pedigree, let us see whether there are any common ancestors. Sire ≠ 3 is a common ancestor being the maternal grand sire of ≠ 13 and ≠ 15 and the sire of ≠ 14. Furthermore, this particular defect, namely, arthrogryposis was peculiar to the Charolais breed and sire ≠ 3 was pure Charolais which further suggests that this sire may be the one responsible for the introduction of the defective gene.

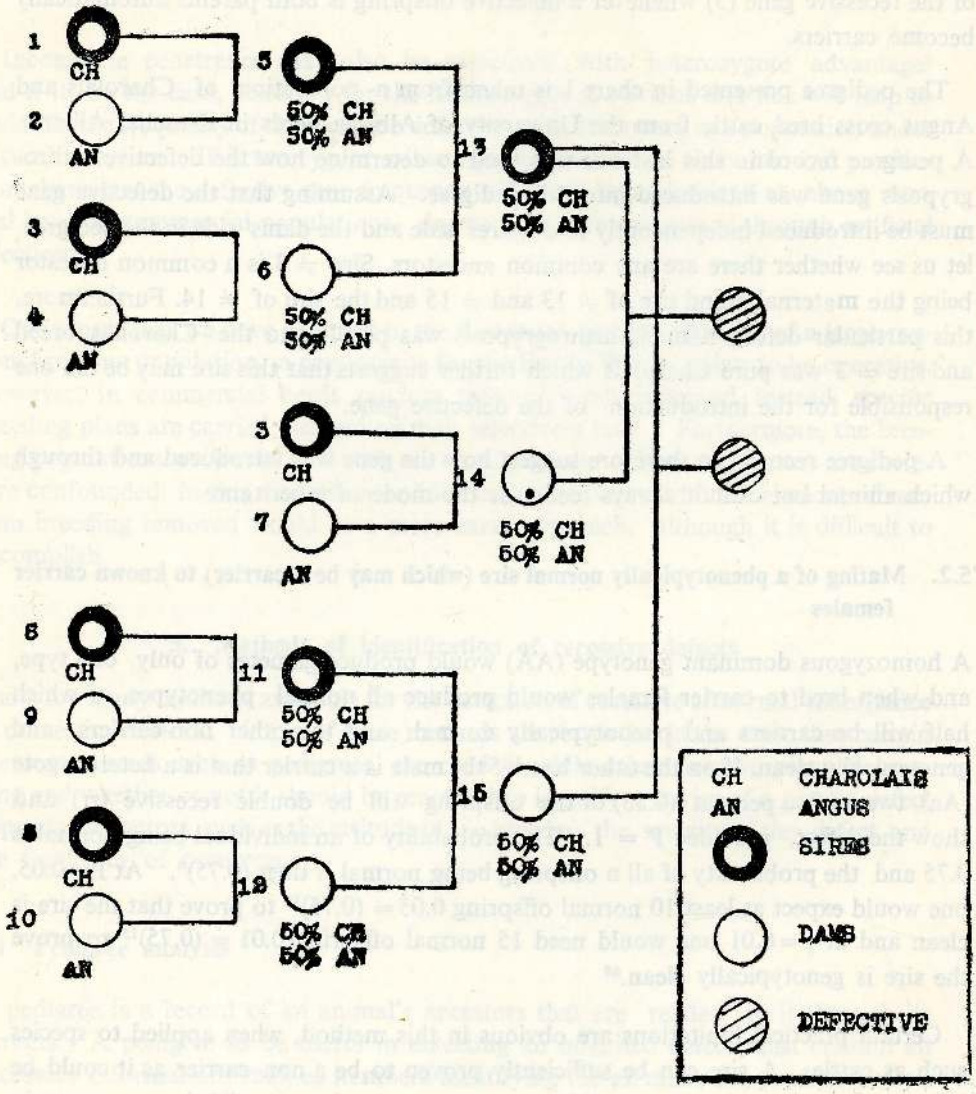
A pedigree record can therefore suggest how the gene was introduced and through which animal but cannot always recognise the mode of inheritance.

5.2. Mating of a phenotypically normal sire (which may be a carrier) to known carrier females

A homozygous dominant genotype (AA) would produce gametes of only one type, and when bred to carrier females would produce all normal phenotypes, of which half will be carriers and phenotypically normal and the other non-carriers and genotypically clean. If on the other hand if the male is a carrier that is a heterozygote (Aa), twenty five percent (0.25) of the offspring will be double recessive (rr) and show the defect, provided P = 1. The probability of an individual being normal is 0.75 and the probability of all n offspring being normal is then $(0.75)^n$. At P=0.05, one would expect at least 10 normal offspring $0.05 = (0.75)^{10}$ to prove that the sire is clean and at p=0.01 one would need 15 normal offspring $0.01 = (0.75)^{15}$ to prove the sire is genotypically clean.[69]

Certain practical limitations are obvious in this method, when applied to species such as cattle. A sire can be sufficiently proven to be a non-carrier as it could be bred to many dams but one would have to use a dam's entire lifetime to ascertain whether she is a carrier of a defective gene. Secondly, one could do this test only if a nucleus herd of carrier cows was available.

Pedigree Chart.-1



5.3 Sire daughter matings.

If a carrier sire is bred to non-carrier dams, half its progeny would be carriers. If all or a random sample of daughters (progeny) are bred back to the sire and one defective offspring detected, the sire becomes proven as a carrier. However, about twice the number of sire x daughter matings are necessary to reach the same levels of probability as when known carrier females are used.[69] A very serious disadvantage in using this procedure is that, sires are too old when the offspring of their daughters are obtained, especially among species that have long generation intervals.

5.4 Mating a sire/dam to a double recessive sire/dam

The procedure applies only to situations where the defect is semi-lethal and there is no associated reproductive failure. It can be used to detect carrier sires or dams. In this method one parent is always homozygous and recessive (rr). If the other parent is a carrier and P = 1, then 50% of the offspring would show the defect. If on the other hand, the other parent was normal the defect would not be seen in any of the offspring. The probability of all offspring being normal is then $(0.5)^n$ If four or five offspring from such a mating combination were normal, P = 0.06 and 0.03 respectively or the chances are 94% or 97% that the animal in question is normal. This is a very powerful test but has its limitations.[69]

6. Why do recessive genes persist in populations?

Recessive genes that are responsible for certain undesirable abnormalities appear to persist in populations sometimes at stationary frequencies and at other times, at above normal frequencies. I will now attempt to theorise on why such genes persist in populations inspite of their adverse effects.

6.1. Recurrent mutation

Mutations result in a change in gene frequencies from one allelic state to another at a prescribed rate. The rate of mutation was determined to be around 1×10^{-5} per generation[58] and based on this value, mutations were classified as rare events.[23] If a mutation was of a recessive and disadvantageous type selection, complete against the recessive state, and there was no heterozygote advantage, the frequency of the recessive gene must reduce over time. However, if the mutation involved an area on the DNA or chromosome which tended to be more mutable than other loci, the same disadvantageous recessive phenotype may once again be introduced into the population due to the recurrent nature of such mutations.

Since recurrent mutation is a weak force in changing gene frequencies compared with say selection, one cannot expect deleterious recessive gene frequencies to be maintained at high and stationary levels in breeding groups by this process.

6.2. Frequency dependent selection

Frequency dependent selection in its simplest defunction means that a gene or genotype is selected when rare and selected against when common.[58] Its fitness therefore depends on gene frequency. Frequency dependent selection is seen to be operative in the production of balanced polymorphisms in mimicry[23], and in the esterase 6 locus in *Drosophila melanogaster*, as reported by Kojima and Yarborough.[46] On this basis a recessive gene which may be a disadvantage at high frequencies but an advantage at low frequencies may be maintained at a stationary frequency in populations. However, for this equilibrium gene frequency to be maintained we must presume that the recessive gene in question could confer some selective advantage to another genetic system associated with fitness, only when it reaches a low frequency. Furthermore, although frequency dependent selection can establish a low and stationary frequency for a recessive gene its potential in maintaining the frequency of a recessive at a high frequency is questionable.

6.3. Heterozygote advantage

Heterozygote advantage is one of the most effective methods whereby defective and recessive genes are maintained at either stationary or above normal frequencies in populations. Fisher[22] stated that a single factor may be in a stable equilibrium under selection if the heterozygote has a selective advantage over both homozygotes. A classical case of heterozygote advantage is seen in the instance of sickle-celled anaemia in human populations. The disease is controlled by a recessive gene and when homozygous causes anaemia and is usually lethal.[1] Heterozygotes also show the sickling trait in the red blood cells and are slightly anaemic under low oxygen tensions.[2] In spite of the fact that recessive homozygotes suffer from a lethal disease, the heterozygotes and consequently the lethal gene is common in certain regions of the world where malaria is prevalent. Allison[1] stated that the sickling trait confers marked immunity towards malaria. Thus, as the heterozygotes are at a selective advantage, the defective gene frequency appears to be stationary in such populations, and balanced blood type polymorphisms established.[23]

Many experiments were also reported by Dobzhansky[13] on *Drosophila pseudoobscure*. The first was in respect to the character's arrow head AR/AR and pike's peak PP/PP. The selection of the AR/PP heterozygote was favoured. In a second case the standard St/St, and Charicahua Ch/Ch loci inversions could be cited. At 28°C to 30°C the average longevity of the St/St homozygotes was greater than either the Ch/Ch or Ch/St types. However, at 0-4°C there was a distinct advantage in longevity for the heterozygote (Ch/St).[58]

In the recessive genetic defect affecting Charolais cattle, namely, arthrogryposis Berg and Goonewardene[5,6] showed that heterozygote advantage in dams was one reason for the persistence of the defective gene at a high frequency in certain cross,

bred Charolais populations. An arthrogryposis carrier dam population was compared with a control population consisting of dams with similar breeding, and managed under similar conditions. Fertility as measured by the number of successful calvings was better in the arthrogryposis carrier herd. Longevity was also better among carrier dams compared with the control. Heterozygote advantage pertaining to a primary fitness character is therefore of great importance in maintaining recessive and deleterious gene frequencies stationary in certain breeding groups. Lerner[51] cites many examples where heterozygote advantage has been recognised.

6.4. Lack of penetrance and incomplete selection

In many instances a defective gene cannot be easily removed from a population due to incomplete penetrance. In extreme situations there could be zero penetrance, in the recessive state and if animals concerned reproduce normally, all their F 1 progeny would be carriers (assuming that one parent was proven clean). Consequently, the defective gene will be at a high frequency in these populations, especially if the recessive homozygote was a sire that was used extensively in an initial breeding program. Evidence to support the existence of homozygous recessive arthrogrypotic Charolias sires, was reported by Goonewardene and Berg[29] and two case histories in support of the above will be discussed.

A particular sire referred to as (A) was mated to 3 of its daughters in the same year and 3 arthrogrypotic calves resulted. This was the first glimpse of evidence to suggest that this particular sire may have been a recessive homozygote. If sire (A) was a carrier in a true sense (heterozygous) only half its daughters would be carriers and if mated back to its daughters only 25% would be defective. Although the numbers involved are insufficient for a statistical analysis there is room to believe that sire (A) was a double recessive carrier.

A more positive example of homozygosity among sires was reported by a farmer in the province of Alberta in Canada. During the spring of 1970, seven cases of arthrogryposis were observed. While examining the history and breeding records in this herd, the introduction of the defective gene was traced to a pure bred Charolais bull (C) purchased in 1968. This bull was bred to a number of non-Charolais dams mainly Shorthorns the resulting progeny being half Charolais, Shorthorn crosses. In 1971 a full Charolais bull (D) was purchased and used on some yearling and 2 year old heifers, which included among them 15 half Charolais cross daughters of bull (C). In 1972 a total of 32 calves were born through sire (D), 15 of which came from the half Charolais daughters of sire (C). Of these 15 calves, 8 were normal and 7 crippled (positive lesions of arthrogryposis). This approximates closely to a 50 : 50 ratio of normal : crippled calves.

Assuming that the defect was conditioned by a recessive gene pair, both parents must be at minimum carriers (heterozygotes) to drop a crippled calf. All of the half Charolais daughters of (C) would be carriers only if one parent were homozygous recessive. It would appear very likely that bull (C) was the double recessive parent as the defect is unlikely to come through non Charolais dams that were bred to (C). A ratio of 1 : 1 normal: defective calves is expected in a test cross where a heterozygote is bred to a recessive parent. When the daughters (C) were crossed to sire (D), 7 of the calves born were defective. The observed ratio indicates that sire (D) was also a homozygous recessive carrier of the defective condition. If sire (D) was heterozygous, only 25 % of the calves would be crippled provided penetrance was complete. An interesting observation was that sire (D) had very weak front legs and barely able to stand and walk around. The progeny from the daughters of bull (C) bred to bull (D) also had weak limbs at birth which corrected itself after 2-3 weeks.

6.4.1. Dominance modification

Fisher[20] in his classic paper titled "the possible modification of the response of the wild type to recurrent mutations" stated that under experimental conditions, mutant types which had been kept as stock for several generations had been observed to show their mutant peculiarities in a materially lower degree than at first appearance. This observation was clarified by the fact that the effect of a gene can be varied by changes in the rest of the hereditary material and consequently that they are susceptible to selection. Fisher's[20] experiments showed that it is not the recessive mutant gene that is modified instead, the other genes involved in the expression of the phenotype are modified through selection and thereby dominance in the phenotype is achieved. A similar phenomenon appears to operate with respect to arthrogryposis a recessive genetic defect in Charolais cattle. Due to the accumulation of favourable modifier genes the defect has been almost completely suppressed in the phenotype among certain pure bred Charolais bulls. However, among cross bred Charolais animals which do not have the correct sequence of modifier genes selected out, the defect is seen clearly and gene penetrance is complete.

7. Lines of action

There are two broad methods by which one could overcome genetic defects; elimination of the defective from the population or reduction of the defective gene frequency by selection and planned mating. The first is difficult to achieve and depends on the types of genes involved and the second method could therefore be considered a reasonable approach.

The action to be taken if a lethal or semi - lethal genetic abnormality is discovered in a herd would depend on the type of herd, and the seriousness of the abnormality.[69] The remedial measures practised in a commercial herd may be somewhat different from those practised in breeding a herd. However, two methods are available to a breeder to reduce the frequency of the genetic defect, namely, selection (culling) and breeding (plan mating).

(*a*) All males and females that have ever produced offspring with lesions characteristic of the genetic abnormality under study must be culled.

(*b*) Replace sires and dams with animals that have either had no history of the defect in their pedigrees or minimal probabilities of being a carrier.

(*c*) Cull all animals that are closely related to the defective offspring even if they are normal, until they are proven clean.

(*d*) Avoid the over use of a particular herd sire especially if he is not fully progeny tested.

(*e*) Cross breed to reduce the occurrence of a genetic defect that may be common to a particular breed group.

8. Conclusions

The present paper discusses some aspects related to the genetics of inherited abnormalities. The first question one should ask when an abnormality appears in a herd is whether it is environmental or hereditary. A hereditary basis is best indicated if the abnormality is confined to certain breeding individuals. Hereditary abnormalities often go undetected especially when progeny are born dead and serious consideration must be given to this aspect. Genetic defects are often of a recessive type. Recessive genetic defects are difficult to select against, and selection becomes very ineffective when the defective gene frequency is low. Furthermore, if penetrance of the defective gene is incomplete, selection will be still less effective in reducing gene frequencies.

Heterozygote advantage and incomplete gene penetrance were recognised as two important factors that help to keep defective gene frequencies stationary in populations. Complete elimination of recessive defective genes from a population is virtually impossible especially if penetrance is incomplete. Thus a reduction of gene frequencies must be achieved through a system selection and planned breeding.

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Appendix 1

Partial Listing of Genetic Abnormalities — Cattle, Sheep, Goats and Swine.

Abnormality	Inheritance	Reference/Source
Cattle		
Achondroplasia 1	Lethal-partially dominant requiring two genes to have a lethal effect. Dexter x Kerry Jersey, Hereford & Friesian cattle.	Lasley (1978)
Achondroplasia II	Lethal-Mode of inheritance appears to be recessive Telem ark, Jersey, Guernsey, Ayrshire cattle.	Lasley (1978)
Achondroplasia III	Lethal-recessive Jersey cattle.	Lasley (1978)
Achroteriasis	Single autosomal recessive gene	Geringer (1977)
Adactly	Autosomal and recessive.	Liepold *et al* (1970)
Agnathia	Lethal-Sex linked recessive, Angus and Jersey Cattle.	Lasley (1979)
Amputated	Lethal-recessive and autosomal Swedish Friesians.	Lasley (1978)
Arthrogryposis	Lethal-autosomal recessive, incomplete penetrance-Charolais cattle.	Berg *et al* (1974)
Brachygnathia	Non lethal-recessive gene probable.	Dunn *et al* (1972)
Bull dog head	Non lethal-recessive Jersey cattle.	Lasley (1978)
Cerebral hernia	Lethal-probably recessive, Holsteins.	Lasley (1978)
Cerebrospinal fluid pressure increase	Probably recessive.	Fransen *et al* (1958)
Comprest condition	Lethal partially dominant.	Lasley (1978)
Congenital atazia	Autosomal and recessive.	Johnston *et al* (1958)
Congenital cataract	Non lethal-recessive Hereford.	Gregory *et al* (1943)
Congenital debility	Condition transmitted probably genetic, Brown swiss cattle.	Derlogea *et al* (1958)
Congenital head abnormalities and Brachynathia	Autosomal dominant.	Ernest *et el* (1977)
Congenital ichthyosis	Inherited as a lethal factor, Zebu cattle.	Verjacko *et al* (1974)
Congenital lethal Spasms.	Lethal-recessive.	Gregory *et al* (1944)
Congenital porphyria	Non lethal-simple recessive.	Madden *et al* (1958)
Corkscrew claws	Probably genetic.	Bouckaert *et al* (1958)

Abnormality	Inheritance	Reference Source
Culard (double muscling)	One pair of modified genes with a wide range of activity.	Hanset (1972), Kidwell *et al* (1952)
Curved limbs	Lethal-recessive Guernsey.	Freeman (1958)
Dermatosparaxis	Lethal-recessive mode of inheritance.	Hanset *et al* (1974)
Doddler cattle	Lethal-monofactorial autosomal recessive.	High *et al* (1958)
Duck legged cattle	Non lethal-autosomal dominant.	Lasley (1978)
Dwarfis. achondroplastic	Probably recessive.	Tyler *et al* (1959).
Epilepsy	Dominant.	Lasley (1978)
Epitheliogenesis imperfecta.	Inheritance as a single autosomal recessive.	Liepold *et al* (1973)
Flexed pasterns	Semi lethal-autosomal recessive Jersey cattle	Lasley (1978)
Hairlessness	Recessive gene-reported in many breeds.	Lasley (1978)
Harelip	Not well understood epistasis may be involved, Shorthorn.	Lasley (1978)
Hydrocephaly	Lethal-recessive, reported in several breeds.	Lasley (1978)
Hypoplasia of ovary	Non lethal-recessive gene with reduced penetrance.	Lasley (1978)
Impacted molars	Lethal recessive in Shorthorn cattle.	Lasley (1978)
Limber legs	Semi lethal-autosomal recessive.	Lamb *et al* (1976)
Long headed dwarf	Non lethal-recessive Angus and Hereford cattle.	Lasley (1978)
Micrencephaly	A genetic basis suggested Hereford cattle.	Fielden (1959)
Mummified foetuses	Lethal-sex linked recessive.	Deaton *et al* (1959)
Muscle contracture	Lethal-recessive.	Lasley (1978)
Muscle contracture and chondrodysplasia syndrome.	Lethal suggested that it is due to a dominant gene with incomplete penetrance	Johanston et al (1958)c
Neuraxial oedema	Lethal-autosomal recessive inheritance.	Weaver (1974)
Occular colombomata	Dominant mode of inheritance Charolais.	Barnett *et al* (1972)
Osteopetrosis	Inherited as an autosomal recessive, Angus cattle.	Huston *et al* (1971)
Polydactylism	Non lethal-probably an autosomal dominant.	Lasley (1978)

Abnormality	Inheritance	Reference/Source
Prolonged gestation	Lethal-recessive	Lasley (1978)
Screwtail	Non lethal recessive	Lasley (1978)
Short spine	Lethal-recessive.	Lasley (1978)
Shorter dwarfism	Semi lethal-recessive.	Johnston *et al* (1950)
Spastic paresis and crooked fore legs	Pentahybrid inheritance with complementary gene action.	Gehrke (1969)
Spinal bifida	Lethal-dominant gene low penetrance.	Nes (1959)
Stumpy	Non lethal-recessive.	Lasley (1978)
Umbelical hernia	Limited to males dominant, Friesian cattle.	Lasley (1978)
Upright pastern	Recessive multifactorial gene effect.	Harmori (1959)
White heifer disease	Sex linked, recessive Shorthorn cattle.	Lasley (1978)
Wry tail	Non lethal-recessive, many breeds.	Lasley (1978)
Xanthosis	Simple recessive.	Hayward *et al* (1978)
Sheep/Goats		
Amputated	Mode of inheritance not well established.	Lasley (1978)
Blindness	Homozygosity for a single recessive factor.	Zwiep (1958)
Congenital (goat) Afibrinogenemia	Mode of inheritance is incompletely dominant.	Breukink *et al* (1972)
Dwarfism	Semi lethal, recessive	Lasley (1978)
Muscle contracture	Lethal-recessive.	Lasley (1978)
Taillessness	Apparently inherited as a dominant with incomplete penetrance.	Carter (1976)
Swine		
Atresia ani	Lethal-two pairs of dominant genes involved (epistasis); other modes of inheritance and environment may be involved.	Lasley (1978)
Brain hernia	Semilethal-recessive.	Widmaier (1959)
Congenital porphyria	Inheritance due to dominant gene.	With *et al* (1959)
Cranium bifidum	Simple recessive, incomplete penetrance, 2 pairs of genes may be involved	Stewart *et al* (1972)
Crypt ochidism	Sexlimited, recessive.	Johnston *et al* (1958)[a]

Abnormality	Inheritance	Reference Source
Epitheliogenesis imperfecta	Semi lethal-single autosomal recessive gene	Fischer (1958)
Hair Whorls	Non lethal-two pairs of dominant genes (epistasis)	Lasley (1978)
Haemophilis	Semilethal-recessive pol and China breed.	Lasley (1978)
Hydrocephalus	Lethal-recessive.	Lasley (1978)
Mule foot	Non lethal-dominant	Lasley (1978)
Paralysis	Lethal-recessive.	Lasley (1978)
Rhinitis	Simple dominant, inheritance	Koch *et al* (1958)
Splayleg	Dominant, Sex linked.	Lax (1971)
Tongue abnormalities cleft palate and harelip	Autosomal recessive	Nes (1958)
Unbifurcated hooves	Semilethal-dominant.	Gligor *et al* (1959)

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Food Beliefs and Practices Among Sri Lankans

I. Temporary Food Avoidances by Women

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1. Introduction

It is seldom that man eats all available edible material. Cultural patterns set by his parents and associates, both by observation and by explicit instruction, classifies for him food items as being appropriate or inappropriate in certain situations. The general food beliefs of any group or community are deeply entrenched in their minds and practised. Such beliefs can therefore significantly influence the nutritional status of the community and become a factor of importance in any nutrition program.

Health workers, whose duties include advising the public on the correct choice of foods, could profit from a study of food belief systems of the people among whom they work. Such a study would provide a clearer picture of the framework within which their advice will be followed. Tradition and folk-beliefs greatly influence the diet of women during adolescence, pregnancy and lactation, and undernutrition is common in these groups.

Studies on temporary food avoidances and taboos among Tamils in South India[1,2,3,6] emphasise the influence of beliefs, attitudes and customs on the diet of women during menarche, menstruation, pregnancy, puerparium and lactation. Although a few studies have been carried out by the Department of Nutrition, Medical Research Institute, among urban slum dwellers around Colombo, there is no published data on temporary food avoidances among the Sinhalese. This is a report of a survey carried out among Sinhala women. As religion influences customs and taboos, the study was restricted to Buddhists, who form about 70% of the population. A preliminary report on this survey has been published.[4]

2. Methods

A questionnaire was prepared which sought information on foods avoided during various periods of a woman's life: viz. at puberty, during menstruation, pregnancy, puerperium, lactation and post-menopausal life. The questionnaire enumerated foods commonly eaten in Sri Lanka, and questions were designed so as to ascertain whether each item was avoided all the time or only temporarily.

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In the first study the questionnaire was administered to 221 young women attending a Course of Instruction on Child Welfare, organised by the School of Social Work. They hailed from both urban and rural areas in various districts of Sri Lanka. They had all studied up to a minimum level of Grade 8 in their secondary education. The purpose of the questionnaire was explained to them in small groups (8 to 10) and each person was asked to respond according to the practice in her home. As all of them had some basic knowledge of the science of food and nutrition, they were specifically required to avoid stating what they know to be good or ought to be done, but mention only what is actually done in their own households.

In the second study, the questionnaire was administered to women in Bambarabedde, a remote village in the District of Kandy (see Annex). Fifty families were chosen at random from the Grama Sevaka's householder's list. The mother of each family was selected, about one-sixth of the total adult female population of the village being thus included in the study. Prior to the survey, the enumerator visited the homes with two of the villagers, to establish rapport with the householders.

3. Results

The pattern of food avoidances was similar in the two groups studied, and are therefore considered together (Table 1).

TABLE 1: Food Avoidances by Sri Lankan Sinhala Women

Foods	At Menarche	During Subsequent Menstruation.	Pregnancy	Puerperium	Lactation	Menopause
	%	%	%	%	%	%
All or some items of non-vegetarian foods	97	22	48	98	35	04
Beef	55	22	46	65	30	04
Pork	43	20	40	77	22	05
Egg	32	18	20	47	06	—
All fish	16	18	09	12	06	04
Small bony fish	—	—	28	86	32	—
Milk	22	10	28	18	04	—
Bread fruit	—	—	—	24	13	—
Jak fruit	—	—	—	20	—	04
Manioc	—	—	—	30	13	—
Tomatoes & Aubergines	—	—	27	33	28	04
Green leafy vegetables	26	24	27	36	—	—
Sesame seeds and oil	20	08	—	—	—	—
Papaw	22	25	22	22	14	—
Pineapple	28	38	66	38	14	—
Mango	24	20	—	27	06	—

3.1. Puberty

Most girls during their first menstrual period seem to conform to certain strict rules in the choice of food. The most striking prohibition was that of non-vegetarian foods. All items of non-vegetarian foods, including dried fish, were avoided by 8%, all meats by 28%, beef by 55%, pork by 43%, eggs by 32%, all varieties of fish by 16% and shell-fish by 30%.

Among the reasons given for such avoidances, the most common was the fear of pollution ("killa"). Custom, fear of abdominal pain and menorrhagia, and the belief that some foods were "heaty", also influenced food habits.

The other foods avoided were the papaw (22%), pineapple (28%), mango (24%), and green leafy vegetables (18%), cow's milk (22%) and colocasia yams (16%), the most common reason being fear of excessive blood loss. Green leaves were thought to be indigestible.

3.2. Menstruation

Although subsequent menstrual periods are also "pollution periods", the precautions required are few. Only 22% continued their abstentions from all or some of the non-vegetarian foods that they exercised at puberty. Pineapple, papaw, mango and colocasia yams were avoided, as these foods were believed to cause excessive blood loss and abdominal pain. Beef and shellfish were considered "heaty" and therefore avoided.

At this time, 56% did not conform to any strict rules in the choice of food. All meats and fish were avoided by 18%, beef by 22% and shellfish by 30%, green leafy vegetables were avoided by 24% of the women.

3.3 Pregnancy

The "hot" or "cold" nature of foods seemed to influence the choice of foods during pregnancy, 39% avoiding "heaty" foods and 28% avoiding "cooling" foods. The classification of foods as "hot" or "cold" is not well demarcated.

Eating non-vegetarian foods was considered harmful, pork, prawns and crabs being avoided most commonly. Small bony fish and 'red' fish were also avoided.

The dominating fear was that of abortion. Other reasons for abstaining from animal foods were (a) aversion to the sight and/or the smell of such food (b) poor digestibility (c) fear of harming the foetus. Some feared that fish bones may injure the foetus. Milk was avoided by 28% as it is considered "cooling".

Tomato and manioc were considered to lead to inflammation of the abdomen. Tomato and aubergines were not eaten by 27% in the belief that the peel might get stuck in the womb. Pickles, breadfruit, jak fruit, gingelly seeds and oil were considered poorly digestible or "heaty". Pineapple (66%) and papaw (22%) were avoided as they were thought to induce abortion.

3.4 Puerperium

For the first 10 days after delivery the mother is kept on a very restricted diet. Nearly all mothers avoided non-vegetarian foods, 78% avoiding even milk.

Many women adhere to a strict dietary regimen of rice, toast, coffee and "miris hodhi" (a soup made with onions, garlic and condiments) during the first 10 days after partus.

During the next 4 weeks, 65% avoided beef, 77% pork, 47% eggs, 86% small bony fish and 18% milk. "Cooling" foods were avoided by 55% and "heaty" foods by 22%.

Reasons for such avoidances were a fear that such foods harm the infant, fear of pollution, custom, lack of appetite for them, fear of abdominal pain, diarrhoea, dizziness and fits. Pieces of meat and fish were also believed to remain in the gut and cause cancer.

Of the vegetarian foods, pineapple (38%), leafy vegetables (36%), tomatoes (33%), aubergines (33%), manioc (30%), breadfruit (24%) and jak fruit (20%) were the most commonly avoided. Colocasia yams were avoided by 16%, while 12% avoided all yams and potato, and 6% any kind of vegetable. These foods were believed to cause abdominal pain, increased blood loss, chills and colds, convulsions and flatulence.

3.5 Lactation

Restrictions on the diet were less severe than during the puerperium. Some women, however, continued their avoidances throughout the period of breast-feeding.

Foods commonly avoided were small bony fish (32%), beef (30%), prawns and shell-fish (24%), pork (22%), manioc, breadfruit and pickles. "Cooling" foods were avoided because they "cool" the milk and the baby may catch a cold. Some foods were believed to be poorly digested. Custom dictated some avoidances. Bones of fish were believed to injure the breast and also harm the baby. Milk was avoided by 14% due to its "cooling" effect.

Fruits were more freely eaten during the later months of lactation than during the puerperium. Only 14% avoided pineapple, 6% mangoes, 28% tomatoes and aubergines. Other fruits, vegetables and leaves were eaten by most. Manioc was avoided by only 13%. Reasons given were the "hot" or "cold" nature of the food, the danger of causing inflammation of baby's throat, flatulence and indigestion. Tomato and mango were thought to discolour breast milk.

3.6. Post-menopausal period

Food taboos hardly exist after menopause. Among those who usually consume non-vegetarian foods only 2% avoided pork. Manioc, jak and breadfruit were avoided by only 4% and aubergines by 2%. Other fruits and vegetables were eaten by all.

4. Discussion

As in studies in Tamilnad,[1,2,3] in this study, too, no significant differences were noticed between answers given by uneducated women living in an isolated village and those given by women who had had a formal education and have easy access to media such as radio and newspapers. Food avoidances have thus been able to persist in spite of innovations.

In general, foods avoidances among the Sinhala women studied are similar to those among the Tamils[1,2,3] and the Malays.[7,8] The major avoidance at puberty and during menstruation are those of animal foods, particularly meat and fish. During pregnancy, the main concern is the fear of abortion, which results in the avoidance of "heaty" foods which are believed to induce uterine haemorrhage. After delivery, abstentions are mainly foods considered "cooling", and in addition, eggs, tubers and groundnuts.

4.1 Puberty

Coming of age is a memorable date in the life of a Sinhala or Tamil girl and is marked by segregation and ceremonies. She is segregated partly to protect her from hostile powers and demons, and partly to prevent her "pollution" from spreading. She has to conform to strict rules of behaviour which includes choice of food.

The most striking prohibition is the avoidance of non-vegetarian food, the percentage of those avoiding all such foods being smaller among the Sinhalese. Eggs were avoided by one-third of Sinhala women whereas in Tamilnad, girls are encouraged to eat eggs "to strengthen the body for future pregnancies", and to make their breasts grow. As the questionnaire used in the present study did not seek information on foods that are specially recommended at puberty, it would not be correct to infer that such beliefs do not exist among the Sinhalese.

4.2 Menstruation

Subsequent menstruations are still considered pollution periods although less dangerous and requiring fewer precautions. More than half the women did not conform to any pattern of food avoidances. As restrictions on animal foods decrease, during later menstruations, so also do those on vegetables and fruits decrease, green leafy vegetables being an exception.

4.3 Pregnancy

As in Tamilnad[2], animal foods are avoided because the sight or smell of these foods would cause excessive vomiting. Reasons such as the fear that the baby would grow too big or develop skin ailments given by the Tamils[2], and in Andhra Pradesh,[4] were not advanced by Sinhala women. Only about 22% avoided papaya, compared with over 80% in Tamilnad. The reasons given by both groups are the same: papaya is "heaty", cause uterine bleeding, resulting in abortion. Pineapple avoidance was as strong among both Sinhalese and Tamils, the reason given being its power to induce abortion, a belief also held by Malays and Chinese in Malayasia, Java and in Bali.[2]

The reason given by the Sinhalese for avoidance of sesame seeds and oil were that they were "heaty" and poorly digestible. Tamils, on the other hand, believe that sesame stimulates the ovaries, hastening maturity. The grain is avoided during pregnancy because of the fear of abortion, being considered only second to papaya as an abortifacient[2].

4.4 Puerperium and Lactation

A severely restricted diet in the first few days after partus is common among both Tamils and Sinhalese. Nearly all mothers are given a strictly vegetarian diet. Meat and fish are believed to endanger the health of the baby, causing skin eruptions, diarrhoea and fits. Dried fish may be eaten, because "it increases the flow of milk."[2,8] Eggs may be avoided for several days after delivery as they are believed to cause flatulence, indigestion and diarrhoea, and make the milk indigestible to the baby. Milk is avoided for its "coldness". Permitted foods and behaviour appear to be designed to keep the body "hot" and prevent toxicity of the suckling.[8]

Among both Tamils and Sinhalese the major avoidances among vegetarian foods are the fruits[2] - papaw, jakfruit, mango, pineapple. Tubers are avoided because they cause flatulence, and could be responsible for fits, cramp, diarrhoea and constipation in the infant.

The principal explanations for avoidances are

i. belief in the thermal quality of foods (the "hot - cold" theory).

ii. belief in pollution and the purity or impurity of foods.

4.5 The Hot-Cold Theory

Many women never question the prohibitions about food, and accept what their elders tell them to eat or not to eat. The reasons given are within the framework of traditional medicine and its theory which attributes "thermal" qualities to foods. How deeply rooted these beliefs are is shown by the fact that educated persons often try to superimpose scientific medical terminology on ancient beliefs. "Coldness" concentrates on vegetables and certain milk products, "heat" on animal food and sweet fruits.

4.6 Purity and Pollution

The concept of purity and pollution strongly affects many aspects of life including food habits. Foods may be intrinsically pure like the products of the cow, or intrinsically impure like pork. Although considerations of purity are important for food avoidances, it is seldom given as a reason, the majority of women preferring to give explanations such as nausea, or disease that would befall the mother or baby.

The lack of differentiation between urban and rural dwellers may be in the hidden character of food avoidances which allow them to persist in spite of innovations. No restrictions are apparent when, for example, a new fruit like the apple is added to the normal diet. On the other hand, a traditional fruit like the mango continues to be avoided at certain periods. A majority of avoidances affect only those foods whose consumption is optional, and not the staple.

Annex

Bambarabedde is an agricultural village in the Central Province, 6½ miles from Hunnasgiriya, a town on the Kandy-Mahiyangana road. Its population is 1656, made up of 278 Sinhala Buddhist families, family size ranging from 3 to 13. Only a few households owned any land, most of the inhabitants being daily paid labourers employed by the Grama Sevaka, working his fields of paddy and tobaco. Only about 10 %of the women did not leave home for work. The village had one school conducting classes from the Kindergarten to the G.C.E. Ordinary Level Examination. Of the 492 children between 6 and 16 years of age, only 296 were attending school at the time of the survey. Only 46 %of the women interviewed had completed primary education and only 8% had continued to secondary school, so that 46% had not

been to school at all. There is no bus service to the village, the road not being motorable. The Co-operative store supplied rice and a few other essential items of food, so that the villagers have to walk 6½ miles for most of their requirements. The nearest dispensary is at Hunnasgiriya and the nearest Hospital at Meda Maha Nuwara.

This village was selected for the study as it is isolated and agricultural, and its inhabitants live under very poor conditions and have had a low level of education.

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Sow and Litter Performance of Pure Bred and Cross Bred Pigs in Sri Lanka

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Abstract: The main objective of this study was to evaluate the sow and litter performance of pure and cross bred pigs maintained in the mid-country area of Sri Lanka. Pure large white, landrace and their reciprocal crosses were the breeds represented in this study. Data was collected from records of 36 sows maintained at Victoria farm from 1976 to 1980 inclusive. Pure breds had larger litter sizes at birth and at 8 weeks than the cross breds. Pure large white had the largest litter size at birth (9.92) and at 8 weeks (8.1). Also pure breds had significantly higher litter weight at birth and at 8 weeks than the cross breds. Litter weight at birth was significantly higher in the landrace (14.09 kg) than the large white (12.76 kg). However, no difference was observed on the litter weight at 8 weeks between these breeds. Weaning to oestrus interval was significantly shorter in the pure breds with large white pure recording the shortest interval (8.24 days). Analysis also reveals significant parity effects on litter weight at birth, 8 weeks and weaning to oestrus interval.

1. Introduction

In order to meet the animal protein requirements of Sri Lanka, it becomes necessary to focus our thinking into various lines of meat production. Pig industry assumes a great importance in this respect. Among the farm animals, the pig has been identified to be a very efficient converter of cereal feed into meat. This is true because a single exotic breed of sow producing 16 baconers per annum slaughtered when seven months old produced a total live weight of 3,200 lbs of pig meat.[4]

The first step towards the expansion of a pig industry in Sri Lanka was started in 1959 with the establishment of a state Pig farm at Welisara. The initial breeding stock of exotic breeds large white, landrace and Berkshires were kept on this farm for supplying breeding material for the future expansion of the industry. At present 40% of our pig population is made up of these exotic breeds and their crosses.[4] Very little information is available regarding the production parameters of these breeds. Such data is necessary to select ideal breed or breeds of pigs for future expansion programmes and to achieve high efficiency. Therefore the present study was undertaken in one of the major pig farms in Sri Lanka to evaluate the sow and litter performance of large white, landrace and their reciprocal crosses.

2. Experimental

The data for this study was obtained from the sow performance records maintained at Mahaberiatenne Farm, National Livestock Development Board, Teldeniya, Sri Lanka. The elevation in this area is about 300 M above sea level, the temperature ranges from 20-29°C, relative humidity 72% and the annual rainfall is between 1300 to 1800 mm.

The general management practices adopted in the farm are as follows:- The gilts and sows in the farm are kept indoors and maintained in the fattening pens in groups of four, before breeding and during the early stages of pregnancy. Before breeding, they are given locally mixed feed containing 16% crude protein at the rate of 5 lbs per sow/day. They are observed for signs of oestrus daily and they are bred twice during oestrus. The amount of concentrate is increased by 1 lb every month of pregnancy with a maximum of 8 lbs. One week before the expected date of farrowing, they are transferred into individual farrowing pens. Sufficient care is given at farrowing and thereafter to prevent loss of piglings. For lactating sows, a maximum of 12 lbs of feed is offered. A creep feed of crude protein content of 20-21% is gradually introduced to the piglings one week after farrowing and given ad-lib upto 2 months of age when they are weaned from the sow and transferred to the fattening unit.

Nine sows each were selected at random from Large White, Landrace, Large White x Landrace, (where Large White is the male) and Landrace x Large White (where Landrace is the male) breeds.

The sows selected were those which had at least five litters. The boar effect was neglected in the analysis. Analysis of variance was done for each of the following parameters to detect difference among breeds. The parameters studied are litter size and weight at birth, and at 8 weeks, mortality from birth to 8 weeks, weaning to oestrus interval, services per conception and litter index, which is the number of litter per year/sow.

3. Results and Discussion

The overall sow and litter characteristics of the present study compared with others' findings are given in Table 1. The differences in sow and litter performances, among the breeds studied, are shown in Table 2. The parity effects on the above parameters are illustrated in Figure 1.

TABLE 1. Sow and Litter Characteristics with Means and Standard Errors Compared with Averages from Other Sources

Sow and litter characteristics	Present Study X	SE	Fahmy & X	Bernard SE	X	Strang SE
Litter size at birth	9.42	0.38	8.60	0.12	10.90	0.13
Litter size at 8 weeks	7.62	0.32	7.09	0.12	8.81	0.11
Average litter wt. at birth (kg)	1.34	0.02	1.04	0.01	—	—
Average litter wt. at 8 weeks (kg)	10.92	0.35	13.50	0.12	16.78	0.21
Litter wt. at birth (kg)	13.07	0.48	9.40	0.13	—	—
Litter wt. at 8 weks (kg)	86.29	2.44	92.69	1.74	143.88	2.39
Mortality, (%) 0-8 weeks	18.93	0.30	17.0	0.16	18.40	0.77

TABLE 2 Sow and Litter Characteristics of Large White, Landrace and Their Reciprocal Crosses (Mean — X, Standard Error — SE)

Sow and litter Characteristics	BREED Large white (LW)		Landrace (LR)		LW x LR		LR x LW	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Litter size at birth	9.92[a]	0.22	9.82[a]	0.44	9.26[a]	0.31	9.39[a]	0.58
Litter size at 8 weeks	8.10[a]	0.18	7.72[b]	0.38	7.14[c]	0.26	7.50[c]	0.48
Litter wt. at birth (kg)	12.76[a]	0.28	14.09[b]	0.56	12.16[a]	0.39	13.28[a]	0.72
Litter wt. at 8 weeks (kg)	90.74[a]	1.39	88.77[a]	2.79	81.17[b]	1.98	84.49[b]	3.61
Mortality 0-8 weeks (absolute value)	1.41[a]	0.17	2.92[b]	0.35	1.82[b]	0.24	1.58[a]	0.45
Weaning to oestrus interval (days)	8.24[a]	2.52	19.30[a]	5.07	31.75[c]	3.57	13.77[b]	6.52
Services per conception	1.10[a]	0.03	1.18[a]	0.06	1.25[a]	0.06	1.16[a]	0.57
Litter index	1.99[a]	0.07	1.91[a]	0.07	1.89[a]	0.07	2.01[a]	0.05

The superscripts indicates differences and similarities along rows significant level $P < 0.05$

3.1 Litter size at birth and at 8 weeks.

Large white and Landrace had larger litter sizes at birth and at 8 weeks, compared to their reciprocal crosses. Large white breed had the largest litter size at birth (9.92) and at 8 weeks (8.1). Parity had significant effects on litter size at birth and at 8 weeks. Litter size at birth decreased after the third farrowing and litter size at 8 weeks decreased after the fourth farrowing. The values observed for litter size at birth and at 8 weeks in this study are in agreement with western standards.[1,2,5] The reason for the decline in litter size at birth and at 8 weeks is not clear, however many factors such as ovulation rate, fertilization rate, implantation rate and refractoriness of the ovaries to gonadotrophins could have contributed to this difference.

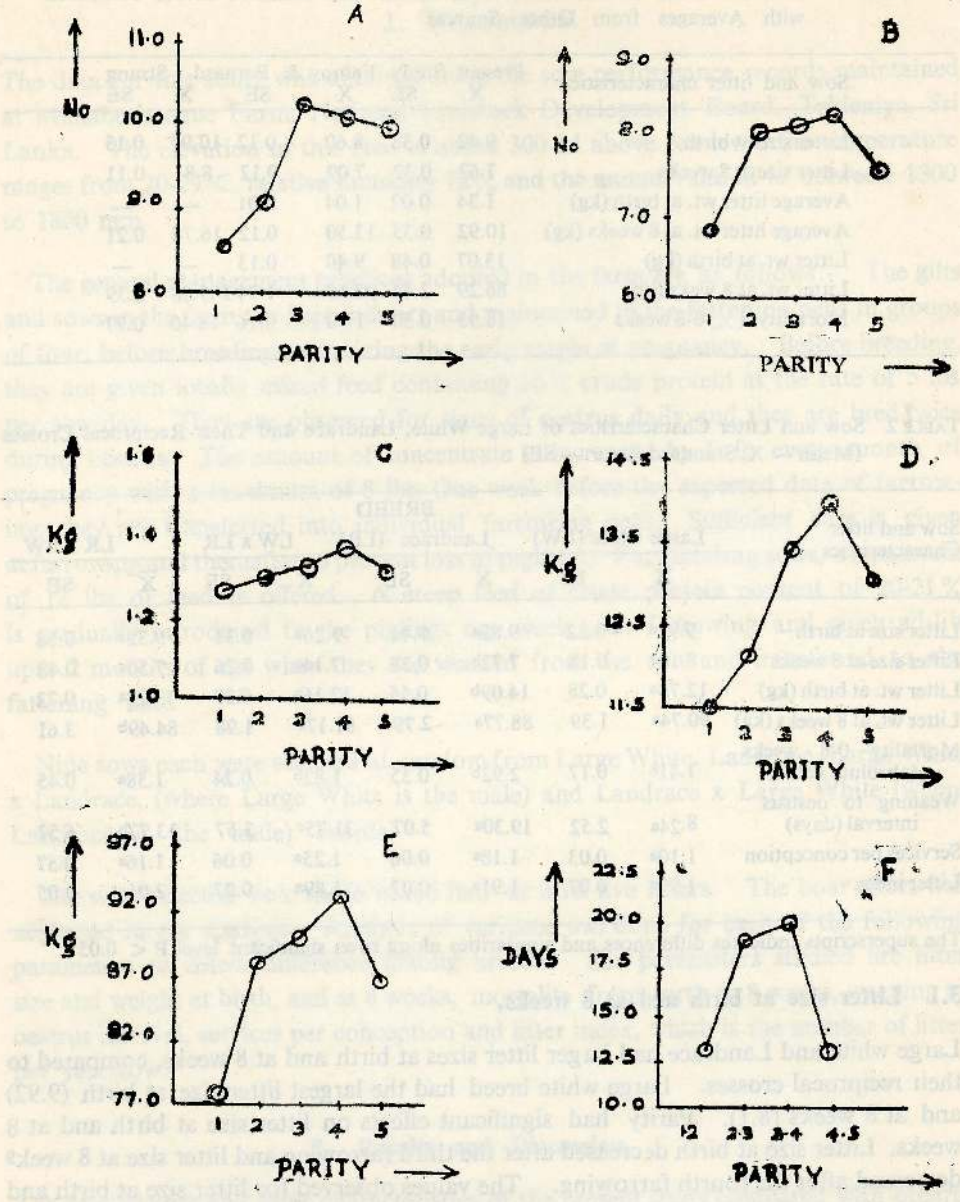

Figure 1. Effect of Parity on Litter size at birth (A), Litter size at 8 weeks (B), Average pig weight at birth (C), Litter weight at birth (D), Litter weight at 8 weeks (E), Weaning to onset of oestrus (F).

3.2 Litter weight at birth and at 8 weeks

The litter weight at birth was significantly greater in Landrace and Landrace X large white than large white and large white X Landrace cross. However the litter weight at 8 weeks was higher in large white compared to Landrace (90.74 vs 88. 77 kg). Parity had significant effect on litter weight at birth and 8 weeks. The litter weight at birth and at 8 weeks decreased after the fourth farrowing. Significant breed X parity interaction was also observed on the litter weight at 8 weeks. The average litter weight at birth of all breeds studied was greater than the values reported in the literature.[1,4] On the contrary, the weaning weight at 8 weeks was much below the values reported by above workers. The difference may be attributed to (*a*) poor quality of sow and weaner ration fed and (*b*) the effect of climate.

3.3 Piglet mortality

The mortality was highest in Landrace (2.92) and lowest in large white (1.41). The overall mortality observed was comparable to values reported by others.[1 5] This low mortality reflects the high standard of management adopted at farrowing and thereafter. It has been reported that the larger the litter size the greater the mortality. However, in the present study, large white breed had the largest litter size at birth and also the lowest mortality rate.

3.4 Weaning to oestrus interval

Pure large white breed had significantly shorter weaning to oestrus interval (8.24 days). Parity had significant effect on weaning to oestrus interval. The weaning to oestrus interval was longer upto third farrowing and decreased thereafter. The average weaning to oestrus interval observed in this study (13.77 days) was in agreement with values (15.4 to 24 days) reported in the literature.[1] It has been observed in this study as well as by others[1,4] that the interval decreases in length with the advance of parity. It is also observed in this study that 60% of the total population of sows come into oestrus within 10 days after weaning and conceived. Also around 75% of the total population had a weaning to oestrus period of 38 days.

3.5 Services per conception and litter index

Large white breed needed the least number of services (1.10) compared to others. This parameter is mainly a sow character reflecting its reproductive efficiency. Litter index was highest in Landrace breeds (2.01). However all breeds studied attained the stipulated standard for female selection (1.7). Litter index is also a prerequisite to produce a 'ton of meat on four hooves'.

4. Conclusion

The sow and litter characteristics investigated in this study are necessary technological constraints which should be overcome for profit optimisation in the swine industry. All parameters studied are comparable to western standards except the weaning weight which was well below the values reported. This can be attributed to the nutrition of the sow and piglings during the suckling period. Further, in most of the farms and in small holdings, the porker weight and baconer weights are reached much later than what was reported in the literature. Therefore in order to get a 'ton of meat' every year, from exotic sows, the nutritional problem must be looked into.

This study recommends the use of large white breed for future expansion of our pig industry. In addition to the favourable parameters observed in this study, others too have recommended this breed for future expansion.[3] The Landrace breed is not preferred by most of the pig breeders in Sri Lanka, due to their weakness on hind legs.[3] The large black and their crosses are not liked by the consumers because of seedy bacon.[3] This study also sheds some information on culling of sows for profit optimisation. According to this study, the sows productive performance decreased after the fourth farrowing. Therefore sows should be culled for meat after their fourth or fifth farrowing.

Acknowledgement

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The Effects of Nitrogen and Spacing on the Growth and Yield of Soyabean (*Glycine max.* (L) merr.) Under Coconut

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Abstract : The effects of nitrogen fertilizer application and spacing on the growth and yield of soyabean (cv. Bragg) grown as an intercrop under a mature stand of coconut in the intermediate zone of Sri Lanka during the north-east monsoonal rainy period are reported. Nitrogen had a significant effect on the seed yield and the number of pods per plant. The highest yield (447.8 kg ha^{-1}) and pod number were recorded at 33.6 kg N ha^{-1}. Nitrogen had no significant effect on plant height, nodule number, Leaf Area Index (LAI), dry matter yield, % protein and %oil in seeds, and yield components other than pod number. Closer row spacings had a significantly larger seed yield, LAI and dry matter yield than wowi der rspacings. Spacing had no significant effect on any of the other attributes studied.

1. Introduction

Soyabean with its many and varied uses is one of the most remarkable legumes, yet it is only within comparatively recent years that its real value has been fully recognised. The highly nutritious soyabean with high quality protein would prove to be the immediate answer to bridge the ever widening protein gap that exists in developing countries including Sri Lanka, due to the lack of cheap and readily available sources of protein. As a result of this tremendous potential, increased emphasis is placed on the cultivation of soyabeans.

In a coconut plantation planted at a spacing of 7.8 m x 7.8 m on the square system, during the juvenile stage and later under mature stands of over 30 years, sufficient light reaches ground level for satisfactory growth of an intercrop.[6] In such a palm-intercrop association there would be competition for soil moisture and nutrients if both or any one of them is in supply below the combined demand of the two crops.[6] Competition for plant nutrients can be minimised or avoided by independent application of fertilizer to both palm and intercrop, and competition for soil moisture between the palms and intercrops can be minimised or avoided by selecting the intercrops according to the rainfall pattern of the locality. On this basis, soyabean being a 3-4 month's crop is one of the most suitable crops that could be grown as an intercrop under coconut in the intermediate and dry zones of Sri Lanka during monsoonal rainy periods.

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Though there is ample information on the culture of soyabean as a monocrop[2,3,4,8] the same when it is grown in association with coconut is lacking. The general agronomic practices recommended for soyabean as a monocrop will not necessarily apply when it is grown as an intercrop. Nitrogen fertilization and spacing (plant density) are two important agronomic factors in the successful establishment of soyabean as an intercrop under coconut. This paper reports an investigation into the effects of varying the levels of nitrogen fertilizer application as well as spacing on the growth and yield of soyabean (*Glycine max* (L) Merr., cv. Bragg), grown as an intercrop under coconut during the North East monsoonal rainy period in the intermediate zone of Sri Lanka.

2. Materials and Methods

The experiment was conducted during the 1973/74 Maha season at Ratmalagara Estate, Madampe, N.W.P., under a mature stand of coconut (*Cocos nucifera* L. var. *typica*) of about 50 years old, planted on the square system of planting with a spacing of 9.0 m x 9.0 m. The experimental area had a very uniform soil which was a sandy clay loam with a dark grey brown top soil and a yellowish brown sub-soil with ironstone gravel and manganese nodules (A.S. Amarasinghe, personnal communication). It had a pH of 5.5 and 1105 ppm of total N. The weekly rainfall at the experimental site during the experimental period are summarised in Table 1.

TABLE 1. Weekly rainfall (cm) at the experimental site during the experimental period.

Period	Total Rainfall (cm)	Period	Total Rainfall (cm)
1 Nov. '73 — 7 Nov. '73	14.2	20 Dec. '73 — 26 Dec. '73	7.4
8 Nov. '73 — 14 Nov. '73	0.3	27 Dec. '73 — 2 Jan. '74	5.8
15 Nov. '73 — 21 Nov. '73	2.2	3 Jan. '74 — 9 Jan. '74	0
22 Nov. '73 — 28 Nov. '73	4.1	10 Jan. '74 — 16 Jan. '74	0
29 Nov. '73 — 5 Dec. '73	3.0	17 Jan. '74 — 23 Jan. '74	0
6 Dec. '73 — 12 Dec. '73	0.3	24 Jan. '74 — 30 Jan. '74	0
13 Dec. '73 — 19 Dec. '73	9.7		

The experimental design was a split plot with 3 replicates. The main treatments were 5 nitrogen levels, 0, 11.2, 22.4, 33.6 and 44.8 kg ha^{-1}. Each main plot was 36 m x 9 m with a guard row of 3 m. Spacings of 37.5 x 7.5, 45.0 x 7.5, 52.5 x 7.5 and 60.0 x 7.5 cm formed the subtreatments, each subplot was 9 m x 9 m, i.e. one coconut square. A basal dressing of 67.3 kg ha^{-1} of P_2O_5 and 44.8 kg ha^{-6} of K_2O in the form of concentrated super phosphate and muriate of potash respectively, were applied to each sub-plot on 2 November 1973. The seeds of soyabean (cv. Bragg) were innoculated with Nitrigin 'S' and planted in rows at a uniform within-row spacing of 7.5 cm with 2 seeds per hill on 3 November 1973. An area of 2 m radius from the base of

each palm was left unplanted. The stand was thinned to one plant per hill on 10 November 1973. Nitrogen was applied in the form of ammonium sulphate, half the total dose on 2 December 1973 and the other half on 2 January 1974. Prophylactic sprays of Malathion 50% at the rate of 25 ml in 4.5 litres of water were given at fortnightly intervals from 2 weeks after sowing. All plots were manually weeded on 24 November and 15 December 1973. 2.27 kg of C.R.I. 'C' fertilizer mixture (containing 5 parts by weight of ammonium sulphate (20.5% N), 2 parts by weight of saphos phosphate (12.0% P), and 3 parts by weight of muriate of potash (49.8% K) was broadcasted in the manure circle 1.65 m around the base of each palm and forked in[1] in late October before the commencement of the experiment.

The sampling procedure adopted was as follows. Each sub-plot of 9 m x 9 m was divided into two plots, each of 4.5 m x 9 m. One of them formed the sampling plot and the other the harvest plot. Ten plants were selected at random along the diagonals of each sampling plot. They were tagged and their heights were measured at 2, 4, 6 and 8 weeks after planting. On the same dates and at 10 weeks after planting ten more plants were selected at random along the diagonals of the sampling plot, they were uprooted and washed carefully, and observations on the number of root nodules were made. Leaf laminae of these plants were separated and the Leaf Area Index (LAI) was measured using the disc method[7]. The dry weight of tops were recorded after drying at 85°C in a ventilated dehydrator for over 36 hours. At crop maturity on 27 January 1974, from each harvest plot, 10 plants were selected at random along the diagonals and observations on number of podding nodes per plant, pods per plant and seeds per pod were made. The yield per harvest plot and weight of 100 seeds were also recorded. Percent crude protein and percent oil of the seed samples were determined using Kjeldhal method and Soxhlet method respectively.

3. Results

3.1 Seed yield and its components

Nitrogen had a significant effect on the seed yield ($P < 0.05$) (Table 2a). The highest yield of 447.8 kg ha^{-1} was recorded at 33.6 kg N ha^{-1} which was significantly superior to the yield at all the other nitrogen levels which were themselves not significantly different. Of the yield components, only the number of pods per plant was significantly affected by nitrogen application (Table 2a). The highest pod number per plant of 23 was again recorded at 33.6 kg N ha^{-1} which was significantly greater than that at no nitrogen and 11.2 kg N ha^{-1} ($P < 0.05$).

Seed yield dropped significantly from closer spacing of 37.5 cm (428.3 kg ha^{-1}) and 45 cm (426.2 kg ha^{-1}) between rows to wider spacing of 60.0 cm (328.7kg ha^{-1}) between rows ($P - 0.05$) (Table 2b). Spacing had no significant effect on yield components (Table 2b).

TABLE 2. The effect of (a) nitrogen application and (b) spacing on the ha^{-1}) and seed yield (kg its components of soyabean under coconut.

(*a*) Nitrogen (kg ha^{-1})	Seed yield (kg ha^{-1})	Number of podding nodes/plant	Number of Pods/plant	Number of seeds/pod	100 seed weight(g)
nil	381.1	7.1	17.4	1.9	13.4
11.2	384.5	7.4	17.7	1.9	14.0
22.4	380.0	7.5	18.9	1.9	13.1
33.6	447.8	7.7	22.7	1.9	13.8
44.8	368.0	7.6	20.8	1.9	13.4
LSD(P = 0.05)	49.9	NS	4.1	NS	NS
(*b*) Spacing/Plant density (cm) (plants m^{-2})					
37.5x7.5/35.6	428.3	7.4	18.0	1.9	13.5
45.0x7.5/29.6	426.2	7.4	19.2	1.9	13.8
42.5x7.5/25.4	385.9	7.5	20.9	1.9	13.4
60.0x7.5/22.2	328.7	7.5	20.0	1.9	13.4
LSD P = 0.05)	84.6	NS	NS	NS	NS

Nitrogen x spacing interaction had no significant effect on either the seed yield or its components.

3.2 Composition of seed

Different nitrogen levels and different spacings and their interactions had no significant effect on the % crude protein and % oil of the seeds.

3.3. Nodulation

Neither nitrogen nor spacing had any significant effect on changing the nodule number of plants. The results showed considerable irregularity in the nodule counts obtained at different nitrogen levels.

3.4. Dry matter yield

Nitrogen had no significant effect on the dry matter yield at any stage. Dry matter yield generally increased with increase in nitrogen level up to 33.6 kg ha^{-1} and then decreased (Table 3a).

Spacing had a significant effect on the dry matter yield at all harvests decreasing linearly as the spacing between rows increased i.e. as the plant density decreased (Table 3b). There were no significant nitrogen x spacing interaction at any harvest.

TABLE 3. The effects of (a) nitrogen application and (b) spacing on the dry matter yield (gm^{-2}) of soyabean under coconut.

(a) Nitrogen (kg ha^{-1})	Weeks after sowing				
	2(17/11/73)	4(1/12/73)	6(15/12/73	8(29/12/73)	10(12/1/74)
nil	6.3	24.0	89.9	156.8	227.7
11.2	5.7	23.3	87.4	147.1	193.4
22.4	6.5	31.3	99.3	192.3	170.1
33.6	7.2	30.8	123.8	188.3	184.0
44.8	6.2	27.1	108.9	196.9	243.4
LSD (P = 0.05)	NS	NS	NS	NS	NS
(*b*) Spacing/Plant density (cm) (plants m^{-2})					
37.5x7.5/35.6	8.1	32.6	128.2	204.4	255.8
45.0x7.5/29.6	6.5	30.3	14.8	192.9	214.4
52.5x7.5/25.4	5.8	25.5	89.8	156.5	184.6
60.0x7.5/22.2	5.1	21.6	74.5	151.2	160.1
LSD(P =0.05)	0.5	3.2	21.6	43.6	51.2

3.5. Leaf Area Index (LAI)

Nitrogen had no significant effect on the LAI at any stage of the experiment (Table 4a). At all nitrogen levels the maximum LAI was achieved at 6 weeks after planting. The highest LAI of 2.64 was recorded at 33.6 kg N ha^{-1}.

Spacing had a significant effect on the LAI at all harvests. The LAI increased significantly as the spacing between rows decreased, i.e. as the plant density increased (Table 4b). The highest LAI of 3.05 was recorded at the closest row spacing of 37.5 cm at 6 weeks after sowing. The interaction of nitrogen x spacing was significant at 6 weeks after sowing ($P < 0.05$), but no distinct trends were evident.

TABLE 4. The effects of (a) nitrogen application and (b) spacing on the Leaf Area Index of soyabean under coconut.

(a) Nitrogen (kg ha^{-1})	Weeks after sowing				
	2(17/11/73)	4(1/12/73)	6(15/12/73)	8(29/12///73)	10(12/1/74)
nil	0.15	0.75	2.7	1.92	0.94
11.2	0.12	0.69	2.26	1.95	1.03
22.4	0.17	0.88	2.18	2.04	0.75
33.6	0.21	0.87	2.64	2.01	0.71
44.8	0.14	0.89	2.55	2.20	0.88
LSD(P =0.05)	NS	NS	NS	NS	NS
(b) Spacing/Plant density (cm) (plants m_{-2})					
37.5x7.5/35.6	0.20	0.99	3.05	2.59	1.12
45.0x7.5/29.6	0.17	0.96	2.54	2.17	0.95
52.5x7.5/25.4	0.14	0.70	2.08	1.90	0.75
60.0x7.5/22.2	0.11	0.61	1.69	1.52	0.63
LSD(P =0.05)	0.04	0.19	0.37	0.38	0.35

3.6. Plant height

Nitrogen had no significant effect on plant height at the first and second harvests. Plant height increased significantly up to 22.4 kg N ha^{-1} and then decreased, at 6 weeks ($P < 0.001$) and at 8 weeks ($P < 0.01$) after sowing (Table 5a).

Spacing had no significant effect on plant height at the first two harvests. However, closely spaced plants were taller than widely spaced ones at 6 weeks and 8 weeks after sowing ($P<0.05$) (Table 5b).

TABLE 5. The effects of (a) nitrogen application and (b) spacing on the plant height (cm) of soyabean under coconut.

(a) Nitrogen (kg ha^{-1})	Weeks after sowing			
	2(17/11/73)	4(1/12/73)	6(15/12/73)	8(29/12/73)
nil	10.4	19.7	31.8	32.6
11.2	9.9	19.6	33.1	33.7
22.4	11.3	22.5	35.5	37.4
33.6	11.2	23.4	33.7	34.6
44.8	9.6	1ơ7	32.4	33.2
LSD(P =0.05)	NS	NS	1.2	1.9
(b) Spacing/Plant density (cm) (plants m_{-2})				
37.5x7.5/35.6	10.7	21.8	34.6	35.1
45.0x7.5/29.6	10.5	21.0	34.1	35.2
52.5x7.5/25.4	10.2	20.4	32.4	32.4
60.0x7.5/22.2	10.6	20.6	32.0	32.5
LSD(P =0.05)	NS	NS	2.0	2.1

4. Discussion

4.1. Seed yield

Nitrogen applied at the rate of 11.2, 22.4 and 44.8 kg ha^{-1} did not have any significant influence on the seed yield, when compared with no-nitrogen plots. Only at 33.6 kg ha^{-1} was there a significant increase in seed yield. The failure of response of nitrogen addition up to 22.4 kg ha^{-1} in this study may have been due to the high soil nitrogen status (1105 ppm) and to the considerable amount of nitrogen supplied to the plants through the fixation process though the amount of nitrogen fixed was not measured. In this study there was considerable irregularity in nodule counts and as a result nitrogen had no significant effect on nodule number. Since nodule mass was found to be a better estimate of nodulation than nodule number,[2] and no nodule weights were taken in this study, nodule count alone does not possibly represent all

the effects of nitrogen on nodulation and nitrogen fixation. The failure of response to high nitrogen levels of 44.8 kg ha^{-1} may probably have been due to the poor distribution of dry matter to the reproductive parts which was reflected in the drop in the harvest index from 24% at 33.6 kg N ha^{-1} to 15% at 44.8 kg N ha^{-1}. The inability of inoculated soyabean to respond to high levels of nitrogen application has been reported by several workers.[2,3,8]

Significantly greater seed yields were obtained at the closer row spacings of 37.5 cm and 45.0 cm than at the wider row spacing of 60.0 cm (Table 2a). Lueschen and Hicks[5] found that increasing plant density in the range of 17.1 to 51.3 plants m^{-2} had little effect on seed yield. The most common result reported by other authors[4,5] was that the yield components changed as a response to increasing density. In this study the fact that the yield components have not been affected by spacing i.e. plant density (Table 2a) indicates that the lower yields in wider spacings could be mainly attributed to the lower plant population and higher populations will have to be examined before an optimum could be arrived at.

4.2. Growth attributes

The maximum height was attained at 22.4 kg ha^{-1}, and the gradual decrease in height at higher nitrogen levels may have been due to the tendency of the plants to lodge in these treatments. The increase in plant height with decrease in spacing could be attributed to the tendency of soyabean plants to grow in search of limited sunlight under the shade of coconut.

High dry matter production and LAI were influenced mainly by spacing. Absence of response to LAI and dry matter yield to nitrogen application again indicates the nitrogen fixation by inoculated soyabeans at low levels of nitrogen and the failure of inoculated soyabean to respond to high levels of nitrogen application.

4.3. Suitability of soyabean as an intercrop for the intermediate zone

The mean yield of 392.3 kg ha^{-1} is fairly low compared to the yields of over 1000 kg ha^{-1} obtained from monocropped soyabean in other parts of Sri Lanka[2] (H. M. E. Herath, personnal communication). The lower yields realised in this experiment could be attributed to the severe moisture stress the crop experienced due to the lack of rainfall during the period of pod filling in early January (Table 1), aggravated by competition for the limited soil moisture available from the coconut roots, leading to a dropping of a large number of pods formed.

Short aged varieties of soyabean such as Bragg, mature in 3 months and as such could fit into the monsoonal rainy period in the intermediate zone of Sri Lanka if planted with the onset of rains.

However further experiments are needed on the time of sowing of soyabean in relation to the onset of monsoonal rains so as to coincide the pod filling stage with the tail end of the monsoons in order to minimise or avoid competition for soil moisture between the palms and the intercrop during this period and thus obtain high yields of soyabean under coconut.

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Observations on the Mosquitoes (*Diptera: Culicidae*) of Udawattakele Forest, Sri Lanka

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Abstract: Thirty-six species of mosquitoes were recorded during a field study at the Udawattakele Forest Reserve, Kandy, Sri Lanka. Immatures of 17 species were collected from breeding sites (bamboo stumps, kitul-palm stumps, tree holes, temporary ground pools), the highest occurrences being for *Culex* (*Lophoceraomyia*) *uniformis* (Theobald), *Aedes* (*Stegomyia*) *krombeini* Huang, *Aedes* (*Stegomyia*) *albopictus* (Skuse) and *Toxorhynchites* (*Toxorhynchites*) *splendens* (Wiedemann) from the natural container habitats, and *Aedes* (*Verrallina*) *pseudomediofasciatus* (Theobald) and *Anopheles* (*Cellia*) *elegans* (James) from ground pools. Sixty-four types of single and multi-species occurrences were recorded from breeding sites. A positive interspecific association was shown between *Ae. albopictus* and *Ae. krombeini*, and a negative association between *Ae. albopictus* and *Tx. splendens*, in the bamboo stump habitat. Twenty-one species were taken at day-time human bait catches, the most prevalent being *Ae. albopictus* and *Armigeres* (*Armigeres*) *subalbatus* (Coquillett), for which a preliminary interpretation of the biting activity levels within the forest is given. *Aedes krombeini*, a recently described member of the medically important *scutellaris* group of *Aedes* (*Stegomyia*), though breeding commonly in the area, was only rarely attracted to the human bait.

1. Introduction

One hundred and thirty one species of mosquitoes in 16 genera are known from Sri Lanka.[14] There is, however, a dearth of information relating to the biology of the majority of these species in Sri Lanka, with much of the attention, of necessity, being focussed upon those mosquitoes that are of direct medical importance. Published information relating to the Sri Lankan Culicidae, in general, are contained in works such as Barraud[1], Carter,[2,3,4] Carter and Wijesundera[5], Chow *et al*[6], Christophers[7] James,[12,13] Senior-White,[20,21] and Wijesundara.[28] More recent contributions include the publications of workers attached to the Southeast Asia Mosquito Project (SEAMP) and Medical Entomology Project (MEP) of the Smithsonian Institution, and deal mainly with bio-taxonomic aspects of the mosquito fauna of the Oriental and S-E Asian regions, including Sri Lanka.

The present paper presents some ecological observations on mosquitoes occurring in the Udawattakele Forest Reserve, Kandy, in the Central Province of Sri Lanka. Surrounded by urban areas, this small patch of isolated forest harbours many species of sylvan and peridomestic mosquitoes, which have not hitherto been studied systematically. This investigation focussed on the breeding biology and diurnal man-biting activity of these mosquitoes, aspects that are of particular interest in view of the large human population in immediate proximity to the forest, and its popularity as a human recreational area.

2. The Study Area

Approximately 254 acres (101.6 ha) in extent, Udawattakele Forest is situated on undulating terrain at an elevation of 600m above mean sea level, within the municipal limits of the town of Kandy, Central Province, Sri Lanka (latitude 7° N, longitude 81°E). The habitat is best described as a degraded secondary forest, with remnant forest flora such as *Mangifera zeylanica* (Bl.) Hook.F., *Canarium zeylanicum* (Retz.) Bl., *Diospyros sylvatica* Roxb., *Pterocarpus indicus* Willd., *Michelia champaca* L., *Artocarpus nobilis* Thw., *Myristica dactyloides* Gaertn., and *Pterospermum canescens* Roxb. A total of 46 acres (18.4 ha) was planted with species such as *Filicium decipiens* (Wight & Arn.), *Artocarpus heterophylla* Lam., *Pericopsis mooniana* (Thw.), *Mesua nagassarium* (Burm.f.) Kosterm,. *Michelia champaca* L., *Sweitenia macrophylla* King, *Alstonia macrophylla* Wall, and *Chukrasia tabularis* A. Juss, during 1922—1936, and these species now contribute significantly to the forest canopy.

The mean annual temperature of the area is 24.5°C and mean annual rainfall 2131 ± 30 mm. However, rainfall records at the Central Agricultural Research Institute, Gannoruwa (approximately 8km from the forest) show that during the 15 month period of the present study (February 1980 to April 1981 inclusive), the total precipitation was only 1849.80 mm, with rain occurring on 174 days. Low rainfall (<100mm /month) occurred in February-March, September and December 1980, and January-February 1981. All other months received more than 100mm rain, the highest values being for November 1980 (333.4mm) and April 1980/81 (209.1 and 205.1mm respectively). These data are of relevance since rainfall is one of the major factors affecting the availability of mosquito breeding sites in the forest, and thus their density and species composition.

3. Materials And Methods

Field collections at Udawattakele Forest were carried out during February 1980 to April 1981. Monthly collections of mosquito immatures were made in a survey area of approximately 25 acres (10 ha). The main breeding habitats studied were stumps of the giant bamboo (*Dendrocalamus giganteus* Munro), stumps of the kitul palm (*Caryota urens* L.), tree holes below a height of 5m from ground level (the limitation being one of accessibility), and small temporary ground pools. The borders of a large natural pond situated in the survey area, as well as crab holes along a stream leading to it were also investigated. Approximately 400 ml of water was pippetted from each potential breeding site, after suitable agitation to break up any localised aggregations of mosquito immatures. In a few instances where less than this volume of water was available, the entire quantity was taken. The pH of the water was measured on collection, using BDH pH paper. The larvae (3rd and 4th instar) and pupae in each sample were counted and reared to the adult, usually in individual tubes.

Diurnal man-biting mosquitoes were collected by means of 15mt stationary two-man landing-biting catches at points situated 100m apart along the footpaths within the forest, under conditions of partial to dense shade at ground level. All mosquitoes landing /biting on the exposed face, arms and legs of the seated baits were collected in individual numbered tubes. One hundred and eighty such 15mt catches were done, arranged so as to total 20 catches for each hour between 0900 and 1800 hours.

The species identifications (based on adult habitus and terminalia features, and immatures where obtained) were made with reference to the descriptions and keys contained in the series of publications by taxonomists at SEAMP and MEP (Smithsonian Institution), and other relevant works[1,5,7,17,28]. Reference collections of adults have been deposited in the Entomology Division, Department of National Museums, Sri Lanka, and the British Museum (Natural History).

4. Results

4.1 Species List

A full list of the 36 species of mosquitoes collected during the study is given below, with the genera arranged according to the systematic sequence in Stone *et al*[27]. Generic and subgeneric abbreviations used later in the text follow Reinert[19]. The method of collection of each species is also indicated, i.e. immature collections from breeding sites (Br), adults from bait catches (Ba) and random hand-net catches (N):

Anopheles (*Anopheles*) *peditaeniatus* (Leicester) 1908.....Ba
Anopheles (*Anopheles*) *aitkenii* group, Reid & Knight 1961.....Ba/N
Anopheles (*Cellia*) *elegans* (James) 1903 .....Br
Toxorhynchites (*Toxorhynchites*) *splendens* (Wiedemann) 1819 .....Br
Tripteroides (*Tripteroides*) *affinis* (Edwards) 1913 .....Br/N
Tripteroides (*Rachionotomyia*) *aranoides* (Theobald) 1901.....Br
Orthopodomyia anopheloides (Giles) 1903.....Br
Heizmannia (*Heizmannia*) *greeni* (Theobald) 1905.....Br/Ba
Heizmannia sp. .....Ba
Aedes (*Finlaya*) *aureostriatus* (Doleschall) 1857.....Br/Ba/N
Aedes (*Finlaya*) *gubernatoris* (Giles) 1901.....Ba
Aedes (*Finlaya*) *pseudotaeniatus* (Giles) 1901.....Ba
Aedes (*Finlaya*) sp. (*niveus* subgroup).....Br
Aedes (*Christophersiomyia*) *annulirostris* (Theobald) 1905 .....Ba
Aedes (*Stegomyia*) *aegypti* (Linnaeus) 1762 .....Ba/N
Aedes (*Stegomyia*) *albopictus* (Skuse) 1894 .....Br/Ba/N
Aedes (*Stegomyia*) *novalbopictus* Barraud 1931 .....Ba/N
Aedes (*Stegomyia*) *krombeini* Huang 1975 .....Br/Ba
Aedes (*Stegomyia*) *mediopunctatus* (Theobald) 1905 ..... Br/Ba

Aedes (*Stegomyia*) *w-albus* (Theobald) 1905 ..... Ba
Aedes (*Aedimorphus*) *jamesi* (Edwards) 1914 ..... Ba
Aedes (*Aedimorphus*) *vittatus* (Bigot) 1861 ..... Ba
Aedes (*Paraedes*) *chrysoscuto* (Theobald), ref. Reinert 1981 ..... Ba/N
Aedes (*Verrallina*) *pseudomediofasciatus* (Theobald) 1910 ..... Br/Ba
Armigeres (*Armigeres*) *subalbatus* (Coquillett) 1898 ..... Br/Ba/N
Culex (*Lutzia*) *fuscanus* Wiedemann 1820 ..... N
Culex (*Eumelanomyia*) *brevipalpis* (Giles) 1902 ..... Br
Culex (*Lophoceraomyia*) *uniformis* (Theobald) 1905 ..... Br/N
Culex (*Lophoceraomyia*) *lasiopalpis* Sirivanakarn 1977 ..... N
Culex (*Lophoceraomyia*) *wardi* Sirivanakarn 1977 ..... N
Culex (*Culiciomyia*) *nigropunctatus* Edwards 1926 ..... N
Culex (*Culiciomyia*) *pallidothorax* Theobald 1905 ..... N
Culex (*Culex*) *fuscocephala* Theobald 1907 ..... Br/N
Culex (*Culex*) *mimulus* Edwards 1915 ..... Br
Culex (*Culex*) *sitiens* group & subgroup, Edwards 1932 ..... Ba
Culex (*Culex*) *pseudovishnui* Colless 1957 ..... Ba/N

The specific status of bait-caught females of the *An. aitkenii* group is uncertain, since valid species identifications cannot be made on the characters of this sex alone.[17] However, a single net-caught male displayed terminalia characters similar to the species *aitkenii* (James) 1903, as described by Reid[17], and it is possible that the females too, may belong to this species.

Males of the *Aedes* (*Finlaya*) species of the *niveus* subgroup are close to *Ae. niveoides* Barraud 1934, but this identification cannot be confirmed at present. Two females of a species of *Heizmannia* taken at bait are clearly distinct in habitus and terminalia from *Hz. greeni*, the only known representative of this genus in Sri Lanka, and does not appear to belong to any of the species recognised from the Oriental and S-E Asian regions. The status of this species, as well as the occurrence of *Ae. w-albus* and *Ae. novalbopictus* in Sri Lanka will be discussed in future papers.

4.2 Survey of Breeding Habitats

(a) Species Occurrences

A total of 189 samples were taken from the 4 main breeding habitats surveyed, of which 145 (76.6%) were positive for immatures of the Culicidae. Bamboo and Kitul-palm stumps appear to be the most heavily utilized, with 84.4% (97/115) of the former and 82.6% (19/23) of the latter containing immatures. The corresponding figures for tree holes and ground pools are 60% (12/20) and 54.8% (17/31) respectively. No mosquito immatures were collected from the borders of the pond situated in the area, while 10 samples from crab holes yielded 1 positive collection containing immatures of *Cx. uniformis*.

Numerical data on the species occurring in the 4 main breeding habitats studied are presented in Table 1. *Culex uniformis* and *Ae. krombeini* appear to be the most abundant of the container-breeding species, while *Ae. pseudomediofasciatus* predominates in the ground pool habitat. *Aedes albopictus*, though almost as frequent in occurrence as *Ae. krombeini*, occurs, in much smaller numbers per sample, and may be less abundant than *krombeini* in this habitat. Among species encountered less frequently, *Tp. affinis* and *Ar. subalbatus* were noteworthy in being relatively more numerous in positive samples than the other natural container breeders.

TABLE 1. Species occurrences at Breeding Habitats

(*Note: Figures in parenthesis refer to actual numbers of immatures*)

Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	All Habitats
Number of Samples	115	23	20	31	189
Number + ve for Culicidae	97	19	12	17	145
1. *Cx. uniformis*					
Number of + ve Samples	39	10	8	2	59
Mean Immatures/+ ve Sample	6.4	9.10	13.50	3.00	7.73
Median ,, ,,	44	7	13	—	5
Range ,, ,,	1-47	1-21	1-30	—	1-47
2. *Ae. krombeini*					
Number of + ve Samples	30	3	7	1	41
Mean Immatures/+ ve Sample	13.37	7.67	3.00	(2)	10.90
Median ,, ,,	4	10	1	—	3
Range ,, ,,	1-111	1-12	1-8	—	1-111
3. *Ae. albopictus*					
Number of + ve Samples	31	4	3	—	38
Mean Immatures/+ ve Sample	4.61	2.25	2.67	—	4.21
Median ,, ,,	2	1	2	—	2
Range ,, ,,	1-31	1-6	2-4	—	1-31
4. *Tx. splendens*					
Number of + ve Sample	32	3	—	—	35
Mean Immatures/+ ve Sample	1.19	1.33	—	—	1.20
Median ,, ,,	1	1	—	—	1
Range ,, ,,	1-4	1-2	—	—	1-4

Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	All Habitats
5. *Ae. aureostriatus*					
Number of + ve Samples	13	12	2	—	27
Mean Immatures/+ ve Sample	2.77	2.25	1.5	—	2.44
Median ,, ,,	2	2	—	—	2
Range ,, ,,	1-11	1-6	—	—	1-11
6. *Ae. pseudomediofasciatus*					
Number of + ve Samples	2	1	—	12	15
Mean Immatures/+ ve Sample	5.00	(1)	—	16.25	13.73
Median ,, ,,	—	—	—	10	7
Range ,, ,,	—	—	—	1-65	1-65
7. *Tp. aranoides*					
Number of + ve Samples	14	—	—	—	14
Mean Immatures/+ ve Sample	11.86	—	—	—	11.86
Median ,, ,,	3	—	—	—	3
Range ,, ,,	1-68	—	—	—	1-68
8. *An. elegans*					
Number of + ve Samples	—	—	—	10	10
Mean Immatures/+ ve Sample	—	—	—	7.10	7.10
Median ,, ,,	—	—	—	6	6
Range ,, ,,	—	—	—	1-16	1-16
9. *Ae.* (*Fin.*) *sp.*					
Number of + ve Samples	2	4	2	—	8
Mean Immatures/+ ve Sample	2.00	2.00	2.00	—	2.00
Median ,, ,,	—	2	—	—	2
Range ,, ,,	—	1-3	—	—	1-3
10. *Tp. affinis*					
Number of + ve Samples	6	1	1	—	8
Mean Immatures/+ ve Sample	14.67	(9)	(3)	—	12.50
Median ,, ,,	10	—	—	—	9
Range ,, ,,	7-38	—	—	—	3-38
11. *Ar. subalbatus*					
Number of + ve Samples	6	—	—	1	7
Mean Immatures/+ ve Sample	22.67	—	—	(5)	20.14
Median ,, ,,	10	—	—	—	10
Range ,, ,,	2-66	—	—	—	2-66

Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	All Habitats
12. *Hz. greeni*					
Number of + ve Samples	6	—	—	—	6
Mean Immatures/+ ve Sample	1.83	—	—	—	1.83
Median " "	2	—	—	—	2
Range " "	1-3	—	—	—	1-3
13. *Cx. fuscocephala*					
Number of + ve Samples	—	—	—	3	3
Mean Immatures/+ ve Sample	—	—	—	4.67	4.67
Median " "	—	—	—	5	5
Range " "	—	—	—	3-6	3-6
14. *Cx. mimulus*					
Number of + ve Samples	—	—	—	3	3
Mean Immatures/+ ve Sample	—	—	—	1.33	1.33
Median " "	—	—	—	1	1
Range " "	—	—	—	1-2	1-2
15. *Cx. brevipalpis*					
Number of + ve Samples	3	—	—	—	3
Mean Immature/+ ve Sample	3.00	—	—	—	3.00
Median " "	1	—	—	—	1
Range " "	1-7	—	—	—	1-7
16. *Or. anapheloides*					
Number of + ve Samples	2	—	—	—	2
Number of Immatures	(6)	—	—	—	(6)
17. *Ae. mediopunctatus*					
Number of + ve Samples	1	—	—	—	1
Number of Immatures	(5)	—	—	—	(5)

The predatory larvae of *Tx. splendens* occurred mainly in bamboo stumps, and in the majority of samples only one immature was present. Larvae of *Toxorhynchites* are well known to prey heavily on other culicid immatures, and the data from the 97 mosquito positive bamboo stump samples presents an interesting comparison: in the 32 samples containing larvae of *Tx. splendens* the mean number of other culicid immatures per sample was 3.9 (124/32), while in the 65 samples without the predator, the mean was 17.8 (1157/65). The two means are significantly different, with $t = 2.64$, $n = 95$ and $p < 0.01$, and are a probable indication of the predatory activities of this species.

Table 1 also shows the immature habitat preferences of the more frequently occurring species, with *Ae. pseudomediofasciatus* and *An. elegans* being predominantly ground breeders, and *Cx. uniformis*, *Ae. krombeini*, *Ae. albopictus*, *Tx. splendens*, *Ae. aureostriatus*, and *Tp. aranoides* mainly inhabiting natural containers. Only *Cx. uniformis* and *Ae. krombeini* were collected from all four habitats, though both seem to be predominantly container breeders.

(b) Species Associations

Sixty four types of single and multi-species occurrences were recorded, and these are set out in Table 2. Of the 145 samples positive for culicids, 65 (45%) contained single species, 43 (30%) contained two species, 23 (16%) contained three species, and 14 (9%) contained four or more species associated. The last category consisted of 11 four-species, 2 five-species and 1 six-species associations (Table 2).

TABLE 2. Species Composition at Breeding Habitats
(The figures indicate numbers of occurrence)

Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	Total
Number of Samples	115	23	20	31	189
Number Positive for Culicidae	97	19	12	17	145
(a) Single Species					
1. *Ae. albopictus*	07	—	—	—	07
2. *Ae. krombeini*	04	—	01	—	05
3. *Ae. aureostriatus*	01	03	—	—	04
4. *Ae. pseudomediofasciatus*	—	—	—	06	06
5. *Hz. greeni*	01	—	—	—	01
6. *Tp. affinis*	—	01	—	—	01
7. *Tp. aranoides*	01	—	—	—	01
8. *Ar. subalbatus*	02	—	—	—	02
9. *Tx. splendens*	16	—	—	—	16
10. *An. elegans*	—	—	—	02	02
11. *Cx. uniformis*	11	04	04	—	19
12. *Or. anopheloides*	01	—	—	—	01
Total by Habitat	44	08	05	08	65

	Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	Total
	(b) Two Species Associated					
13.	*Ae. albopictus* + *Ae. krombeini*	07	—	01	—	08
14.	*Ae. albopictus* + *Tx. splendens*	01	—	—	—	01
15.	*Ae. albopictus* + *Cx. uniformis*	02	—	—	—	02
16.	*Ae. krombeini* + *Ae. aureostriatus*	01	—	—	—	01
17.	*Ae. krombeini* + *Ae.* (*Fin.*) *sp.*	—	—	01	—	01
18.	*Ae. krombeini* + *Cx. uniformis*	02	01	—	—	03
19.	*Ae. aureostriatus* + *Ae.* (*Fin.*) sp.	01	—	—	—	01
20.	*Ae. aureostriatus* + *Tp. affinis*	01	—	—	—	01
21.	*Ae. aureostriatus* + *Tp. aranoides*	03	—	—	—	03
22.	*Ae. aureostriatus* + *Tx. splendens*	—	01	—	—	01
23.	*Ae. aureostriatus* + *Cx. uniformis*	02	03	01	—	06
24.	*Ae. aureostriatus* + *Cx. brevipalpis*	01	—	—	—	01
25.	*Ae. pseudomediofasciatus* + *Tx. splendens*	01	—	—	—	01
26.	*Ae. pseudomediofasciatus* + *An. elegans*	—	—	—	01	01
27.	*Ae. pseudomediofasciatus* + *Cx. uniformis*	—	—	—	01	01
28.	*Ae.* (*Fin.*)sp. + *Tx. splendens*	01	—	—	—	01
29.	*Hz. greeni* + *Tp. aranoides*	01	—	—	—	01
30.	*Tp. affinis* + *Tp. aranoides*	01	—	—	—	01
31.	*Tp. aranoides* + *Cx. uniformis*	01	—	—	—	01
32.	*Ar. subalbatus* + *An. elegans*	—	—	—	01	01
33.	*Tx. splendens* + *Cx. uniformis*	05	—	—	—	05
34.	*An. elegans* + *Cx. mimulus*	—	—	—	01	01
	Total by Habitat	31	05	03	04	43

	Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	Total
	(c) Three Species Associated					
35.	*Ae. albopictus* + *Ae. krombeini* + *Ar. subalbatus*	01	—	—	—	01
36.	*Ae. albopictus* + *Ae. krombeini* + *Cx. uniformis*	03	—	01	—	04
37.	*Ae. albopictus* + *Ae. krombeini* + *Tp. affinis*	01	—	01	—	02
38.	*Ae. albopictus* + *Ae. aureostriatus* + *Ae. (Fin.) sp.*	—	02	—	—	02
39.	*Ae. albopictus* + *Ar. subalbatus* + *Tx. splendens*	01	—	—	—	01
40.	*Ae. krombeini* + *Ae. aureostriatus* + *Cx. uniformis*	—	—	01	—	01
41.	*Ae. krombeini* + *Ae. (Fin.) sp.* + *Cx. uniformis*	—	—	01	—	01
42.	*Ae. krombeini* + *An. elegans* + *Ae. pseudomediofasciatus*	—	—	—	01	01
43.	*Ae. krombeini* + *Tx. splendens* + *Cx. uniformis*	02	—	—	—	02
44.	*Ae. krombeini* + *Tx. splendens* + *Cx. brevipalpis*	01	—	—	—	01
45.	*Ae. aureostriatus* + *Ae. (Fin.) sp.* + *Cx. uniformis*	—	01	—	—	01
46.	*Ae. pseudomediofasciatus* + *Tx. splendens* + *Cx. uniformis*	—	01	—	—	01
47.	*Ae. pseudomediofasciatus* + *An. elegans* + *Cx. fuscocephala*	—	—	—	02	02
48.	*Tp. aranoides* + *Tx. splendens* + *Cx. uniformis*	01	—	—	—	01
49.	*Tp. aranoides* + *Cx. uniformis* + *Or. anopheloides*	01	—	—	—	01
50.	*An. elegans* + *Cx. uniformis* + *Cx. mimulus*	—	—	—	01	01
	Total by Habitat	11	04	04	04	23
	(d) Four or More Species Associated					
51.	*Ae. albopictus* + *Ae. krombeini* + *Ae. aureostriatus* + *Ae. (Fin.) sp.*	—	01	—	—	01
52.	*Ae. albopictus* + *Ae. krombeini* + *Ae. aureostriatus* + *Tp. aranoides*	01	—	—	—	01
53.	*Ae. albopictus* + *Ae. krombeini* + *Ae. aureostriatus* + *Tx. splendens*	—	01	—	—	01
54.	*Ae. albopictus* + *Ae. krombeini* + *Ae. aureostriatus* + *Cx. uniformis*	01	—	—	—	01

	Habitat	Bamboo Stumps	Kitul Stumps	Tree Holes	Ground Pools	Total
55.	*Ae. albopictus* + *Ae. krombeini* + *Hz. greeni* + *Tx. splendens*	01	—	—	—	01
56.	*Ae. albopictus* + *Ae. krombeini* + *Hz. greeni* + *Cx. uniformis*	01	—	—	—	01
57.	*Ae. albopictus* + *Ae. krombeini* + *Ar. subalbatus* + *Cx. uniformis*	01	—	—	—	01
58.	*Ae. albopictus* + *Tx. splendens* + *Cx. uniformis* + *Cx. brevipalpis*	01	—	—	—	01
59.	*Ae. krombeini* + *Tp. aranoides* + *Tx. splendens* + *Cx. uniformis*	01	—	—	—	01
60.	*Ae. pseudomediofasciatus* + *An. elegans* + *Cx. fuscocephala* + *Cx. minulus*	—	—	—	01	01
61.	*Hz. greeni* + *Tp. affinis* + *Tp. aranoides* + *Cx. uniformis*	01	—	—	—	01
62.	*Ae. albopictus* + *Ae. krombeini* + *Tp. aranoides* + + *Ar. subalbatus* + *Cx. uniformis*	01	—	—	—	01
63.	*Ae. mediopunctatus* + *Hz. greeni* + *Tp. affinis* + *Tp. aranoides* + *Cx. uniformis*	01	—	—	—	01
64.	*Ae. albopictus* + *Ae. krombeini* + *Ae. aureostriatus* + *Cx. uniformis* + *Ae. pseudomediofasciatus* + *Tp. affinis*	01	—	—	—	01
	Total by Habitat	11	02	—	01	14

A summary of the joint occurrences of species (all habitats combined) is presented in Table 3. Frequent joint occurrences between some species are evident, in particular between *Cx. uniformis*, *Ae. krombeini* and *Ae. albopictus*. The degree of interspecific association for species occurring in bamboo stumps, from which a sufficient number of samples (115) were obtained to permit further analysis, was tested by means of 2x2 contingency tables and the corrected chi-square (X^2) test as given in Southwood.[26] Since the test in this form is valid only where the expected occurrences (calculated on the hypothesis of random association) are greater than 5, only the four most frequently occurring species are considered: *Cx. uniformis*, *Ae. krombeini*, *Ae. albopictus* and *Tx. splendens*. A comparative measure of the degree of association is provided by the Coefficient of Interspecific Association (C_{AB}) of Cole.[8]

TABLE 3. Summary of Joint Occurrences of Species at Breeding Habitats (The figures indicate numbers of occurrence)

	Cx. uniformis	*Ae. krombeini*	*Ae. albopictus*	*Tp. aranoides*	*Tx. splendens*	*Ae. aureostriatus*	*Ae. pseudomediofasciatus*	*Tp. affinis*	*Hz. greeni*	*Ar.sub albatus*	*An. elegans*	*Ae. (Fin.) sp.*	*Cx. brevipalpis*	*Ae. mediopunctatus*	*Cx. mimulus*	*Cx. fuscocephala*	*Or. anopheloides*
Total occurrences	59	41	38	14	35	27	15	08	06	07	10	08	03	01	03	03	02
Occurrences Associated	40	36	31	13	19	23	09	07	05	05	08	08	03	01	03	03	01
Cx. uniformis	—	17	12	07	10	10	03	03	03	02	01	02	01	01	01	—	01
Ae. krombeini	17	—	24	03	06	07	02	03	02	03	01	03	01	—	—	—	—
Ae. albopictus	12	24	—	02	05	07	01	03	02	04	—	03	01	—	—	—	—
Tp. aranoides	07	03	02	—	01	04	—	03	03	01	—	—	—	01	—	—	01
Tx. splendens	11	06	05	02	—	02	02	—	01	01	—	01	02	—	—	—	—
Ae. aureostriatus	10	07	07	04	02	—	01	02	—	—	—	05	01	—	—	—	—
Ae. pseudomedio-fasciatus	03	02	01	—	02	01	—	01	—	—	05	—	—	—	01	03	—
Tp. affinis	03	03	03	03	—	02	01	—	02	—	—	—	—	01	—	—	—
Hz. greeni	03	02	02	03	01	—	—	02	—	—	—	—	—	01	—	—	—
Ar. subalbatus	02	03	04	01	01	—	—	—	—	—	01	—	—	—	—	—	—
An. elegans	01	01	—	—	—	—	05	—	—	01	—	—	—	—	03	03	—
Ae. (Fin.) sp.	02	03	03	—	01	05	—	—	—	—	—	—	—	—	—	—	—
Cx. brevipalpis	01	01	01	—	02	01	—	—	—	—	—	—	—	—	—	—	—
Ae. mediopunctatus	01	—	—	01	—	—	—	01	01	—	—	—	—	—	—	—	—
Cx. mimulus	01	—	—	—	—	—	01	—	—	—	03	—	—	—	—	01	—
Cx. fuscocephala	—	—	—	—	—	—	03	—	—	—	03	—	—	—	01	—	—
Or. anopheloides	01	—	—	01	—	—	—	—	—	—	—	—	—	—	—	—	—

Contingency Table[26]

Species B	Species A	
	Present	Absent
Present	a	b
Absent	c	d

a, b, c, d, refer to numbers of occurrence, and species A occurs more frequently than species B. Details of the calculation of X^2 and C_{AB} are given in Southwood.[26] The data are as follows:

Cx. uniformis + *Ae. krombeini*
a = 13, b = 17, c = 26, d = 59; $X^2 = 1.09$; $C_{AB} = + 0.14 \pm 0.11$

Cx. uniformis + *Ae. albopictus*
a = 11, b = 20, c = 28, d = 56; $X^2 = 0.34 \times 10^{-4}$; $C_{AB} = 0.02 \pm 0.11$

Cx. uniformis + *Tx. splendens*
a = 10, b = 22, c = 29, d = 54; $X^2 = 0.35$; $C_{AB} = -0.08 \pm 0.21$

Ae. albopictus + *Ae. krombeini*
a = 19, b = 12, c = 11, d = 73; $X^2 = 24.84$; $C_{AB} = + 0.48 \pm 0.09$

Tx. splendens + *Ae. krombeini*
a = 5, b = 25, c = 27, d = 58; $X^2 = 3.32$; $C_{AB} = - 0.40 \pm 0.25$

Tx. splendens + *Ae. albopictus*
a = 4, b = 27, c = 28, d = 56; $X^2 = 5.78$; $C_{AB} = - 0.54 \pm 0.25$
(with 1 degree of freedom the 5% level of significance is shown by $X^2 = 3.84$)

The above data show that the associations of *Cx. uniformis* with the other three species are due to chance occurrence. A positive interspecific association is indicated between *Ae. albopictus* and *Ae. krombeini* with the latter species appearing to be the dominant partner; of the 19 joint occurrences in bamboo stumps 7 were in the absence of other culicid species and the ratio of the immatures of *krombeini/albopictus* was 2.03 (140:69); in the 12 joint occurrences in the presence of other culicids, the ratio increased to 3.64 (211:58). A negative interspecific association is shown between *Tx. splendens* and *Ae. albopictus*, and probably between the former species and *Ae. krombeini*.

(c) pH of Breeding Water

Water samples from ground pools occupied a narrow range, from pH 5.0 to 6.5, and thus no indications are forthcoming regarding the tolerance range of the species breeding in this habitat. It is interesting, however, that the 3 occurrences of *Ae. pseudomediofasciatus* (chiefly a ground breeder) in natural containers were in acidic water within this range. Samples from natural containers varied widely (pH 5.0-10.0) and most of the container breeding species occurred over a broad pH range: 5.0 - 9.0 for *Ae. albopictus*, *Ae. krombeini*, *Tx. splendens*, *Cx. uniformis* and *Cx. brevi palpis;* 5.0-10.0 for *Ae. aureostriatus* and *Tp. aranoides;* 5.0-8.0 for *Ae.* (*Fin.*) sp.; 6.0-9.0 for *Ar. subalbatus*. However, *Hz. greeni* ((pH 5.0 - 6.5) and *Tp. affinis* (pH 5.0 - 7.0) were collected only from acidic or neutral water. *Orthopodomyia anopheloides* was found in two samples of alkaline water (pH 7.5 and 8.0 respectively) while the single occurrence of *Ae. mediopunctatus* was from acidic water (pH 5.5).

4.3 Diurnal Bait Catches

The species taken at human bait are listed in Table 4, together with the numbers caught and percentages of the total catch. *Aedes albopictus* and *Ar. subalbatus* were the most prevalent man-biters, but five other species were also collected regularly at these catches (*Ae. chrysoscuta*, *Ae. aureostriatus*, *Ae. novalbopictus*, *Ae. w-albus* and *Hz. greeni*) though comprising much smaller percentages of the overall catch. This could be a reflection not only of host attractivity, but also of the abundance levels and diel biting rhythms of these species.

TABLE 4. Mosquito Species Collected at Human Bait Catches

Species	Females	
	Number Caught	Percentage of Total Catch
Ae. albopictus	576	40.65
Ar. subalbatus	353	24.91
Ae. chrysoscuta	124	8.75
Ae. aureostriatus	100	7.05
Ae. novalbopictus	98	6.98
Ae. w-albus	58	4.18
Hz. greeni	58	4.18
Cx. pseudovishnui	16	1.13
Ae. krombeini	10	0.71
An. aitkenii gp.	08	0.56
Ae. mediopunctatus	04	< 0.5
Ae. annulirostris	03	"
Heizmannia sp.	02	"
Ae. vittatus	01	"
Ae. pseudotaeniatus	01	"
Ae. gubernatoris	01	"
Ae. pseudomediofasciatus	01	"
Ae. jamesi	01	"
Cx. sitiens gp.	01	"
An. peditaeniatus	01	"
Ae. aegypti (No females; 02 males collected settled on baits)		

The technique used in the bait catches, though not designed directly to study diurnal biting rhythms, and suffering from certain limitations in this regard (see Service[22]), provides indications of major periods of biting activity during the time span investigated. With equal numbers of catches ranging over the same catch points being done per 1 hour period, it is possible to provide a preliminary interpretation of the activity patterns of the two most common man-biters in the forest, *Ae. albopictus* and *Ar. subalbatus* (Table 5). In both species, biting occurred throughout the period 0900 - 1800 hours, under the conditions of partial to dense shade within the forest, but the major period of activity seems to occur earlier in *Ae. albopictus* (with the peak period occurring in late afternoon and declining towards sunset) than in *Ar. subalbatus* (where the biting activity increases towards sunset).

TABLE 5. Percentage Catch of *Aedes albopictus* and *Armigeres subalbatus* Between 0900 - 1800 Hours at Human Bait Catches.

Local Time	0900-0959	1000-1059	1100-1159	1200-1259	1300-1359	1400-1459	1500-1559	1600-1659	1700-1759
Ae. albopictus	3.8	3.6	3.8	1.9	9.2	18.0	26.7	18.2	14.6
Ar. subalbatus	9.4	10.9	7.4	5.7	9.1	11.3	12.2	12.5	21.5

5. Discussion

Both sylvan and peridomestic mosquitoes were encountered in Udawattakele Forest. Species such as *An. elegans*, *An. aitkenii* gp., *Ae. chrysoscuta*, *Ae. pseudomediofasciatus*, *Ae. aureostriatus*, *Hz. greeni*, *Tp. affinis*, *Tp. aranoides*, *Cx. uniformis*, *Cx. wardi*, *Cx. lasiopalpis*, *Cx. mimulus* and *Cx. brevipalpis* are generally regarded as being mainly forest-dwelling in habit.[1,9,17,18,23,24,25] Species commonly associated with human habitations are *Ae. aegypti*, *Ae. albopictus*, and *Ar. subalbatus*, as well as others such as *An. peditaeniatus*, *Cx. fuscocephala* and *Cx. pseudovishnui*[9,24]. Of the potential vector species, only *Ae. albopictus* appears to be relatively abundant in the forest, being collected regularly from breeding sites and bait catches.

Apart from the apparently endemic *Ae. krombeini* (and possibly the *Ae.* (*Fin.*)sp.), the species found breeding in the forest also occur in other areas of the Oriental and S-E Asian regions. The data in Tables 2 and 3 contribute to the body of information on immature species associations in relation to habitat types, that are of interest both in a local context (where there is a paucity of published data) and in the wider context of the overall distributional range of these species. Of particular interest are the associations of *Ae. krombeini*, *Hz. greeni*, *Ae. mediopunctatus*, *Ae. pseudomediofasciatus*, *Tp. affinis*, *Tp. aranoides*, and *An. elegans*, for which little published information exists.

The positive interspecific association between *Ae. albopictus* and *Ae. krombeini* in bamboo stumps indicates the requirement of similar conditions in these two species, since other possibilities such as a predator-prey relationship or mutualism[26] can be excluded in this case. *Ae. krombeini* appears to be the more successful competitor of the two, both in the presence and absence of other culicid immatures. It is interesting that Huang[11] too mentions the frequent association of these two species in immature collections from Sri Lanka (including Udawattakele Forest).

The negative interspecific association between *Tx. splendens* and *Ae. albopictus* (and possibly *Ae. krombeini*) could be due to non-occurrence in the same sites because of differing environmental requirements or tolerances. The bamboo stumps all occurred under shade, and thus differences of light and temperature are not likely to be important in this regard. Both *Tx. splendens* and *Ae. albopictus* are tolerant of a similar pH range. Though a close examination of the data reveals that *Ae.*

albopictus shows 78% of its occurrences in bamboo from acidic water (pH 5.0 - 6.5) and 21% occurrences from alkaline water (pH 7.0 - 8.5), compared to 57% and 39% respectively for *Tx. splendens*, this is probably not an important factor in the regular non-occurrence of these two species in the same sites. A factor that does appear to contribute to such a situation is the quality of the water: approximately 33% of the occurrences of *Tx. splendens* in bamboo were from foul or turbid water, while not a single immature of *Ae. albopictus* was collected from such samples, whether from bamboo, kitul-palm or tree holes. Another possibility that must be considered here is predation by *Tx. splendens* larvae on immatures of *Ae. albopictus*, particularly if the latter is a preferred prey species. Larvae of *Tx. splendens* appear to be non-specific, feeding on immatures of several mosquito species in the laboratory (personal observations), but their prey preferences are unknown. A situation where the predator eliminates a preferred prey species before switching to other acceptable prey cannot entirely be ruled out, especially in the small container habitat (bamboo stumps) in question. Further studies will be necessary before the nature of this negative association can be clarified.

Apart from the *Heizmannia* sp. *Ae. chrysoscuta* and *Ae. novalbopictus*, all the others taken at bait have been recorded previously in the literature as biting humans. However, with the exceptions of *Ae. aegypti* and *Ae. albopictus*, they appear to be mainly zoophilic in their host preferences. The highly anthropophilic *Ae. aegypti* does not seem to be common within the forest (no breeding occurrences, and only 2 males attracted to human bait), though it occurs in the urban areas adjacent to the forest (personal observations). However, *Ae. albopictus* occurred commonly within the forest, and was the chief diurnal man-biting species collected.

One of the significant findings of the present study concerns *Ae. krombeini*, a recently described[11] member of the medically important *scutellaris* group of *Aedes* (*Stegomyia*). This species comprised an insignificant part of the total catch (0.71%) compared to several other *Stegomyia* species, in particular, *Ae. albopictus* (40.65%). The survey of breeding habitats indicated that *krombeini* is probably more abundant than *albopictus* in this area, and thus its low incidence at human bait shows that it is either a primarily zoophilic species not greatly attracted to humans or a mainly nocturnally active mosquito (or both).

An interesting feature of the catches was the regular attraction of males of *Ae. albopictus* to the human bait. A total of 141 males of this species were captured during the series of catches, while settled upon bait, but much greater numbers than actually caught were present, usually hovering around the catchers. Copulation in flight was observed at nearly every occasion that males were present. The host has been shown to be a focal point for mating in species such as *Ae. sierrensis*[15], *Ae. varipalpus*[16], and probably *Ae. aegypti*[10], and it is possible that the same phenomenon occurs in *Ae. albopictus* as well.

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The Incidence of Brucellosis in the District of Colombo

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Abstract: Incidence of Brucellosis in dairy herds in District of Colombo (now Districts of Colombo and Gampaha) has been surveyed by use of the Milk Ring Test (MRT) and confirmed by quantitative tests like Standard Agglutination Test (SAT) Complement Fixation Test (CFT) and Coombs Test (CT) on suspected sera. In all 305 herds involving 1478 dairy cows were tested giving herd infection of 1.6% and the individual animals infected as 0.9% The comparatively low infection should not leave room for any complacency. The situation could very well signify the beginning of a widespread infection.

1. Introduction

Brucellosis has been prevalent in Sri Lanka for several years and therefore it is most appropriate to determine its incidence in localised areas through the veterinary services available in that area. The occurrence of Brucellosis in the country has been proved by serological evidence as well as isolation of the causal organism from aborting animals.[5]

The reluctance on the part of the owners to permit bleeding their cows for serological tests imposes a limitation of any widespread survey into the incidence of Brucellosis. On the other hand, the adoption of the Milk Ring Test (MRT) offers immense potentialities for screening a given population provided the test is reasonably specific and sensitive. The accepted status of the test is that it has found widespread use in localising infected herds, as well as in ensuring that Brucella free herds remain so.[7]

It was therefore decided to screen a representative population of cows in the District of Colombo, which is the area of operation of the Veterinary Investigation Centre, Welisara. This paper records the first detailed study of the incidence of Brucellosis the District of Colombo (now Districts of Colombo and Gampaha).

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2. Materials and Methods

The population tested in the study is mainly the dairy cows which feed the milk collecting centres (MMC) situated in Narahenpita, Meepe, Minuwangoda, Badalgama and Nittambuwa that existed in District of Colombo in 1976. Milk suppliers of the Multi-Purpose Co-operative Society of Attanagalla were also tested. Also a few farms that did not supply milk to the National Milk Board were tested. The animals belonging to milk suppliers of Narahenpita, Meepe, Minuwangoda collecting centres and also those belonging to non-suppliers for Milk Board were tested on the MRT individually, whereas those relating to Badalgama, Nittambuwa centres and suppliers to Multi-Purpose Co-operative Society of Attanagalla were tested on bulk milk samples.

2.1 Scheme of Testing

If positive samples are encountered while testing bulk milk samples, all cows corresponding to that milk sample are tested individually on the MRT method in order to track the possible reactor/reactors. All individual animals found positive on the MRT are bled and Rose Bengal Plate Test (RBPT) undertaken on the sera at the Veterinary Investigation Centre, Welisara. Immaterial of the results of the RBPT of the serum, duplicate samples of the serum, and the milk preserved in merthiolate are forwarded to the Veterinary Research Institute, Gannoruwa, Peradeniya for testing on quantitative tests like Standard Agglutination Test (SAT), Complement Fixation Test (CFT) and Coombs Test (CT). All these three tests were done as no single diagnostic test suitable for routine use can be depended upon to detect every infected animal.[2] Therefore, cows whose serum react on RBPT and give minimum titres for positivenseas, by any one of the above tests, are considered infected with Brucellosis.

2.2. Tests Used

1. *Milk Ring Test*:- The test is based on coloured antigen employed reacting with the antibody present in the milk sample and the agglutinating mass thus produced coating itself on the fat globules. The fat globules aggregating antibody normally present in the fresh milk, which rises to the surface of milk column to produce the cream layer.

Thus a positive reaction is indicated by a coloured cream ring on the top and white milk column below, whereas a negative reaction is shown by a white cream ring on the top and a coloured milk column below.

Extensive studies at the Veterinary Research Institute, Peradeniya, has proved that by finer modification of the original method[1,3] the Milk Ring Test could be adopted even to test individual cows in a herd. Souring of milk in transit parti-

cularly in the tropics imposes a severe limitation on the usefulness of the test, but this can be circumvented by preserving the milk sample with merthiolate. It was also been determined that the incubation of the test sample for agglutination reaction at room temperature for two hours, gives the same results as at 37°C for one hour within an incubator.[6]

(ii) Rose Bengal Plate Test (RBPT.)

The antigen used in the test is prepared at Veterinary Research Institute, Gannoruwa, Peradeniya, from a culture originally imported from the United States of America. It is buffered at pH 3.65 and has a packed cell volume of 8% and is stained with Rose Bengal Dye. The test was performed as described by Alton *et al.*[1]

(iii) Standard Agglutination Test (SAT).

The antigen used in the test is prepared at the Veterinary Research Institute, Gannoruwa, Peradeniya, from S 99 culture originally imported from United Kingdom and is standardised against International Anti-Brucella abortus serum. The test was carried out as described by Alton *et al.*[1] and a titre of 1/40 by this method represents 80 International Brucella antibodies per ml of the serum and is considered positive for Brucellosis.

(iv) The Coombs Test (CT)

The test determines enhancement of titres above the level obtained in the SAT due to incomplete or blocking antibodies, sometimes present being made agglutinable. The ordinary SAT test is used as the starting point for the Coombs Test. The test was done as originally described by Alton *et al.*[1] If there is enhancement of the titre to the level normally considered positive on the SAT, the serum sample is regarded as positive.

(v) Complement Fixation Test (CFT).

Antigen used in this test is the standardised CFT antigen obtained from Central Veterinary Laboratory, Weybridge and the technique of the test is based on the one described by Hill.[4] All samples giving a titre value of 2/4 and over are regarded as positive.

3. Results and Interpretations

Table 1 gives the number of herds tested by MRT against each Milk Board Collecting Centre, and the number of herds found positive in each group. Farmers who do not supply milk to Milk Board are also treated as one group in this survey.

TABLE 1. Number of herds tested by Milk Ring Test

Milk Collecting Centre	Total No. of suppliers	No. of Farms Tested	Total found positive
Narahenpita	41	26	1
Minuwangoda	89	63	—
Meepe	43	31	3
Non-suppliers to Milk Board	---	41	1
Badalgama	118	48	—
Nittambuwa	6	06	—
Attanagalla	98	90	—
	395	305	5

The total number of animals involved in this survey was 1478. This includes the number of animals represented in each bulk milk sample tested at Nittambuwa, Badalgama and Attanagalla centres, i.e. 383 animals and 1095 animals individually tested in farms supplying centres at Narahenpita, Meepe, Minuwangoda and non-suppliers to Milk Board.

The actual location and the number of animals infected are given in Table 2. The infected areas are shown in the map appended at the end of the article.

TABLE 2. Location and number of infected animals

Location of infection	AGA Division.	No. of animals infected
Rajagiriya	Nugegoda	2
Dehiwala	Nugegoda	4
Padukka	Hanwella	2
Meegoda	Hanwella	6
	Total:	14

Data obtained gives the infection percentage as follows:-

Percentage of infected herds	1.6%
Percentage of infected cows	0.9%

4. Discussion

Vaccination of cows with Brucella vaccine has not been practised in this area and therefore the interpretation of titre results on the serum tests are not complicated by this fact. It is to be noted that the MRT and the RBPT could be undertaken even in the field with minimum facilities, whereas the quantitative tests warrant fairly equipped laboratories.

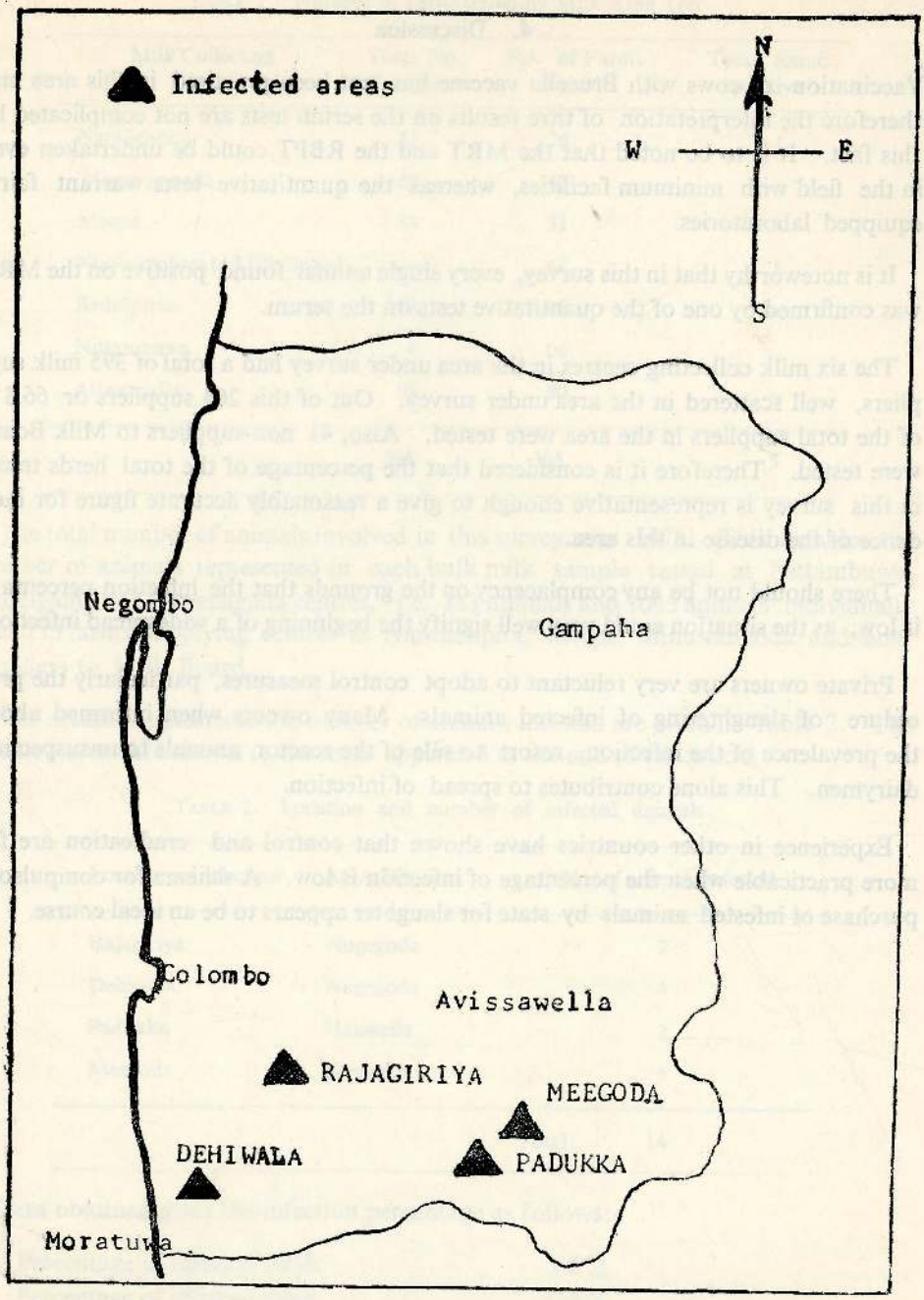
It is noteworthy that in this survey, every single animal found positive on the MRT was confirmed by one of the quantitative tests on the serum.

The six milk collecting centres in the area under survey had a total of 395 milk suppliers, well scattered in the area under survey. Out of this 264 suppliers or 66.8% of the total suppliers in the area were tested. Also, 41 non-suppliers to Milk Board were tested. Therefore it is considered that the percentage of the total herds tested in this survey is representative enough to give a reasonably accurate figure for incidence of the disease in this area.

There should not be any complacency on the grounds that the infection percentage is low, as the situation could very well signify the beginning of a widespread infection.

Private owners are very reluctant to adopt control measures, particularly the procedure of slaughtering of infected animals. Many owners when informed about the prevalence of the infection, resort to sale of the reactor animals to unsuspecting dairymen. This alone contributes to spread of infection.

Experience in other countries have shown that control and eradication are far more practicable when the percentage of infection is low. A scheme for compulsory purchase of infested animals by state for slaughter appears to be an ideal course.



MAP OF THE DISTRICT OF COLOMBO (PRESENTLY, DISTRICTS OF COLOMBO AND GAMPAHA) SHOWING BRUCELLOSIS INFECTED AREAS.

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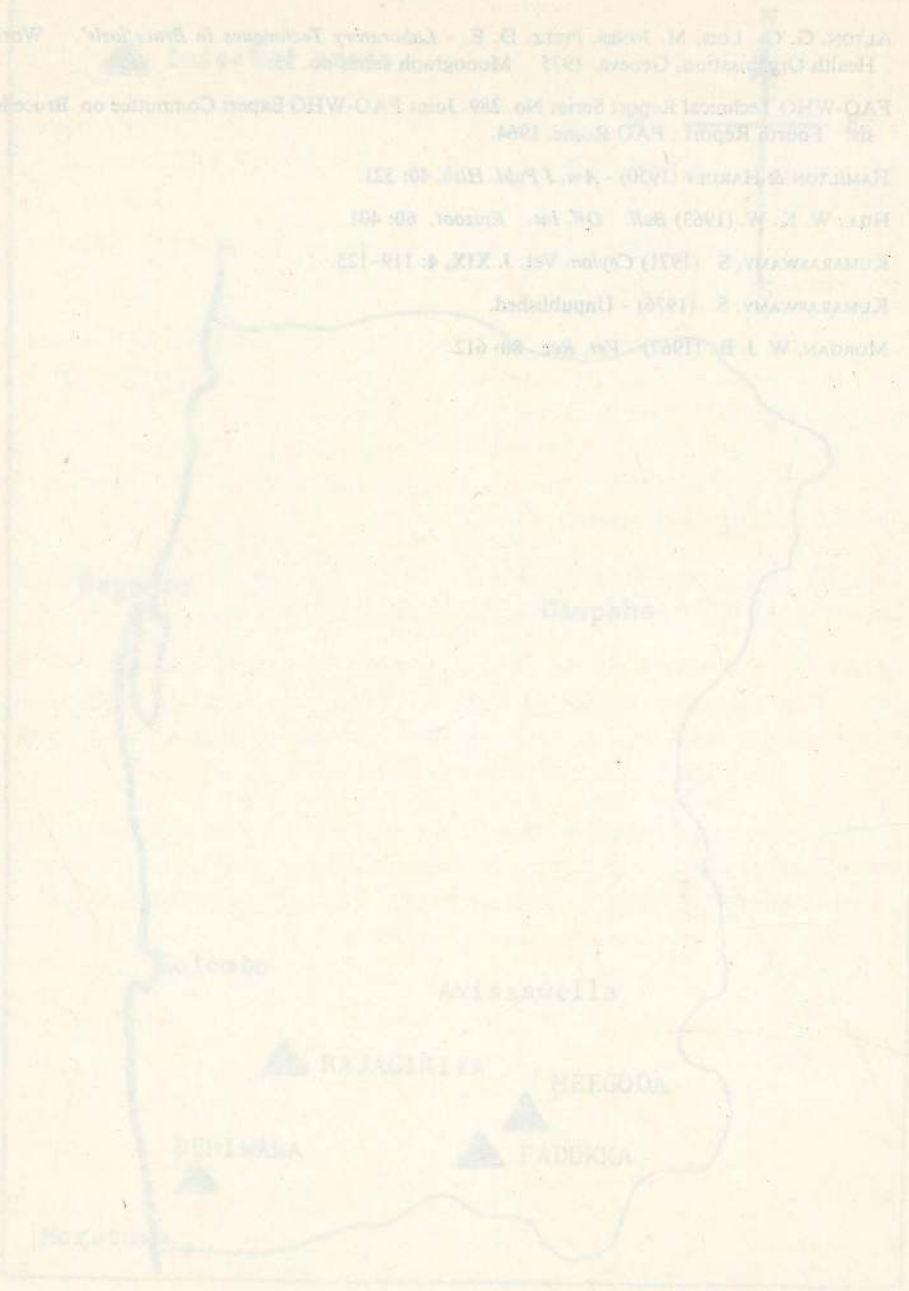

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Studies on Decomposition of Ilmenite from Sri Lanka

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Abstract : Ilmenite and rutile deposits of Sri Lanka are found as beach sands in the East and North-West Coasts. Some 65,000 tons of ilmenite concentrates are currently exported from Sri Lanka each year, primarily to pigment manufacturers, without any beneficiation. This paper reviews some results of laboratory studies that have been carried out by the Ceylon Institute of Scientific and Industrial Research (CISIR) to prepare synthetic rutile from ilmenite using locally available raw materials. The main feature of this process is the use of saw dust for the first time in a beneficiation method as the reducing agent to reduce iron values in ilmenite to acid leachable form. In the process developed ilmenite is first oxidized and this is then reduced by using saw-dust. Reduced ilmenite is leached with hydrochloric acid to remove iron and the final concentrate is calcined to rutile having about 95 % TiO_2. The hydrochloric acid could be recovered from the leached liquor and iron oxide is obtained as a byproduct which could be used as a red pigment.

1. Introduction

Ilmenite and rutile are the only two naturally occurring titanium bearing minerals that have been seriously considered as suitable feedstock for either metal-producing or pigment industries. This is because only rutile and ilmenite are found in large enough commercial concentrations compared with other naturally occurring minerals containing titanium, so as to be suitable for industrial exploitation.

There has been a continuing growth in demand for titanium dioxide pigment, and this industry in the world has continued to expand to meet the spectacular growth in demand due to this inherent superior properties. The total titanium dioxide production capacity is more than 2 million tons a year and the growth rate of TiO_2 consumption averaged 5.5% during the period 1964 to 1972. The future growth is predicted to be about 5% a year.[22]

The existence of natural concentrates of titanium bearing mineral sands such as ilmenite and rutile in a high degree of purity in many places in the coasts of Sri Lanka has been known as far back as 1903. Over the last few decades systematic work on the beach sands of the islands referred to as "black sands" have been carried out by the Geological Survey Department of Sri Lanka, and at present the distribution of these deposits, and their mineralogy is known.[8,12]

2. Ilmenite and Rutile Deposits of Sri Lanka

These deposits in Sri Lanka are found as beach sands in the East and North-West Coast and occur in association with others namely, rutile, zircon and monazite. The largest and most important beach sand deposit occurs at Pulmoddai in the North-East Coast of the island, 34 miles North of Trincomalee. The deposit is approximately 4 miles in length with an average width of about 200 feet. The richest part of the deposit is in the Southern coast, where the percentage of heavy mineral amount to 95%. The approximate composition of the sand is as follows:

		w/w %
Ilmenite	($FeO.\ TiO_2$)	70-80
Rutile	(TiO_2)	8-12
Zircon	($ZrO_2.\ SiO_2$)	8-10

Besides the Pulmoddai deposit there are other deposits of mineral sands in several scattered points on the West Coast from Kundiramalai Bay on the North West Coast to Kirinda on the South of Sri Lanka. These deposits contain heavy minerals varying from 10-20% while occasionally the concentration rises over 80%. In all these deposits ilmenite is the main constituent withzircon next in order of importance.[18]

The Mineral Sands Corporation of Sri Lanka commenced commercial production of ilmenite from Pulmoddai sand in 1963 and rutile in 1968. About 65,000 tons of ilmenite concentrates are currently exported from Sri Lanka each year, primarily to pigment manufacturers, without any beneficiation.

The following Table gives the results of chemical analysis of ilmenite from Pulmoddai.

TABLE 1. Chemical Composition of Sri Lanka Ilmenite

SiO_2	—	0.38
TiO_2	—	53.61
Al_2O_3	—	0.54
Fe_2O_3	—	20.95
FeO	—	20.67
MnO	—	0.95
MgO	—	0.92
CaO	—	0.05
Cr_2O_3	—	0.05

The immense and expanding uses of high purity TiO_2 in the pigment and paper industries, combined with increasing demand for titanium metal, are expected to outstrip the production capacity of available sources of rutile. Therefore development of commercial processes for upgrading these ores is becoming increasingly important.

The traditional pigment-producing process is the "Sulphate Process", in which finely ground ilmenite is digested in sulphuric acid and titanium hydroxide precipitated by hydrolysis. This process creates large quantities of waste in the form of hydrated ferrous sulphate and sulphuric acid, and methods of disposal, such as discharge into rivers or sea, create pollution problems.[1,2]

The recently developed "Chloride Process" is becoming more attractive[1,7] to pigment producers because it produces less effluent and is cheaper to operate. However, the present economics of the chloride process are only favourable for feed materials containing at least 90% titanium dioxide (TiO_2) and with low proportions of metal oxide impurities, such as iron and manganese, which not only consume chlorine but also form troublesome liquid chlorides.

The preferred chloride process feedstock has always been natural rutile of which Sri Lanka currently exports about 16,000 metric tons per annum. Australia currently supplies more than 95% of the world demand of rutile. In recent years, however, the world production of rutile kept pace with demand and prices have been much inflated. Pigment producers have therefore been seeking alternative feeds, particularly high-grade slags and beneficiated ilmenite. Having considered these facts the Ceylon Institute of Scientific and Industrial Research (CISIR) carried out a series of laboratory experiments to upgrade Sri Lanka ilmenite to the more useful and more expensive rutile form by using locally available raw materials.

During the last two decades, many processes have been proposed for upgrading ilmenite, including high temperature smelting, direct and leaching, methods, and reduction processes in which the iron content is reduced either to ferrous oxide and extracted with acid or to metallic iron and removed by acid leaching or accelerated corrosion.[20,22]

The fundamental steps of the process that we have investigated in the CISIR laboratories are as follows—

Ilmenite is first oxidized at a temperature range 900-1000°C for 3.00 hrs. This will facilitate the subsequent reduction stage. This oxidized ilmenite is then reduced in a closed vessel at 1100°C using sawdust which contains a high percentage of carbonaceous material as the reductant. Iron in reduced ilmenite is then leached with dilute hydrochloric acid. Hydrochloric acid leaching was investigated since Sri Lanka has a hydrochloric acid industry and also it was known that commercial units were available for converting ferrous chloride liquor to iron oxide pigment, the latter being recycled in the leaching stage.[3,4] The leached product obtained is calcined at 1000°C to get synthetic rutile having about 95% TiO_2.

3. Experimental

The ilmenite used through out the present work was obtained from the ilmenite separation plant at Pulmoddai. After each stage, chemical analysis and X-ray characterisation of all samples were carried out.

3.1 Chemical Analysis

The chemical analysis of treated samples was always carried out in duplicate. The titanium content of the treated samples was determined by a spectrophotometric method.[13] Atomic absorption methods were employed for the determination of other constituents except Al and Si. Ferrous iron determination was carried out according to the "Wilson" method.[13]

3.2 X-ray characterisation

Solid products were examined by means of a JEOL JD 8X X-ray powder diffractometer equipped with a graphite monochrometer using Cu Kα radiation. XRD patterns were obtained at a scanning rate of 2°/min for qualitative study. The proportions of different phases present in the reaction products were determined by comparing the peak heights of most intense diffraction lines. Powder diffraction patterns were identified from patterns listed in the JCPDS Index.[17]

The differential thermal analysis of samples was carried out by using "MOM Q-Derivatograph". Scanning Electron Microscope microphotographs were taken using a JEOL Scanning Electron Microscope. Other experimental conditions that were used at each stage were as follows :-

3.3 Oxidation

Oxidation of ilmenite ore was carried out in temperature controlled electric furnaces. Calcined samples were quenched into water rapidly to study the phases present.

3.4 Reduction

Reduction of ilmenite was carried out in a sealed stainless steel vessel (Figure 1).

3.5 Dressing

Unreacted saw dust ash was separated out using a simple flotation technique without adding any activating agents or frothers. Running water was passed through a stirred aqueous mixture of reduced ilmenite in a flask and sawdust was collected from the overflowing water. Reduced ilmenite remained in the bottom of the flask.

3.6 Leaching

Leaching of reduced ilmenite was carried out under refluxing conditions at atmospheric pressure. Dilute hydrochloric acid (31 % w/v) was used as the leaching agent.

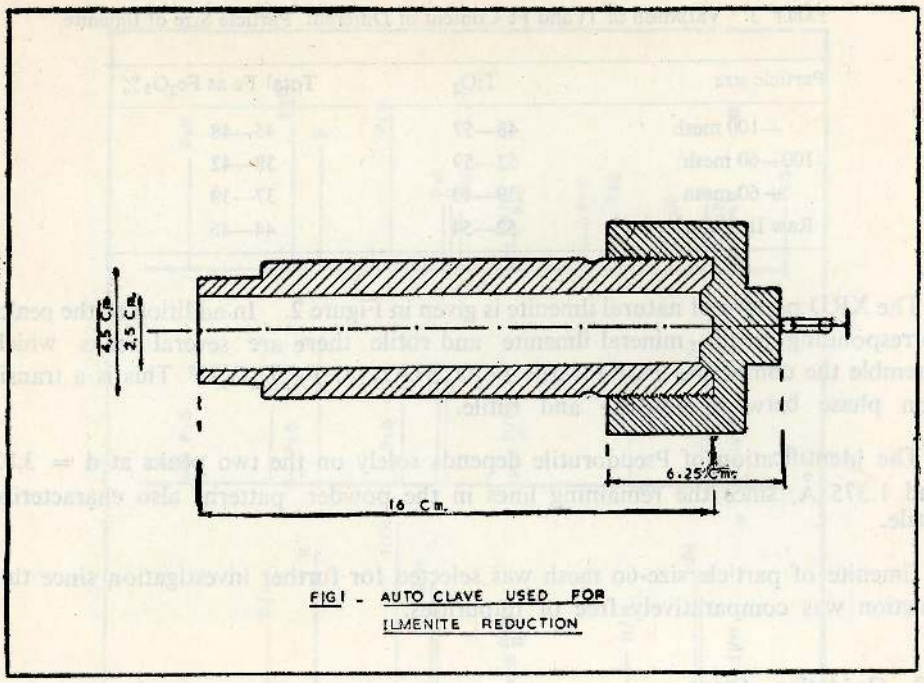


FIG I - AUTO CLAVE USED FOR ILMENITE REDUCTION

3.7 Calcining

Calcination of leached ilmenite was carried out in a temperature controlled furnace and the final product was quenched into water to study the phases present.

4. Results and Discussion

4.1 Preliminary Investigation

A sieve analysis was carried out on the beach sand ilmenite from the Pulmoddai plant and the results obtained are given in Table 2.

TABLE 2. Screen Analysis of Ilmenite Used

Screen size (BS mesh)	Percentage w/w
+60	0.4
−60 + 100	16.0
−100	83.6

A chemical analysis of the above fractions (Table 3) showed that ilmenite of particle size + 60 mesh had low TiO_2 and Fe_2O_3 content when compared with other fractions. X-ray powder diffraction analysis showed that this was due to the presence of other impurities such as α -quartz, zircon, etc.

TABLE 3. Variation of Ti and Fe Content of Different Particle Size of Ilmenite

Particle size	TiO_2	Total Fe as Fe_2O_3 %
—100 mesh	48—57	45—48
100—60 mesh	52—59	38—42
+ 60 mesh	39—40	37—39
Raw Ilmenite	52—54	44—46

The XRD pattern of natural ilmenite is given in Figure 2. In addition to the peaks corresponding to the mineral ilmenite and rutile there are several peaks which resemble the compound Pseudorutile $Fe_2O_3.3TiO_2$ (or $Fe_2Ti_3O_9$).[19] This is a transition phase between ilmenite and rutile.

The identification of Pseudorutile depends solely on the two peaks at d = 3.82 and 1.375 Å, since the remaining lines in the powder patterns also characterize rutile.

Ilmenite of particle size-60 mesh was selected for further investigation since this fraction was comparatively free of impurities.

4.2 Oxidation Stage

Ilmenite samples were oxidized at different temperatures for the same duration and the change in composition observed.

The XRD patterns of the samples oxidized at 800°, 900°C and 1000°C for duration of 3 hrs are given in Figure 2.

The major products formed by oxidation of ilmenite at temperatures greater than 900°C are ferric pseudobrookite and rutile.[14]

This reaction proceeds according to the equation (1) and (2).

$$2FeTiO_3 + \tfrac{1}{2}O_2 \longrightarrow Fe_2TiO_5 + TiO_2 \quad \ldots\ldots(1)$$

$$Fe_2Ti_3O_9 \longrightarrow Fe_2TiO_5 + 2TiO_2 \quad \ldots\ldots(2)$$

To study the optimum duration necessary for oxidation of ilmenite, samples were oxidised at 900°C for different durations. The Scanning Electron Micrographs of the samples oxidised at 900°C for 3 hrs 7 hrs and 24 hrs are given in Figure 3.

Formation of fine pores on the ilmenite particles was observed. With the increase of duration of oxidation the pores are more visible. The presence of micro cracks and pores on the ilmenite particles facilitates the reduction of ilmenite to rutile.

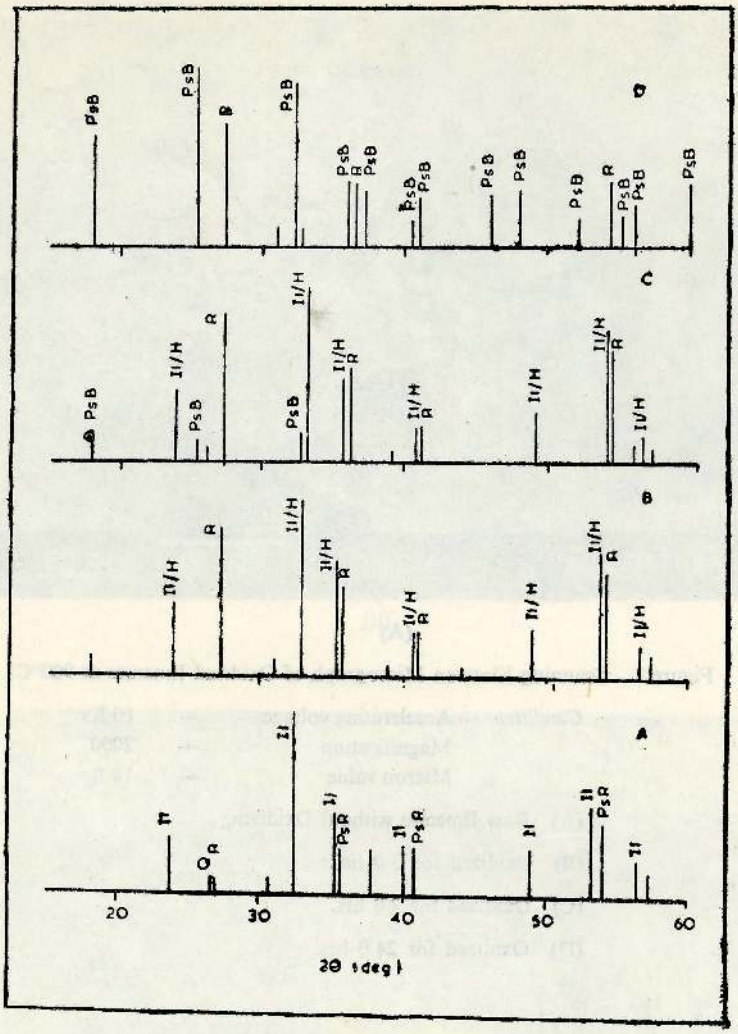
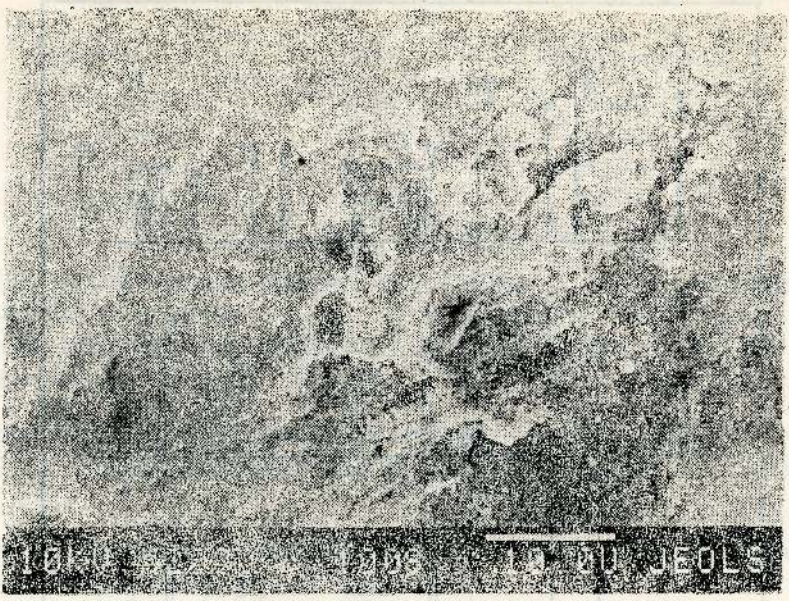


Figure 2. X-ray patterns of raw Ilmenite and oxidised Ilmenite

A — Raw Ilmenite
B — Oxidised Ilmenite 800°C 3 hrs.
C — Oxidised Ilmenite 900°C 3 hrs.
D — Oxidised Ilmenite 1000°C 3 hrs.
I1 — Ilmenite PsR — pseudorutile
R — Rutile Q — Quartz
PsB — Pseudobrookite H — Hematite



(A)

Figure 3. Scanning Electron Micrograph of Oxidised Ilmenite at 900°C

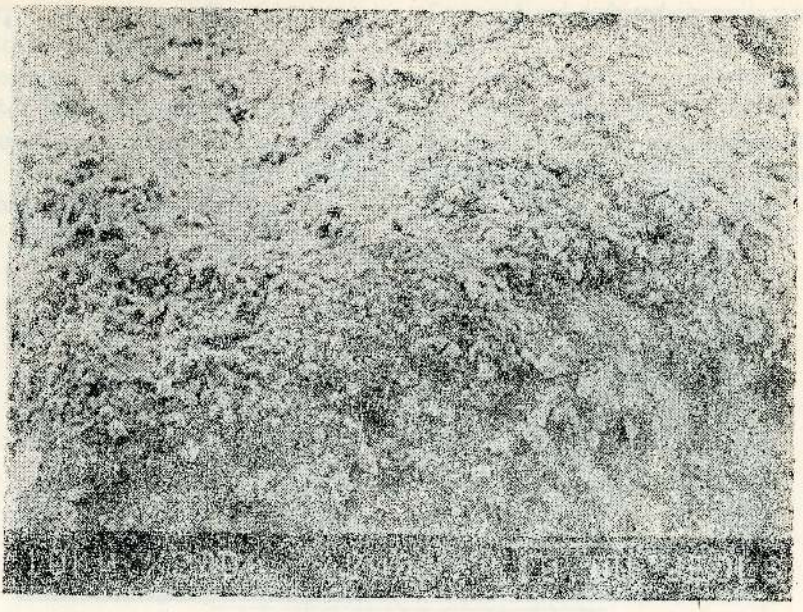
Conditions — Accelerating voltage — 10 Kv
Magnification — 2000
Micron value — 10 η

(A) Raw Ilmenite without Oxidizing

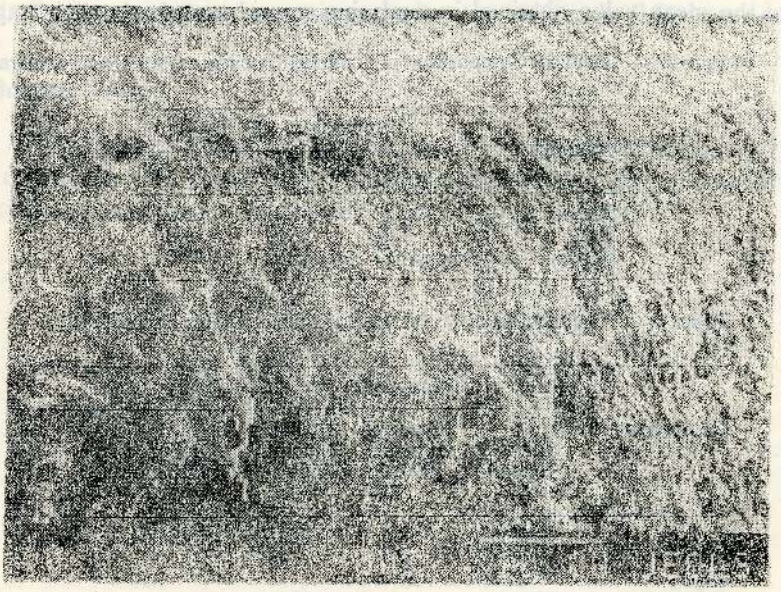
(B) Oxidized for 3.0 hrs.

(C) Oxidized for 7.0 hrs.

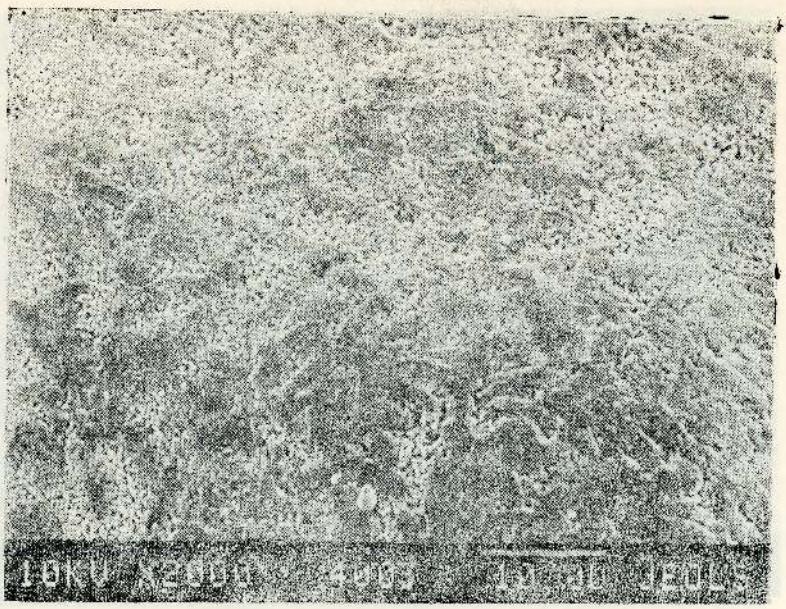
(D) Oxidized for 24.0 hrs.



(B)



(C)



(D)

Chemical analyses of oxidized ilmenite are given in Tables 4 and 5. These tables indicate the mean value obtained in analysing several samples in each stage.

TABLE IV — Chemical Composition of Oxidized Ilmenite at Different Temperatures

Component	Temperature (°C)		
	800	900	1000
TiO_2	60.5	61.2	68.5
FeO	2.64	1.19	0.0
Fe_2O_3	34.57	35.62	29.0

TABLE V — Chemical Analysis of Natural Ilmenite After Each Stage

Component	Composition (weight per cent)			
	Raw Ilmenite	Oxidized Ilmenite 1000°C; 3 h	Reduced Ilmenite 1100°C 3 h	Final product (synthetic rutile)
TiO_2	53.85	68.5	66.07	94.64
FeO	16.76	0.0	—	—
Fe_2O_3	26.35	29.0	—	1.50
Fe (total)	—	—	28.06	—

Figure 4 shows the diffraction patterns of unoxidized reduced ilmenite and also preoxidized reduced ilmenite of same time duration. It is clearly seen that unoxidized reduced ilmenite still contains unreacted ilmenite and we can conclude that for better reduction, ilmenite has to be preoxidized. The amount of iron in the final product is largely decreased if ilmenite is oxidized at a higher temperature (1000°C 3 hrs). Table 6 shows the variation of iron content of synthetic rutile with oxida ion temperature.

TABLE 6. Variation of Ti and Fe content of Synthetic Rutile on Preoxidation Temperature of Ilmenite

Oxidation Temperature (°C)	Synthetic Rutile	
	TiO_2 %	Total Fe as Fe_2O_3 %
700	79.53	12.85
800	89.78	4.79
900	84.89	3.85
1000	93.17	2.88

From the above observation it is clear that to get a higher TiO_2 percentage in in the final product oxidation has to be carried out around 1000°C. Hence, for furthei studies the oxidation stage was carried out at 1000°C foi 3.00 hours duration.

4.3 Reduction Stage

Samples of preoxidized ilmenite were reduced in an autoclave (Figure 1) by using sawdust as the reducing agent, since this contained mainly carbonaceous material. Typical chemical analysis of the sawdust used is given in Table 7.

TABLE 7. Chemical Composition of Sawdust

	w/w %
Loss on ignition	99.44
SiO_2	0.21
CaO	0.21
MgO	0.03
Fe_2O_3	0.02
Al_2O_3	0.11
TiO_2	0.00
K_2O	0.01
Na_2O	0.01
Total	100.06

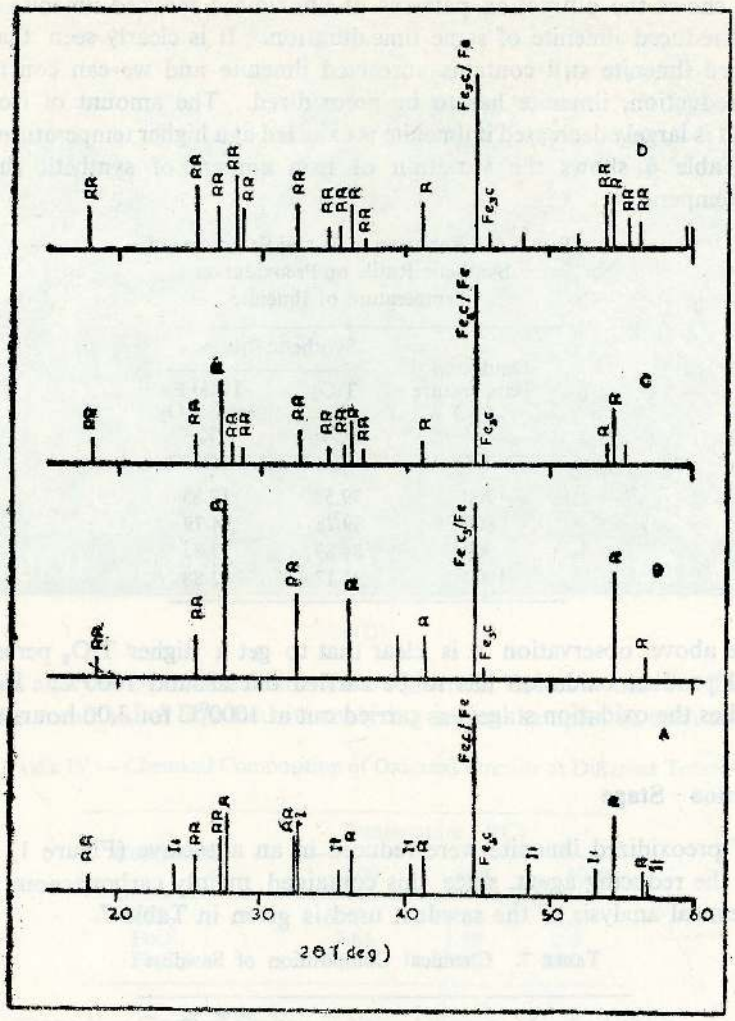


Figure 4. X-ray patterns of reduced ilmenite

A — Raw Ilmenite reduced at 1100°C 3 hrs.
B — Oxidized Ilmenite 800°C reduced at 1100°C 3 hrs.
C — Oxidized Ilmenite 900°C reduced at 1100°C 3 hrs.
D — Oxidized Ilmenite 1000°C reduced at 1100°C 3 hrs.

Il — Ilmenite RR — Reduced rutile
Fe_3C — Cementite R — Rutile
Fe — Iron

4.3.1 Effect of reduction temperature and duration

Initially a 1 : 1 mixture of sawdust (particle size - 44 BS mesh) mixture was used in the reduction stage for 3.00 hrs duration at different temperatures. Figure 4 shows the X-ray patterns of the reduced ilmenite. These observations reveal that sawdust could be used for successful reduction of iron values in ilmenite to metallic iron. In the reduction with sawdust, the reductant is ostensibly solid carbon, and much of the chemistry of carbon in the form of coke and CO has been found by several workers.[6,9,10,11,14] It is also clear that

(i) by keeping the duration of reduction for 3.00 hrs successful reduction occurs at temperatures around 1100°C.

(ii) the first stage of reduction is conversion of Fe^{3+} in pseudobrookite to Fe^{2+} in the form of ilmenite, (Figure 4). As a result the pseudo brookite concentration progressively decreases whereas that of ilmenite increases. This indicates that in the early stage of reduction ilmenite is reformed by a recombination reduction mechanism. The d - spacings of the reformed ilmenite were close to those for stoichiometric $FeTiO_3$.

$$Fe_2TiO_5 + TiO_2 + C \longrightarrow 2\ FeTiO_3 + CO \qquad (1)$$

(iii) the second stage of reduction is conversion of Fe^{2+} to metallic iron, as shown by XRD patterns. Hence, the ilmenite concentration progressively decreased and there was corresponding increase in the concentration of metallic iron and reduced rutile. The reduced rutile form (eq.3) was suboxides of titanium,[10] and no attempt was made to identify these oxides in this paper. (Figure 4).

$$FeTiO_3 + C \longrightarrow Fe + TiO_2 + CO \qquad (2)$$

$$nTiO_2 + C \longrightarrow Ti_n\ O_{2n-1} + CO \qquad (3)$$

Formation of cementite (Fe_3C) was also observed (reaction 4) in the reduced phases of ilmenite, as a result of the reaction between iron and carbon.

$$3\ Fe + C \longrightarrow Fe_3C \qquad (4)$$

Also it was clear from these results that, the optimum duration necessary for complete reduction of ilmenite at a temperature of 1100°C is 3.00 hrs. Figure 5 shows the reduction phases at different temperatures at different time durations.

Hence, for further studies a reduction temperature of 1100°C and a duration of 3 hrs was selected.

Chemical analyses of reduced phases are given in Table VI.

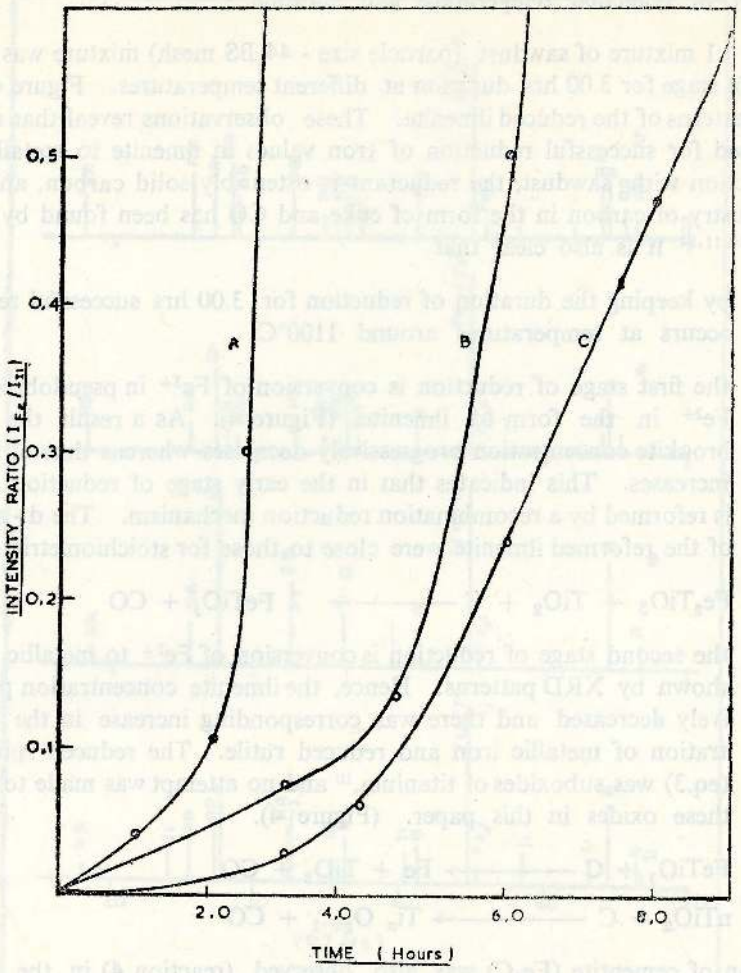


Figure 5. Effect of duration of reduction at different temperatures

$$\text{Intensity ratio} = \frac{\text{(Intensity of Fe line (110)}}{\text{(Intensity of Ilmenite line (104)}}$$

A — Preoxidized Ilmenite reduced at 1100°C
B — Preoxidized Ilmenite reduced at 1000°C
C — Preoxidized Ilmenite reduced at 900°C

4.3.2 Effect of amount of sawdust used for reduction

A series of experiments were carried out with varying amounts of sawdust and oxidized ilmenite at 1100°C for 3 hrs in an autoclave to study the effect of sawdust to ilmenite ratio on reduction. It was noted that sawdust to ilmenite ratio up to 1 : 4 could be used and with this ratio also a little amount of unreacted sawdust was left after reduction. This unreacted sawdust could be separated out and re-cycled. Therefore for further studies equal amounts of sawdust and ilmenite were used for the reduction.

4.3.3 Effect of particle size of sawdust

Sawdust of different particle sizes (-44, 44 - 30, 30 - 22, +22 BS mesh) was used for reduction and it was found that irrespective of the particle size of sawdust used, oxidized ilmenite is reduced at 1100°C. But it was noted that if the particle size is small the mixing before reduction with ilmenite and subsequent dressing of unreacted sawdust was easy.

4.3.4 Dressing

The purpose of this step is to separate unreacted burnt sawdust from reduced ilmenite. Since reduced ilmenite contains metallic iron, this separation could be easily carried out by using a magnetic separator. Also as the density of unburnt sawdust is comparatively low when compared to ilmenite, the separation also could be done by using a flotation technique. For our studies we used a simple gravity flotation technique. Separated unreacted burnt sawdust could be re-used in the reduction process.

5. Leaching Stage

The initial experiments were carried out by using laboratory grade hydrochloric acid (31% w/v) under refluxing conditions at normal atmospheric pressure.

5.1 Effect of Acid Concentration

Acids of different dilutions were used for leaching and each time the amount of metallic iron, TiO_2 and Mg dissolved in the solution were determined (Table 8).

TABLE 8

Strength of acid % v/v of 31% w/v acid	Weight loss in the sample % w/w	Amount dissolved (% w/w)		
		TiO_2	Mg	Fe
15	30.22	0.50	0.11	24.14
20	23.26	0.52	0.10	20.15
25	37.19	1.83	0.11	23.05
56	43.39	8.54	0.14	30.13

From these observations, it is clear that by increasing the concentration of acid the amount of iron leached out also increases. But accordingly the amount of TiO_2 dissolving also increases. Therefore, 20 - 15% v/v of 31% w/v HCl acid is good for the leaching stage.

5.2 Effect of Leaching Time Duration

15% and 20% v/v HCl acid was used for leaching and the amount of metallic iron dissolved in the solution at different time intervals was analysed to study the duration for complete leaching. Results obtained are given in Figure 6.

It is clear that for complete leaching of iron in reduced ilmenite at least 4.00 hrs is essential if 20% HCl of 31% w/v is used.

6. Calcination

XRD patterns of acid leached samples consisted of reduced rutile phases. Therefore, these samples were calcined to convert them to rutile. The DTA of acid leached sample was taken (Figure 7) and it was found to have an endothermic peak at about 550°C and an exothermic peak at about 970°C. The endothermic peak at 550°C indicates the oxidation of the leached sample. The exothermic peak at 970°C indicates the converson of titanium dioxide present in the sample to the rutile type of titanium dioxide.

6.1 Duration of Calcination

Acid leached reduced ilmenite samples were calcined at 1000°C for different time durations to study the optimum time duration required for conversion of reduced titanium dioxide to rutile. The XRD patterns of the oxidized samples were taken and it showed the presence of only the rutile phase.

From these observations the calcining temperature was selected as 1000°C and duration as 3.00 hrs to ensure good results.

6.2 Final Product

Figure 8 shows clearly that the final product is essentially pure rutile, and the mean value of chemical analysis of several samples obtained by this process is given in Table 9.

TABLE 9. Chemical Analysis of Synthetic Rutile Obtained

Component	%w/w
TiO_2	95.97
Fe_2O_3	1.57
MgO	0.86
Al_2O_3	0.80
MnO	1.21
SiO_2	0.69

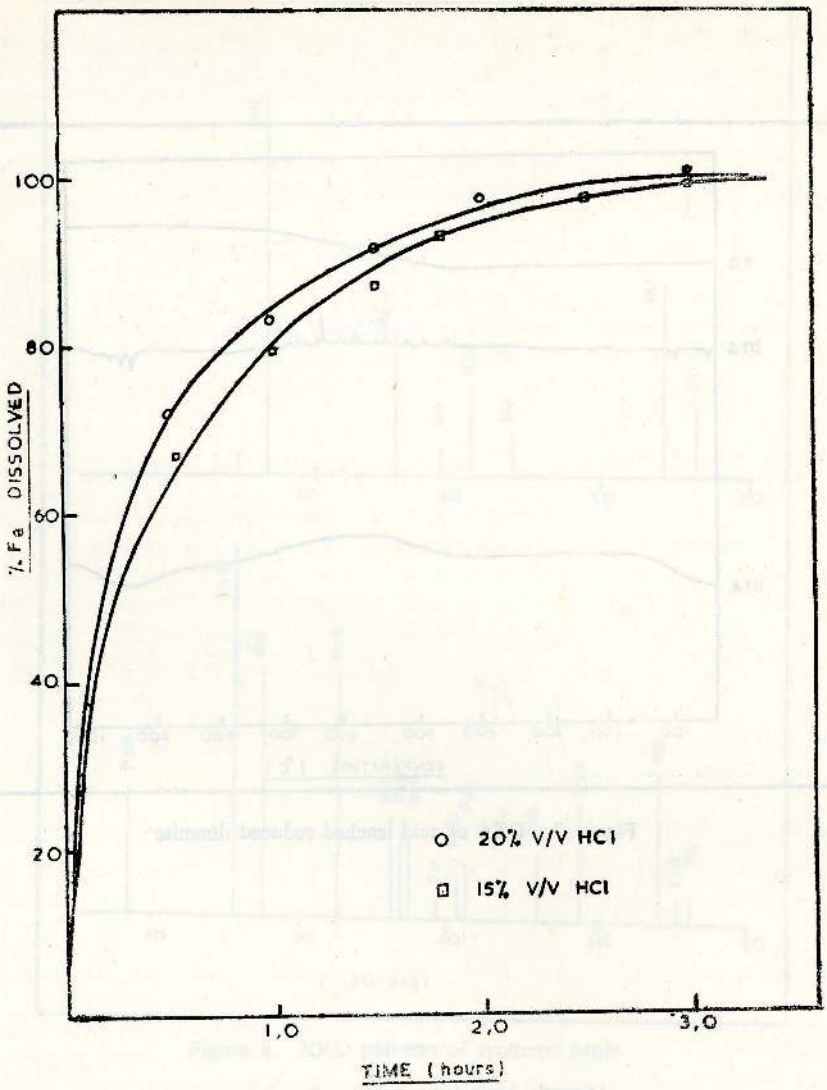


Figure 6. Effect of leaching time duration on the amount of iron leached out from the reduced sample in different acid solutions.

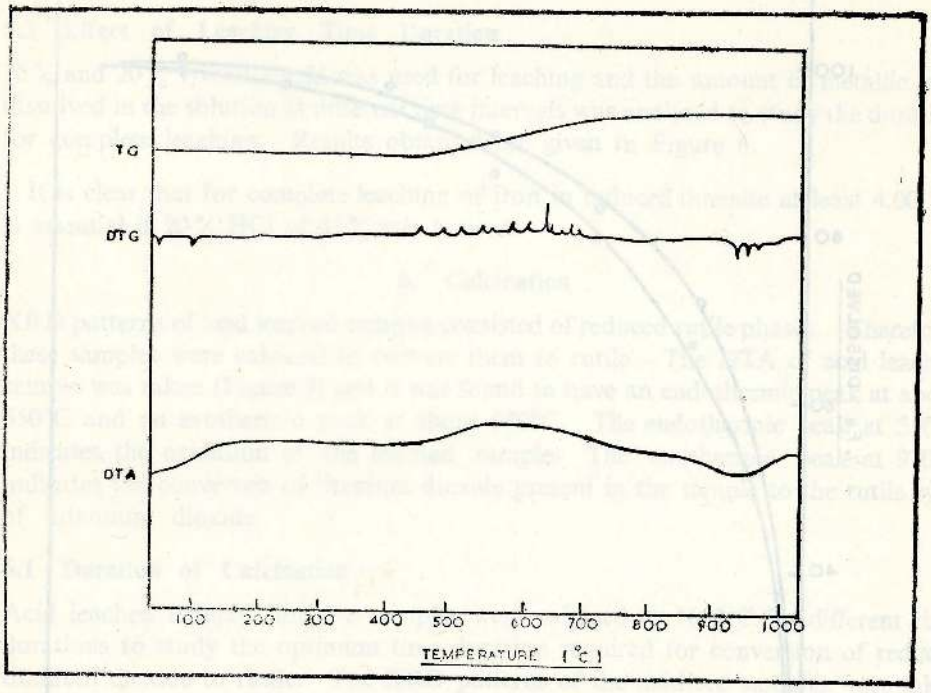


Figure 7. DTA of acid leached reduced ilmenite

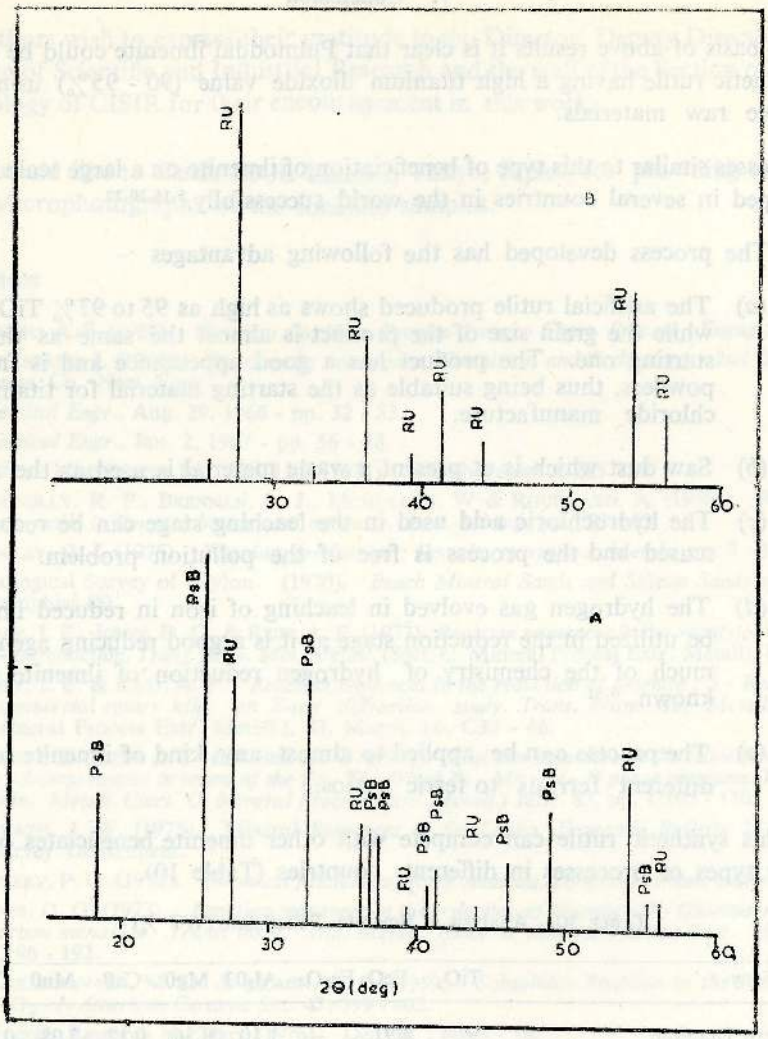


Figure 8. XRD patterns of synthetic rutile

A — from unoxidized ilmenite

B — from oxidized ilmenite

7. Conclusion

On the basis of above results it is clear that Pulmoddai ilmenite could be converted to synthetic rutile having a high titanium dioxide value (90 - 95%) using locally available raw materials.

Processes similar to this type of beneficiation of ilmenite on a large scale have been developed in several countries in the world successfully.[5,16,20,22]

The process developed has the following advantages :-

(*a*) The artificial rutile produced shows as high as 95 to 97% TiO_2 content, while the grain size of the product is almost the same as that of the starting one. The product has a good appearance and is free of fine powders, thus being suitable as the starting material for titanium tetrachloride manufacture.

(*b*) Saw dust which is at present a waste material is used as the reductant.

(*c*) The hydrochloric acid used in the leaching stage can be recovered and reused and the process is free of the pollution problem.

(*d*) The hydrogen gas evolved in leaching of iron in reduced ilmenite can be utilized in the reduction stage as it is a good reducing agent and also much of the chemistry of hydrogen reduction of ilmenite is already known. [6,21]

(*e*) The process can be applied to almost any kind of ilmenite ore having different ferrous to ferric ratios.

This synthetic rutile can compete with other ilmenite beneficiates obtained in similar types of processes in different countries (Table 10).

TABLE 10. Analysis of Ilmenite Beneficiate (WT %) [1]

Company	TiO_2	FeO	Fe_2O_3	Al_2O_3	MgO	CaO	MnO	Cr_2O_3	SiO_2
Western Titanium (Australia)	91.1	4.91	—	1.10	0.36	0.12	2.08	0.05	0.71
Gulf Chemical Metallurgical Corporation (USA)	90.0	—	5.86	—	—	—	—	—	—
Tiron Chemical Corporation (Canada)	92.6	2.71	—	1.65	0.28	0.43	1.57	0.08	0.67
Murphyores & CSIRO (Australia)	95.4	—	1.43	0.30	0.14	0.40	0.05	—	0.64
British Titan (U.K.)	92.1	2.62	1.17	—	—	—	—	—	0.86
Ishihara (Japan)	96.1	—	1.30	0.46	0.07	0.01	0.03	0.15	0.15
CISIR	95.97	—	1.57	0.80	0.86	—	1.21	—	0.69

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The Geology and Tectonic Setting of the Copper-Iron Ore Prospect at Seruwila – North East Sri Lanka

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1. Introduction

The occurrence of copper-iron ore at Seruwila, N.E. Sri Lanka, was discovered by the Geological Survey in 1971, during the systematic mapping programme of the Island on the reconnaissance scale of 1 : 63, 360 (1 inch to a mile). Detailed investigations at this prospect commenced in 1972, and included large scale mapping of the mineralized area, ground magnetometer reconnaissance and detailed surveys. A geochemical prospecting programme which included the collection of soil samples along the geophysical grid lines was initiated in 1976, but was abandoned as the area was found to be highly disturbed due to the past mining and agricultural activities. Abandoned pits with scattered magnetite and secondary copper minerals were traced and found to lie along the negative magnetic anomalies which show a high concentration of ore.[6] The area which is thickly forested is inaccessible and the access was from the survey lines set out on a grid of 20 metres. Drilling investigations carried out so far have revealed that the ore bodies containing magnetite and copper sulphides are lenticular in shape and concordant with the dip and strike of the host-rocks. The lenses of ore could vary from 1-10 metres in thickness. A report released by the Geological Survey in June 1977, incorporates the exploration work carried out up to the end of 1976. Since this prospect is the first base-metal find in Sri Lanka, the need for a detailed exploration programme, with the main objective of the assessment of grade and quantity was essential for the proper evaluation of the ore minerals present.

The feasibility studies for the exploitation of ore, if proved in economic quantities, will follow and a decision will be taken by the Government of Sri Lanka on the financing and execution of this mining venture. Since the Geological Survey is not properly geared to undertake an exploration programme of such magnitude, a world-wide tender was called for this project in 1977 with technical assistance from existing aid programmes in various countries. The offers were evaluated at the Ministry of Industries and Scientific Affairs and the B.R.G.M. in France was successful in getting the tender in early 1979. The detailed exploration programme at Seruwila commenced in July 1979 and was carried out jointly by the French BRGM and the Geological Survey Dept. The State Mining and Mineral Development Corporation

provided all the infra-structure facilities to successfully complete this programme three months ahead of schedule. The author was offered a fellowship to undergo training in various aspects of mineral exploration at the Institute of Geological Sciences in Great Britain under the Technical Assistance Scheme of the Colombo Plan from March-October 1978. During this training period the Seruwila-ore samples were studied in detail under the guidance of Mr. P. R. Simpson of the Applied Mineralogy Unit. This report incorporates the work carried out in U.K. with the main objectives of identifying the various ore minerals and also to unravel the tectonic setting and thus understand the genesis. This work also included a geochemical study of the ores and host-rocks.

2. General Geology of the Prospect

Seruwila falls on the boundary of the 1" Geological sheets of Trincomalee and Katheraveli and the area is underlain by high grade metamorphic rocks of Precambrian age. To the north-west of the area of mineralization, granulite facies rocks such as charnockites and quartzites are predominant and to the south-east, granites granitic gneisses and hornblende-biotite gneisses are the major rock types. The former rocks are grouped under the Highland Series and the latter forms the Vijayan Series. These two lithological zones are the major divisions of the Archean terrain of Sri Lanka.[2] The reconnaissance and detailed mapping of the Seruwila area revealed that the ore mineralization was at the boundary of the Highlands and the Vijayans.

The Seruwila area is flat but the distribution of outcrops is good. The main exposures are granites with pink feldspar, granitic gneisses, hornblende biotite gneisses (Vijayan) and charnockites and quartzites (Highlands). Dolerite dykes were observed mainly in the mineralized zone and these dolerites have tholeiitic affinities. Magnetite outcrops varying from 1-5 metres in length were seen in the mineralized zone. The host-rock for mineralization is an ultra-basic rock, highly weathered on the surface with secondary copper minerals such as malachite and azurite. Fresh host rocks were examined in detail after the surface drilling commenced and the minerals present are scapolite, hornblende, fluor-tremolite, apatite, diopside, with subordinate plagioclase (sodic-oligoclase), rare olivine and perthite. These ultrabasic rocks are highly altered and fractured with filling of secondary carbonate minerals. Some drill cores have shown veins of anhydrite in the host rocks. It is difficult to study both the mineralogical and chemical composition of the original rock due to the high degree of alteration. Nevertheless the host rocks appear to have gabbroic affinities that grade into monzonites. Rocks similar to granodiorites are also associated with the ultra-basic rocks and exposed to the north-east of the prospect. Scapolite forms an important constituent of the ultra-basic rock and crystals upto 2 cms long were seen in some cores. The granites and granitic gneisses occur as

low outcrops which are concordant to the ultra-basic rocks and the ore-bodies. These rocks are mainly composed of orthoclase and perthite with biotite and hornblende and grade into the hornblende biotite gneisses which are exposed to the south-east of the prospect.

A band of limestones (Marble ?) was seen at the contact of the mineralized zone with the country rocks to the north-east and is highly weathered. This limestone is coarse-grained with olivine (fayalite). A coarse grained Anorthosite was observed closely associated with the limestone. The composition of the plagioclase in the anorthosite is labradorite. This is the first recorded occurrence of anorthosite in Sri Lanka and can be compared with other Precambrian anorthosites in India, Africa, Madagascar and Antarctica as seen in the fits for Gondwanaland.[12] The regional strike of the area in N 50° E with steep dips of 70° - 80° to the northwest.

In a stereographic projection of the attitude of rocks in the Seruwila area there is evidence for parallel repetition of beds thus indicating isoclinal folding.

3. Ore - Mineralogy

Nine three-inch core samples of ore, disseminated ore, host rocks, limestones and granites were examined under both reflected and transmitted light in order to understand the relationships of silicate minerals to the ore minerals. Most of the samples were from Hole 16 put down at the southern part of the Seruwila prospect. This hole was selected as it had intersected limestones at depth and these samples have disseminated sulphides. The ore-mineralization at Seruwila is mainly catagorised as:-

(*a*) Massive magnetite - sulphide ore.

(*b*) Disseminated magnetite - sulphide ore.

(*c*) Trace-mineralization in ultra-basic host.

The massive magnetite-sulphide ore bodies vary in thickness from 1-10 metres and are very coarse-grained with magnetite, chalcopyrite, pyrrhotite and pyrite. The disseminated ores are mainly composed of magnetite, chalcopyrite, pyrrhotite, pyrite and the gangue minerals are scapolite, apatite, tremolite, diopside and hornblende. It was observed that chalcopyrite is comparatively well-developed in the massive ores compared with the disseminated ores, thus giving a higher copper content for the massive type. In drill hole 14 the reverse order was seen and thus the earlier observation cannot be generalized for the entire area.

The sulphides in the limestone (marble) sample S/16/22 were of special interest as this sample showed a very coarse grained texture. The sulphides are mainly pyrrhotite, pyrite with less chalcopyrite and magnetite. Pentlandite in the form of exsolution flames were seen in well developed pyrrhotite crystals and these flames were oriented parallel to each other and at right angles to the crystal length. The section was also studied under the electron microprobe using energy dispersive analyses and

the "flames" were confirmed as pentlandite with a composition of approximately Fe 32-37% Co 13-19% and Ni 8-13%. The cobalt content of the pentlandite was higher than the nickel and this fact was also revealed by the trace-element data for the sample determined on the emission spectrograph.

The limestones are coarse grained with calcite as a major constituent. Apatite and olivine occur as accessory minerals. Secondary carbonate veins were seen along fractures of the section and these veins contain sulphide minerals. Valleriite ($Cu\ FeS_2$) ($Mg\ Al\ Fe\ (OH)_2$) was also identified in these veins. Valleriite has also been recorded from Palaborawa carbonatites with copper mineralization[8] and the occurrence of Valleriite in the Seruwila ores may pose problems in the floatation of sulphides as encountered at Palaborawa. The electronmicroprobe studies have also rerevealed smythite (51.1% Fe 45.2% S) occurring as an alteration product of pyrrhotite in the limestones. Secondary veins containing serpentinite, anhydrite or gypsum are also present.

The sections examined revealed that secondary carbonate veins are present in the massive ores, disseminated ores, host-rocks carrying ores and limestones. These veins have sulphides (mainly pyrite, chalcopyrite and pyrrhotite) and secondary, magnetite. Therefore two phases of mineralization have been identified at Seruwila an earlier phase of massive magnetite and sulphides and a later phase of secondary magnetite and sulphides. The host rocks and their silicate minerals were examined in detail in order to understand the genesis of the ore. Scapolite is the most predominant mineral and occurs as well developed laths showing straight extinction and is closely associated with sodic-plagioclase. Well developed laths of tremolite showing high birefrengence were also seen. Hornblende was present in the form of large crystals with a pleochroism from green to brown. In the sections examined, augite and diopside are subordinate to hornblende, scapolite and tremolite. Plagioclase is of the sodic variety and was seen as large laths with alteration to sericite. Apatite was mainly in the form of sub-rounded to oval grains with numerous cracks and commonly seen as inclusions in magnetite. One granite sample (3/16/48) was studied and the mineralogical composition was mainly quartz and perthite with scarce hornblende. The section was from the contact of the granite with the ultra-basic rock.The contact was sharp and the granite did not show ore minerals except for a few scattered grains of sulphides.

4. Geochemistry of the Ore and Host Rocks

20 samples were analysed for the major and trace elements in order to ascertain the genetic relationships of the ore minerals to the host rocks and the granites. The samples were arranged into four groups (a) massive sulphide-magnetite ore (b) disseminated ore (c) ultra-basic rock with trace mineralization (d) granites and granite gneisses.

The major elements were determined on the Telsec-/β probe by direct electron excitation X-ray spectrometry and the trace elements on the Jarrell-Ash emission spectrometer at the Geochemical Division. Prior to the analyses each sample was scanned on the X-ray fluorescene spectrometer to get an idea about the trace-elements present. Copper could not be determined by emission-spectrometry as most of the ores (massive and disseminated) and host rocks had values far above the range of upper values of the standards. The iron values as total Fe_2O_3 were extremely high especially for the ores and thus the results are questionable. The high iron and copper values may have a certain amount of interference on the results of the other elements. The ultra basic rocks have a silica content varying from 34.70% to 51.61% and this variation could be related to the total iron content. The silica in the the disseminated ore showed a high variation from 7.39% - 36.30% and could be again related to the total iron. The massive sulphide - magnetite ores are extremely rich in iron with values up to 99.05% Fe_2O_3 (as total iron). The typical host rocks analysed are comparatively low in magnesia with high calcium and sodium.

The most interesting feature in the increase of fluorine with the total iron content (Fe_2O_3) and this variation was observed for all the samples examined except for the granites. The mineral phases that contain fluorine in the assemblages are apatite, tremolite and hornblende but it appears that there is a preferential enrichment by fluorine in magnetite as compared to the silicate and phosphate. The significance of this discovery will be discussed later. However the interference of iron on the fluorine values by the β - probe method cannot be ruled out at this stage and further work on this result will be carried out on the separated pure magnetite samples by analysing for fluorine by another method.

The trace-element data have revealed that the massive sulphide-magnetite ores are enriched in Co, Ni, Zn, Bi, Be, Ag, Pb and V as compared with the disseminated ore, ultra-basic rocks and the limestones. All these elements show a general tendency to increase with iron pointing to the fact that the trace-element concentrations may be in the magnetite and the sulphides or existing as discrete mineral phases intergrown with the major opaque phases. The low chromium and manganese values in all the samples analysed show that these elements are depleted in the environment of mineralization. The limestones analysed are depleted in the traces that are significant from the massive and disseminated ores but show the presence of silver (1.5 - 2.8 ppm) and comparatively high manganese values (437-754 ppm). The high Y, La, Sr and Ba values in limestones as compared with the other rocks are significant but it cannot be conclusively proved that the limestones are carbonatites without the presence of indicator minerals such as pyrochlore. The ultra-basic rocks are comparatively high in Cr, Mn and Zr. The high chromium values in the ultra-basic rocks may be attributed to the presence of pyroxene and rare olivine. The granites and granitic gneisses are enriched in Sr, Ba and Rb, depleted in all heavy trace elements but shows the presence of beryllium. This may be due to the albitisation of these granites and gneisses.

5. Tectonic setting of the Seruwila Prospect

As described earlier, the Seruwila copper-magnetite prospect is at the margin between the Highland Series and the Vijayan Series-both composed of high grade metamorphic rocks of Archean age. A recent gravity survey of the entire Island on a grid of approximately 4 miles indicated a significant gravity low of an amplitude of approximately - 25 milligals. This gravity low was observed running along the eastern boundary of the Highland Series.[3] The geological interpretation of this gravity low shows that the contact between the Highlands and the Vijayans is a trust zone. The Highland Series is overthrusting the Vijayan Series at a fairly high angle. The geological evidence for a trust contact along this boundary is :-

1. The presence of brecciated silicified rocks and calc-gneisses with tectonic breccias in the eastern part of the Polonnaruwa sheet.[14]
2. The presence of circular domes of serpentinite along the Highland - Vijayan contact in the south-east of the Island.
3. The submarine canyon with wall 1,350 meters high at Trincomalee contiguous with the Highland-Vijayan contact.

The highly crushed and altered nature of the host rocks at Seruwila at the Highland-Vijayan contact clearly indicates that the mineralization is at a tectonic trust-plane that appears to be extensive and could extend along the belt which is approximately 10 miles wide and 230 miles long. This belt runs along the Highland boundary from the north-eastern coast to the south-eastern coast of the Island.

An attempt is now made to understand the genesis of the Seruwila ores with the assembled ore-mineralogical and geochemical data in the light of its tectonic setting along a trust plane.

6. Genesis of the Seruwila Ores

It is quite clear from the examination of the host-rocks that the silicate minerals, scapolite, tremolite, apatite, hornblende and pyroxene are predominant. The unusual development of scapolite was given much thought as this mineral is comparatively rare in ore-assemblages. From the mineralogical examination of the samples it is clear that scapolite is post-magmatic. The association of scapolite with magnetite has been reported from mineral deposits characterised by very large metal resources specially in Russia - Kacharskoya, Sarabayskoe and Sokolotskoe from the Kazakhstan USSR.[13] In these deposits the amount of scapolite is comparable with the quantity of magnetite. Scapolite has also been recorded from near-ore metasomatites in a metasomatic magnetite deposit of Katanga.[5] Scapolite is also recorded from the magnetite deposits of the Swedish Lapland and in Kiruna ores. It is thus

apparent that the association of scapolite with the Seruwila ores may be significant and help in understanding the genesis of the ore. The association of scapolite and apatite clearly shows that the ore-forming solutions were rich in chlorine and fluorine thus pointing to an association with a marine environment. Regional scapolitization can also take place when the original sedimentary-volcanic sequence has significant intercalations of evaporite minerals such as halite, gypsum and anhydrite. Such beds are sources of Cl, S, B, Na, Ca and possibly Sr.[11] Scapolite is generally formed from alkaline solutions and the reactions tend to proceed with increasing acidity of the environment. The entry of fluorine into the apatite at this stage may be due to its higher electronegativity as compared to chlorine and possibly the acidic nature of the ore solutions.

From the ore-mineralogical studies there is evidence of scapolite being later than the ore. The scapolite replaces the ore and cuts it completely. This feature may be a result of serpentinisation processes effecting the host-rocks at shallow depth as part of a system reacting with circulating sea water. The circulation of sea-water may have been driven by a convecting cell attributed to a central hot-spot from the upper mantle. Thus there is evidence to conclude that the Seruwila ores were formed in a marine environment due to the interaction of sea-water with the ore bearing solutions. It was also observed that the fluorine content of the massive and disseminated ores increase with the increasing iron-content. If this discovery is proved beyond doubt by determining the fluorine content on the above by an alternative method, then the fluorine acted as a mode of conveyance for the mineralized fluids. Thus there is evidence to conclude that two generations of oxides are present in the Seruwila ores.

1. Oxides related to formation of the rocks or initial ore development. (Primary magnetite, chalcopyrite, pyrite, pyrrhotite).
2. Oxides formed as a result of late oxidation reactions (secondary magnetite, chalcopyrite, pyrite, pyrrhotite).

Attention is now drawn as to how the Seruwila ores reached the present areas of deposition in relation to the tectonic setting and an application of the modern plate tectonic theories to environments of ore deposition may be considered. Although the relation ship of ore genesis to plate tectonics is not generally clear in Old Precambrian shield areas, there are certain schools of thought who believe that global tectonic processes in rocks dating back to 600 m.y. and possibly up to 2200 m.y. are similar to those that occurred in relatively younger geological periods. An attempt is now made to reconstruct the events that took place during the emplacement of the Seruwila ores. It must be emphasised that it is rather premature to construct a plate-tectonic model with the available data, but analogies to younger ophiolite belts are drawn to bring out the similarities of the Seruwila ores to the tectonic environments of such belts. An ophiolite belt could be identified by its

tectonic setting and also by lithological groups which characterise a marine influence. The trace-element study of the magnetite at Seruwila has pointed to a volcanogenic-sedimentary origin[6] *et al.* and may have been deposited by volcanogenic-sedimentary processes.

The scattered occurrence of chert beds in the mineralized zone may also strengthen the case for a sedimentary environment. The limestones which have secondary serpentinite veins and also anhydrite may be of a sedimentary nature, but the possibility of these limestones being carbonatites cannot be resolved due to the lack of geochemical data. The ultra-basic rocks which have gabbroic affinities may also fit into an ophiolite sequences. The tectonic emplacement of serpentinite bodies to the south along the Highland-Vijayan thrust contact is also significant. The granites at Seruwila have some affinities to Hercynian granites in Europe due to the high content of barium and rubidium and may be considered to be post collision type.[1] Thus the above lithological types have some similarities to idealized complete ophiolite sequences from various parts of the world such as Cyprus, Red Sea, etc. The tectonic setting at Seruwila also indicates that the ophiolites have been significantly altered and crushed into a 'melange'.

The limestones at Seruwila contain magnetite, apatite and subordinate sulphides. Such limestones are common in the Pacific basin along the line of orogenic activity in the eastern margin of the American continents and spreads to Japan, Australia and Malaya.[10] In this paper[10] there is a reference to a mine at Kamishi in Japan where a body of granodiorite and associated igneous rocks intrudes a sequence of Mesozoic limestones, shales and sandstones. An extensive skarn and hornfels zone developed along the contact and lenticular bodies of massive magnetite were deposited in and adjacent to the skarn. Minor amounts of haematite, chalcopyrite, bornite, pyrite and pyrrhotite, sphalerite, Gelena, gold and silver are disseminated in the magnetite. The trace element data on the Seruwila ores and the presence of limestones with magnetite and apatite points to a similar mode of ore formation as at the Japanese occurrence. The probable sequence of events for ore-mineralization at Seruwila can be summarised as follows:-

1. Volcanic eruption below the ocean floor (submarine volcanism) in the form of a strato-volcano giving rise to magma at depth.
2. A deep seated rift in the oceanic and continental crust reaching the mantle brought up the ore bearing fluids and magma thus giving rise to massive copper-magnetite ores and original host rocks (gabbros).
3. The movement of the above magma and separated ore. solutions was in a fluorine and chlorine rich environment (due to marine influence) thus giving rise to a second generation of oxide formation due to late oxidation reactions. At this stage widespread scapolitisation of the host rock took place.

4. The thrusting of the ocean floor over the Vijayan Series. This tectonic movement may have been caused by excess pressure on the Vijayan in a north-west direction. The ocean floor was thus obducted to form a 'melange' at the margin of the Highlands and Vijayans.

It is not clear as to the stage at which granites and limestones were formed in the above sequence. The granites may be post-collision in nature and formed after the Vijayans collided with the Highlands and may be deep-seated younger granites. If this assumption is correct the granites have to be younger than the ore mineralization at Seruwila. The limestones may be igneous in origin and formed from a carbonate magma or may be metamorphosed calcareous sediments of the ocean floor.

The above sequence of events point to the fact that the mineralization at Seruwila was of a submarine-volcanic type and formed due to the fumarolic activity of a strato-volcano below the ocean floor. The mineralized solutions were brought to the areas of deposition by sea water circulation driven by a convecting cell with the heat generated from a central hot - spot. The formation of ores is thus a part of the obducting process (uplift) and the ores have formed due to the reaction of ore solutions with convecting sea-water. Later oxidation reactions of the hydrothermal fluids thus gave rise to late oxide ores which is a second phase of ore formation. The lenticular nature of the ore-bodies was the result of the overthrusting thus giving rise to a 'skarn' type similar to the Japanese occurrence described earlier. Therefore the overall charateristics of the tectonic setting at Seruwila is similar to that of an obducted ophiolite belt and the mineralization has similarities to a 'besshi type' formed by continental collision.[9] Such types of ore bodies are generally absent or rare in the Archean.[4] Pyrite - chalcopyrite ore bodies of this nature are common in ophiolites that show an early stage of orogenic activity and are generated at ocean ridge - rift environment during the initial stages of separation of continental blocks. The abundance of copper and iron in cupreous pyrite deposits suggest that these metals in the volcanogenic family of deposits are mainly of ocean crust-mantle derivation.[4]

7. The Relationship of Mineralization at Seruwila to Continental drift by Ocean Floor Spreading

The recent reconstruction of Gondwanaland fits Sri Lanka at the interspace between Antarctica, Africa, Madagascar and India. Smith and Hallam[12] detached Sri Lanka from India and by inspection fitted it further south. This fit is at 130 m. y. and the present position of Sri Lanka with respect to India was reached at about 100 m. y.[7] In the spreading history of the southern Indian Ocean from 130 m.y. to the present it is observed that Sri Lanka underwent an anti-clockwise rotation with its movement with the Indian sub-continent north-wards. The eastern margin of Sri Lanka at 130 m. y. (upper cretaceous) was in line with the continental margin

of Antarctica and with the separation of the Island from Antarctica, a deep rift at the eastern part of Sri Lanka developed, thus giving rise to a narrow opening between the Highlands and the Vijayans. The sub-marine volcanic activity giving rise to strato-volcanoes may be related to this period (Upper Cretaceous). With the northern flight of Sri Lanka with the Indian sub-continent much pressure was applied on the Vijayan and the narrow opening of the sea between the Highlands and Vijayans closed thus obducting the ocean floor. Thus the mineralized belt at Seruwila which runs south for over 250 miles may have characteristics of a narrow oceanic crust of a marginal sea. It must be stressed that this interpretation is somewhat speculative and it will be critical at this stage to date the sulphide mineralization to prove this point. It is thus tentatively suggested that the ore-mineralization at Seruwila may have taken place during the Upper Cretaceous period (130 - 100 m. y.) and is extensive along the Highland-Vijayan boundary.

8. Present Interpretation of the Tectonic Environment at Seruwila and its Bearing on Future Exploration Programmes

It is now evident that the ore-mineralization at Seruwila is along a deep seated thrust zone at the contact between the two major lithological divisions-Highlands and Vijayans. This deep seated thrust is tentatively interpreted as an obducted ophiolite belt which has undergone a very high degree of alteration and deformation due to the collison and overiding of the Highlands/Vijayans. Thus the lithological characteristis and the tectonic setting at Seruwila is similar to a 'melange' from ophiolite belts in other parts of the world specially in Cyprus and the Red Sea.

This obducted ophiolite zone (melange) is mineralized at Seruwila and is rich in iron (magnetite) and sulphides (mainly copper). There are indications of minor amounts of nickel (pentlandtite rich in cobalt) silver and bismuth. The limestones which are exposed at the north-western contact of the mineralized zone with the country rocks were examined in detail for the first time and contain sulphides with traces of silver. This contact zone has to be very carefully studied for possible cobalt-nickel mineralization. The tectonic interpretation of the Seruwila ores attempted in this paper leads to new ideas of ore mineralization and it appears that hot magmatic or recirculating brines were involved. Thus this marine environment will be encouraging for extensive base-metal mineralization along this thrust contact (ophiolite belt?) which runs for about 250 miles. Metals such as copper, cobalt, nickel and zinc are a possibility along this zone. It is noted that precious metals such as gold and silver may be encountered in such an environment. The possibility of hydrothermal platinum ores have to be kept in mind as most platinum minerals are associated with chalcopyrite. In the New Rambler Mine, Wyoming,[8] the platinum metals are derived by the hydrothermal leaching of a meta-gabbroic complex similar to Seruwila. The presence of

circular bodies of serpentinite to the south of Seruwila along the thrust zone is encouraging and these bodies have not been examined in detail so far. Kimberlites too occur in deep seated fractures and this fact has to be kept in mind when the mineralized belt is examined in detail.

The work carried out at the Geochemical Division of the Institute of Geological Sciences in London has conclusively proved that the tectonic setting and the host rocks at Seruwila are definitely favourable for base metal and possibly precious metal ore-emplacement. Therefore a detailed exploration programme has to be initiated to examine in detail this entire belt which is approximately 2500 sq miles in extent.

The Geological Survey of Sri Lanka can undertake such a task with assistance from foreign surveys under existing technical assistance programmes. It must be stressed that embarking on such an exploration programme very early may eventually pay very rich dividends and give an unimaginable boost-up to the Sri Lankan economy if base metals and possibly precious metals are proved to be present in large quantities which would warrant exploitation.

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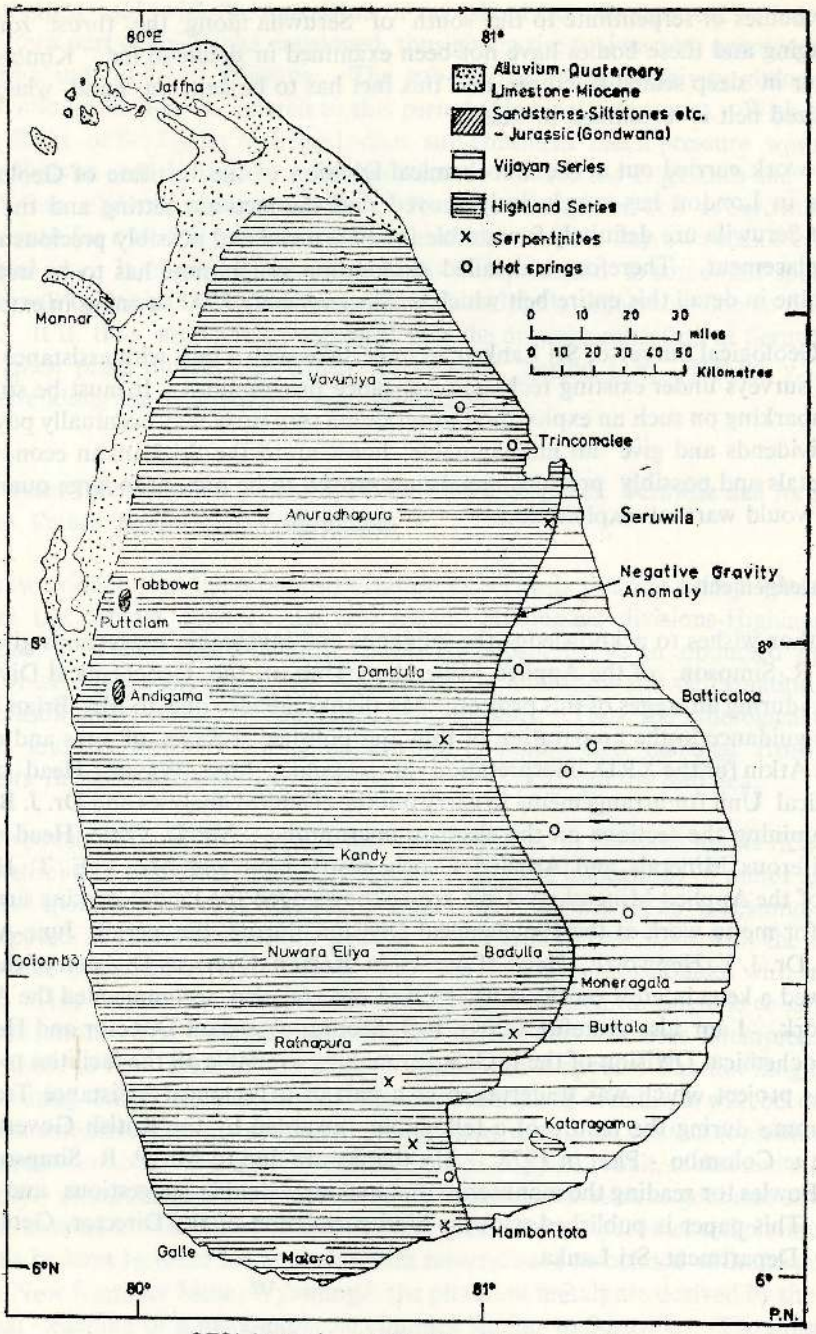
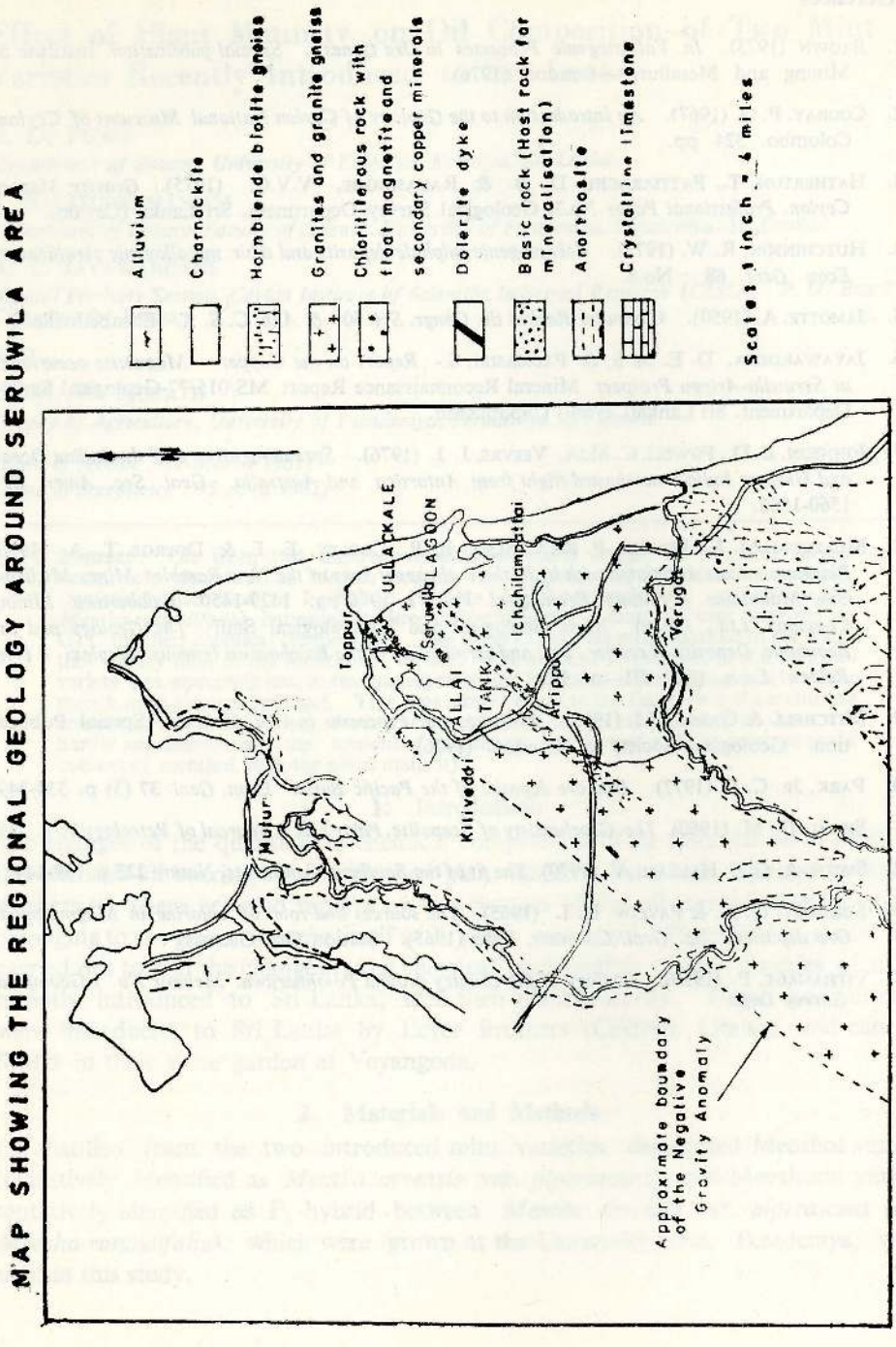


GEOLOGICAL MAP OF SRI LANKA



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Effect of Plant Maturity on Oil Composition of Two Mint Varieties Recently Introduced to Sri Lanka

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Abstract : Oil from two different varieties of mints designated Menthol variety (tentatively identified as *Mentha arvensis* var. *piperascens*) and Menthone variety (tentatively identified as F_1 hybrid between *Mentha arvensis* var. *piperascens* and *Mentha rotundifolia*) harvested in three different stages of maturity were analysed by GLC for their chemical composition. The effect of age was more marked in the Menthol variety than in the Menthone variety. The amount of menthol in the Menthol variety was extremely low at two month stage and increased to its highest level at three month stage (blooming stage). This was almost equal to the decrease in the menthone content of the same variety during this period In the Menthone variety there was hardly any difference in the content of menthone, but showed a slight increase in the content of menthol with the plant maturity.

1. Introduction

The changes of the quantitative chemical composition of the essential oil in most of the essential oil bearing crops with their plant maturity have been reported by many workers.[4,5] There are also reports on the changes of the oil composition of plants belonging to the genus *Mentha* itself with plant maturity.[3] Therefore a study was carried out to find the changes in the chemical composition of two varieties of more recently introduced to Sri Lanka, with their plant maturity. These two varieties were introduced to Sri Lanka by Lever Brothers (Ceylon) Limited and can be found in their spice garden at Veyangoda.

2. Materials and Methods

Oil distilled from the two introduced mint varieties designated Menthol variety (tentatively identified as *Mentha arvensis* var. *piperascens*) and Menthone variety tentatively identified as F_1 hybrid between *Mentha arvensis* var. *piperascens* and *Mentha rotundifolia*), which were grown at the University farm, Peradeniya, were used in this study.

Transplanting of suckers in the field were carried out in June. The suckers were 3 to 4 weeks old when the transplanting was carried out. Plants were harvested at three different stages of maturity, namely, two, three and four months after transplanting. In each case plants were harvested from three separate plots (per variety per harvest) which served as 3 replicates in this experiment. Three months after transplanting stage coincided with the full bloom stage and also gave the highest herbage yield in this experiment. Before distillation the harvested material was dried in the shade till it was about one-third of its fresh weight. Then the semi-dried herb was chopped and 800g of withered herb was well packed into the flask and water was added sufficiently to cover the charge. Oil was obtained by steam distillation procedure using a laboratory type still made of glass. Period of distillation was prolonged up to three hours, to ensure the maximum distillation of oil.[2]

After oil distillation, the oil samples were stored in tightly stoppered bottles under refrigeration until the Gas-Liquid chromatography (GLC), by which the different constituents and their exact amounts in the oil were studied. GLC analyses were carried out using a Varian - 1700 instrument equipped with flame ionization detector. Analysis was carried out with 10% Carbowax 20M column, 3m long and 3mm diameter, held isothermal at 60°C for 2 minutes, programmed at 2°C per minute to 140°C and then 4°C per minute to 160°C. The injector and detector temperatures were 200°C and 220°C respectively and sample size was 0.7 μl. Tentative peak identification was made by comparing retention data with master chart. The technique of peak enrichment was employed to confirm the identification.

3. Results

The age of harvest had an effect on the quantitative chemical composition of oil in mints. This effect was more marked in the Menthol variety than in the Menthone variety. There was a striking difference in the content of menthol of Menthol variety between the different ages of harvest namely two, three and four months after transplanting. The amount of the major component menthol in this variety was extremely low (as low as 0.53%) at two month stage, increased to its highest level 77% at the three month stage and again declined to a low value of about 69.9% at four month stage (Table 1). At the same time, the amount of menthone in this variety (Menthol variety) was extremely high (as high as 81%) at the two month stage, decreased to its lower level of 4% at three month stage and this low level was maintained at four month stage (Table 1). There was hardly any difference in the content of major component menthone in Menthone variety, between the different ages. The amount of menthone was maintained at its high level of 72-76%. However, the menthol content of oil in this variety was low (0.56%) at two month stage, increased to a moderate level (4.9%) at three month stage and this high level was maintained at four month stage (Table 1).

TABLE 1. Chemical Composition of Oil extracted from Plants harvested in different Stages of Maturity

Compound	Menthol variety			Menthone variety		
	2 months	3 months	4 months	2 months	3 months	4 months
1. α-Pinene	0.05	0.09	0.91	1.32	1.14	0.63
2. Camphene	trace	trace	trace	0.03	—	trace
3. β-Pinene 4. Unidentified	0.08	0.22	1.22	1.46	1.40	1.22
5. α-Phellandrene	0.16	0.17	0.04	0.87	0.72	0.63
6. α-Terpenene	—	—	—	—	—	—
7. Limonene	1.37	1.12	1.86	7.49	4.48	5.06
8. π-Terpenene	trace	trace	trace	trace	trace	trace
9. ρ-Cymene	trace	—	trace	0.17	trace	trace
10. Unidentified	trace	trace	trace	trace	trace	trace
11. 3-Hexenol	trace	—	0.06	0.10	0.20	0.33
12. Unidentified	—	—	—	trace	trace	—
13. 3-Octanol	1.03	0.78	0.72	1.18	1.08	1.03
14. Thujone	—	—	—	—	—	—
15. Menthone	81.44	4.78	6.78	73.55	72.17	76.78
16. Iso-menthone	8.27	2.69	2.51	7.35	7.20	4.02
17. Unidentified	trace	—	—	trace	trace	trace
18. Linalool	0.40	0.26	0.18	0.23	0.20	0.22
19. Unidentified	trace	5.74	—	trace	0.71	1.00
20. Menthyl acetate	0.29		3.28	0.32		trace
21. Piperitone oxide	1.90	3.33	9.36	1.66	1.58	1.79
22. β-Caryophylene	trace	trace	trace	trace	trace	trace
23. Menthol	0.55	77.65	69.96	0.86	4.95	4.27
24. Pulegone	0.29	0.54	1.05	0.25	0.52	0.35
25. Carvone	0.84	0.58	0.44	0.53	0.58	0.39
26. Piperitone	4.05	2.07	1.65	2.75	3.26	2.69
* Total monoterpene hydrocarbons	1.66	1.60	4.23	11.34	7.74	7.54

* α-Pinene + camphene + β-pinene + ρ-phellandrene + α-terpene + Limonene + π-terpinene + β-cymene.

There was also remarkable differences in the contents of some of the minor components of oil namely total monoterpene hydrocarbons (Table 1), iso-menthone, piperitone oxide and piperitone between the different stages of the crop. In the Menthol variety there was no difference in the amount of total monoterpene hydrocarbons between the two month stage and three month stage while it increased to a moderate level (4.2%) at four month stage. In the Menthone variety the amount of total monoterpene hydrocarbons was very high at two month stage (11.3%) and declined to 7% at both three and four month stages. The amount of iso-menthone of Menthol variety was high (8%) at two month stage and showed a decline (to 2.6%) at both three and four month stages whereas in Menthone variety it was high (7%) at two month and three month stages and showed a decline (to 4%) at four month stage.

The content of piperitone oxide in oil of Menthol variety was low (1.9%) at two month stage, increased to 3% at three month stage and further increased to a high level (to 9%) at four month stage, whereas its content did not show any appreciable difference between the different ages in Menthone variety. The amount of piperitone in oil of Menthol variety was moderate (4%) at two month stage and showed a decreasing tendency with age, while it did not show any appreciable difference between the ages in Menthone variety.

4. Discussion

The effect of age of plant at the time of harvest on the quantitative chemical composition of mint oil was in agreement with the reports of Parry[4], Viramani and Datta[5] and Murray, Fass and Marble[3] who indicated that harvesting stage of the plant had an influence on the quantity and quality of the essential oil in most of the essential oil bearing crops. These changes in the amount of chemical constituents may be mainly attributed to the flowering physiology of mint since at three months age flowering commonced in both varieties of mints. It was observed that the effect of age was highly remarkable on the menthol content. In fact, the menthol content in Menthol variety rose from trace amount to its very high level of 77% when the plants reached flowering stage (three months). The increase in the menthol content from the early vegetative phase (two months) to 'full bloom' stage (three months) was almost equal to the decrease in the menthone content of oil during this period. This could be explained on the basis that the ketone menthone was the first product of biogenesis of mintoil and the conversion of this ketone to the alcohol menthol was completed when the plants reached the flowering stage. A similar observation have been reported by Datta and Viramani[1] who showed that the menthol content in mint plants increased while the percentage of menthone decreased with increasing age of plants.

Thus it becomes important to harvest the crop at three month stage in Menthol variety in order to obtain the maximum yield of menthol. In the case of Menthone variety where the major component was menthone the time of harvest did not have any appreciable effect on the menthone content of oil. The level of menthone throughout its growing period in this variety was generally high and it may be attributed to its genetic constitution. Thus the stage of harvest need not be an important criterion for the composition of oil in Menthone variety. However, even in this variety it would be desirable to take harvest at three month stage because it was found that the maximum oil yield could be obtained at this stage.

The remarkable changes in the content of some of the minor components of oil may also be attributed to the flowering physiology of the crop. It was noticed that the monoterpene hydrocarbons, iso-menthone and piperitone decreased in their amounts with age. Since these components of mint oil are commercially undesirable,

harvesting at three months stage would maintain these levels low. It was also observed that the content of piperitone oxide increased remarkably with age from 1.9% to 9%. However, the levels of these constituents were comparatively lower at three month stage (3%) than that of four month stage. Therefore harvest after three month stage should be avoided in mint cultivation.

5. Conclusion

The effect of age was highly remarkable in the Menthol variety. The content of menthol, in Menthol variety was extremely low (0.53%) at two month stage and increased to its highest level (77%) at the three month stage and again declined to a low value of about 69.9% at four month stage. Although there was hardly any difference in the content of menthone in Menthone variety, the menthol content of oil in this variety too showed a slight change between the different ages. Since these changes were remarkable during three month stage or at the blooming stage, these changes in the amount of chemical constituents may be mainly attributed to the flowering physiology of mints.

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Takahashi's Antitubercle Phosphatide Kaolin Agglutination Test (KAT) in Extrapulmonary Tuberculosis

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Abstract : A sensitive serodiagnostic test would be of value in the diagnosis of extrapulmonary tuberculosis where the conventional confirmatory tests often need an invasive biopsy. The antitubercle phosphatide kaolin agglutination test (KAT) which has been shown to be of value in the serological diagnosis of pulmonary tuberculosis was investigated on 210 patients with extrapulmonary tuberculosis in comparison with 494 patients with pulmonary tuberculosis and 315 healthy blood donors. The KAT was found to be of no value in the diagnosis of extrapulmonary tuberculosis as the agglutinating titres were low and similar to those of blood donors.

1. Introduction

Takahashi's[3] 'antitubercle phosphatide kaolin agglutination test' (KAT) has been studied by several investigators [2,4,5] as a diagnostic test in pulmonary tuberculosis. The consensus is that it is of value in the diagnosis of pulmonary tuberculous disease. This simple and easily performed serological test may be of particular use in poor countries in which the current diagnostic tests for pulmonary tuberculosis are the more expensive X-ray and bacteriological examinations.

The diagnosis of extrapulmonary tuberculosis on the other hand often requires an invasive biopsy, usually done under general anaesthesia. Thus a reliable serodiagnostic test, if available, would be of value in the diagnosis of extrapulmonary tuberculous disease. This study was done to assess the value of the KAT in the diagnosis of extrapulmonary tuberculosis.

2. Experimental

2.1 The reagents

The test reagents (tris buffer, kaolin suspension and methanolphosphatide antigen) were obtained from the manufacturers of the test kit (Messrs Daichi Seiyaku Co., Tokyo, Japan) and the test was done as prescribed by the manufacturers and as reported in our earlier study of patients with pulmonary tuberculosis.[2]

2.2 The test

Buffered saline alone instead of diluted serum was used with each batch of tests as the suspension control, while a known positive control serum (from rabbits) supplied with the kit, with an antiphosphatide agglutinating titre of over 1 : 512 was used as the positive control.

2.3 The patients

The patients (n = 210, Table 1) examined were those undergoing treatment at the Chest Clinics in Kandy and Colombo, for extrapulmonary tuberculosis, which was diagnosed by biopsy and histological examination in the majority (80%) of patients. The reactivity of their sera was compared with that in patients with active pulmonary tuberculosis (n = 494) and in healthy blood donors (n = 315). Sera were stored at -20°C pending use.

TABLE 1. Diagnostic categories of the 210 patients with extrapulmonary tuberculous disease.

Disease	Number of Patients
Tuberculous adenitis	148
Bone and joint tuberculosis	20
Tuberculous enteritis and peritonitis	18
Genito-urinary tuberculosis	9
Tuberculous meningitis	8
Tuberculous pericarditis	2
Tuberculous mastitis	2
Tuberculous adenitis and peritonitis	2
Tuberculous meningitis and adenitis	1

3. Results

The frequency distribution of antitubercle phosphatide agglutinating titres in sera from patients with extrapulmonary tuberculosis is shown in Figure 1 in comparison with that in patients with pulmonary tuberculosis and in the blood donors. The KAT titres in patients with extrapulmonary tuberculosis were low in contrast to those in patients with pulmonary tuberculosis and resembled those in blood donors.

4. Discussion

In a study of the bacteriology of tuberculous adenitis in South India,[1] *Mycobacterium tuberculosis* was isolated from 100 out of 101 cases (99%) with *Mycobacterium scrofulaceum* having been isolated from only 1 case. Similar results have been obtained in Sri Lanka (Pinto, unpublished data), suggesting that non-tuberculous mycobacteria are uncommon in adenitis. Thus it is unlikely that the preponderance of non-reactivity and low titres in patients with adenitis, was due to non-tuberculous mycobacterial disease.

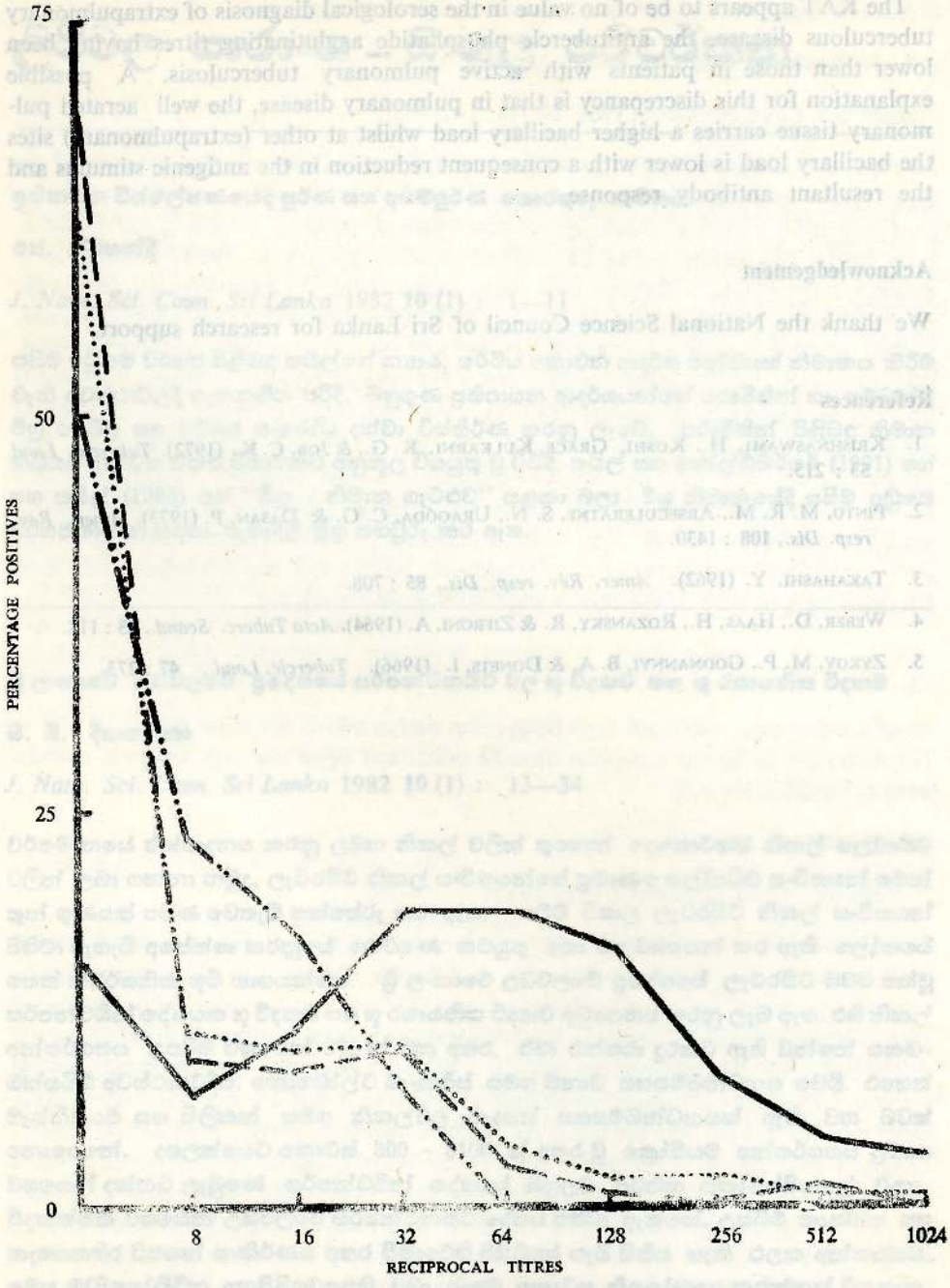

Figure 1. The frequency distribution of antitubercle phosphatide agglutination titres in 210 patients with extrapulmonary tuberculosis (.....), 148 patients with tuberculous adenitis (———) 494 patients with pulmonary tuberculosis (————) and in 315 healthy blood donors (—— · · ——)

The KAT appears to be of no value in the serological diagnosis of extrapulmonary tuberculous disease, the antitubercle phosphatide agglutinating titres having been lower than those in patients with active pulmonary tuberculosis. A possible explanation for this discrepancy is that in pulmonary disease, the well aerated pulmonary tissue carries a higher bacillary load whilst at other (extrapulmonary) sites the bacillary load is lower with a consequent reduction in the antigenic stimulus and the resultant antibody response.

Acknowledgement

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ලිපිවල සාරාංශ – සිංහල පරිවර්තන

ප්‍රතිපායන විශ්ලේෂණයේදී සූර්ණ සහ අසම්පූර්ණ තොරතුරු භාවිතය.

එස්. විරහන්දි

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සසිම අඩුතම වර්ගජ පිළිබඳ තයිල්ගේ න්‍යාය. රේඛීය නොවන ආදර්ශ පන්තියක් නිමානය කිරීම වැනි අවස්ථාවලදී පැනනගින පරිදි, බහුගුණ ප්‍රතිපායන ආදර්ශයන්ගේ පරාමිතීන් හා සම්බන්ධ මිශ්‍ර රේඛීය සහ වර්ගජ සංරෝධ දක්වා විස්තීර්ණ කරනු ලැබේ. පරාමිතීන් පිළිබඳ නිමාන කිසියම් නිශ්චිත ඒකජ සීමාවකට අනුකූල වියයුතු වූ විටදී, තයිල් සහ ගෝල්ඩබර්ගර් (1961) ගේ සහ තයිල් (1963) ගේ "මිශ්‍ර නිමාන ගැටළුව" යළකා බලා මිශ්‍ර නිමානයේදී සසිම අඩුතම වර්ගජ නිමාන සඳහා පැහැදිලි සූත්‍ර තහවුරු කර ඇත.

ශ්‍රී ලංකාවේ උඩවලවේ ප්‍රදේශයේ සර්පන්ටිනයිට් වල භූ විද්‍යාව සහ භූ රසායනික විද්‍යාව

සි. බී. දිසානායක

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වර්තමානයේ නිෂ්පාදනය කරනු ලබන නිකල් වලින් තුනෙන් දෙකොටසක් නිකල් සල්ෆයිඩ වලින් ලබා ගන්නා නමුදු, ලැටරයිට් නිකල් සංචිතයන්ගේ ප්‍රමාණය සල්ෆයිඩ සංචිතයන් මෙන් තුන් ඉණයක් පමණ වෙතැයි තක්සේරු කර ඇත. මෙම විශාල ලැටරයිට් නිකල් සංචිතයන් පිහිටා ඇතැයි අපේක්ෂා කරනුයේ ගවේෂණ කටයුතු ඉතා මඳ වශයෙන් කර ඇති ලෝකයේ තෙත් නිවර්තනික භූමි භාගයන්හිය. ශ්‍රී ලංකාවේ උඩවලවේ ප්‍රදේශයේ ලැටරයිට් බවට පත්වූ සර්පන්ටයින් දේහයක භූ විද්‍යාව සහ භූ රසායනික විද්‍යාව අධ්‍යයනය කරනු ලැබ ඇත. එහි නිකල් අන්තර්ගතය උපරිම වශයෙන් 2% ක් වන අතර, ඒවා එක්තරා දුරකට ඇති වන්නේ යකඩ-ඔක්සයිඩ අවස්ථාවේදීය. කොබෝල්ට් මැංගනීස් සමග මිනාව සහසම්බන්ධතය වෙයි. එහෙත් මැග්නීසියම් සහ සිලිකන් සමග නිකල්වල වැදගත් සහසම්බන්ධතයක් ඇති වන බවක් නොපෙනේ. දශලක්ෂයට කොටස් 300 – 3100 ත් අතර වූ ක්‍රෝමියම් අන්තර්ගතය ප්‍රධාන වශයෙන් දක්නට ලැබුණේ සර්පන්ටයින් දේහයේ බහුලව පවතින ක්‍රෝමයිත්පිනෙල් වලය. විද්‍යාත්මක වශයෙන් උඩවලවේ සර්පන්ටිනයිට් දේහය පිහිටා ඇත්තේ, උස්බිම් කාණ්ඩය සහ නාගෙනහිර විජයන් සංකීර්ණය අතර සීමාවෙහි පිහිටියේ යැයි සිතිය හැකි ඵලක අන්තයකය. මෙය ඔෆියෝලිටික අනුපිළිවෙළෙහි වඩා ජංගම කොටස නියෝජනය කරන්නක් විය හැක.

ශ්‍රී ලංකාවේ නුමුහුන් සහ මුහුන් ඊරියන්ගේ සහ පැටවුන්ගේ කරණියතාව

ආර්. රාජමහේන්ද්‍රන් සහ ආර්. එම්. බී. ප්‍රනාන්දු

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මෙම අධ්‍යයනයේ ප්‍රධාන අරමුණ වූයේ, ශ්‍රී ලංකාවේ මැදරට ප්‍රදේශයේ ඇති කරන නුමුහුන් සහ මුහුන් ඌරන් අතර ඊරියන්ගේ සහ පැටවුන්ගේ කරණියතාව අගැයීමයි. මෙහිදී, නියෝජනය වූයේ නුමුහුන් ලාජ්වයිට් වර්ගයත්, ලැන්ඩ්රේස් වර්ගයත්, ඔවුන්ගේ පරස්පර මුහුන් වර්ගත්ය. දත්ත එක්රැස් කර ගන්නා ලද්දේ වික්ටෝරියා ගොවිපළෙහි, 1976, 1980 වර්ෂද ඇතුළුව ඒ අතරතුර කාලපරිච්ඡේදය පිළිබඳව තබා තිබුණු වාර්තා වලිනි. උත්පත්තියේදීද, සති 8 දීද, නුමුහුන් වර්ගවල පැටවුන් මුහුන් වර්ගවල පැටවුන්ට වඩා සංඛ්‍යාවෙන් විශාල වූහ. උත්පත්තියේදීත් සති 8 දීත් විශාලම ප්‍රමාණයේ (පිළිවෙලින් 9.92 සහ 8.1) පැටවුන් වූයේ නුමුහුන් ලාජ්වයිට් වර්ගයේයි. තවද උත්පත්තියේදීත්, සති 8 දීත් නුමුහුන් වර්ගවල පැටවුන්ගේ බර මුහුන් වර්ග වල පැටවුන්ට වඩා බෙහෙවින් අධික විය. උත්පත්තියේදී ලැන්ඩ්රේස් වර්ගයේ පැටවුන්ගේ බර (කි. ග්‍රෑ. 14.09) ලාජ්වයිට් වර්ගයට (කි. ග්‍රෑ. 12.76) වඩා බෙහෙවින් අධික විය. කෙසේ වුවද සති 8 දී මෙම දෙවර්ගයේම පැටවුන්ගේ බරෙහි වෙනසක් නොපෙනිණ. කිරි වැරීමේ සිට ඔසප්වීම අතරතුර කාල පරිච්ඡේදය, නුමුහුන් වර්ග සම්බන්ධයෙන් බෙහෙවින් කෙටිය. කෙටිම කාලසීමාව (දින 8.24) වාර්තාවූයේ ලාජ්වයිට් නුමුහුන් වර්ගයෙනි. විශ්ලේෂණය කිරීමේදී, පැටවුන්ගේ උත්පත්තියේදී බර, සති 8 දී බර සහ කිරි වැරීමේ සිට ඔසප් වීම දක්වා කාල පරතරය පිළිබඳ වැදගත් සාම්‍යතා බලපෑම් ද හෙලි විය.

පොල් වගාවක අතුරු භෝගයක් ලෙස වවනු ලබන සෝයා බෝංචි (Glycine max (L) merr) වල වැඩීම සහ අස්වැන්න කෙරෙහි නයිට්‍රජන් වලින් සහ පැල සිටුවීමේ පරතරය කෙරෙන් ඇතිවන බලපෑම්

එම්. ජී. එල්. ඩී. මාටින්

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ඊසානදිග මෝසම් කාල පරිච්ඡේදයේ ශ්‍රී ලංකාවේ අන්තර් මධ්‍ය කලාපයේ මේරූ පොල් වගාවක අතුරු භෝගයක් වශයෙන් වගාකළ සෝයා බෝංචි (CV. Bragg) වල වැඩීම සහ අස්වැන්න කෙරෙහි, නයිට්‍රජන් පොහොර යෙදීමෙන් සහ පැල සිටවීමේ පරතරය කෙරෙන් ඇතිවූ බලපෑම් පිළිබඳව වාර්තා කෙරෙයි. ලැබෙන බීජ අස්වැන්න සහ පැලයක ඇති කරල් සංඛ්‍යාව කෙරෙහි නයිට්‍රජන් වලින් වැදගත් බලපෑමක් ඇති විය. අධිකතම අස්වැන්න (හෙ. $^{-1}$ කි. ග්‍රෑ. 447.8) සහ කරල් සංඛ්‍යාව වාර්තාවූයේ හෙක්ටයාර් $^{-1}$ ට නයිට්‍රජන් කි. ග්‍රෑ. 33.6 මට්ටමේදීය. කරල් සංඛ්‍යාව හැරුණු විට, පැලැට්වල උස, ගැටිති සංඛ්‍යාව, පත්‍ර වර්ගඵල සූචිය (එල්. ඒ. අයි), වියළි ද්‍රව්‍ය අස්වැන්න, බීජවල ප්‍රෝටීන් ප්‍රතිශතය සහ තෙල් ප්‍රතිශතය, හා සෙසු අස්වනු සංරචක කෙරෙහි නයිට්‍රජන් වලින් වැදගත් බලපෑමක් ඇති නොවිණ. අඩු පරතරයකින් සිටුවූ පේළි වල බීජ අස්වැන්න, පත්‍රවර්ගඵල සූචිය සහ වියළි ද්‍රව්‍ය අස්වැන්න, පුළුල් පරතරයකින් සිටුවූ පේළි වලට වඩා සැළකිය යුතු තරම් වැඩි විය. අධ්‍යයනයට භාජනය කළ සෙසු ලක්ෂණ කෙරෙහි පරතරය කෙරෙන් වැදගත් බලපෑමක් ඇති නොවීය.

ශ්‍රී ලංකාවේ උඩවත්ත කැලේ වනාන්තරයේ මදුරුවන් (Diptera : Culicidae) පිළිබඳ නිරීක්ෂණ

එච්. පී. අමරසිංහ

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ශ්‍රී ලංකාවේ මහනුවර පිහිටි උඩවත්ත කැලේ සංරක්ෂිත වනයේ කරන ලද ක්ෂෙත්‍ර අධ්‍යයනයේදී මදුරු විශේෂ තිස්හයක් පිළිබඳව වාර්තා විණ. බෝවන ස්ථාන (උණ කොටන්, කිතුල් කොටන් ගස් බෙන, දිය කඩිති) වලින් විශේෂයන් 17 කට අයත් කීට අවස්ථා එක්රැස් කර ගන්නා ලදී. වැඩි වශයෙන් ඩුයේ ස්වාභාවික ධාරක වසස්ථානයන්හි හමුවූ *Culex* (*Lophoceraomyia*) *uniformis* (Theobald), *Aedes* (*Stegomyia*) *krombeini* Huang, *Aedes* (*Stegomyia*) *albopictus* (Skuse) සහ *Toxorhynchites* (*Toxorhynchites*) *splendens* (Wiedemann) මදුරුවන් හා දිය කඩිති වලින් හමුවූ (*Aedes* (*Verrallina*) *pseudomediofasciatus* (Theobald) සහ *Anopheles* (*Cellia*) *elegans* (James) මදුරුවන්ය. බෝවන ස්ථාන වල තනි විශේෂ හා විවිධ විශේෂයන්හි පැවතුම් රටාවක් වාර්තා විය. *Ae. albopictus* සහ *Ae. krombeini* අතර ධන අභිසංගමයක් ද, *Ae. albopictus* සහ *Tx. splendens* අතර සෘන අභිසංගමයක් ද උණ බම්බු වාසස්ථාන වල දක්නට ලැබිණ. දිවා කාලයේදී මිනිසුන් ඇම වශයෙන් යොද මදුරු විශේෂයන් විසි එකක් අල්ලා ගන්නා ලදී. වඩාත්ම බහුල වූයේ *Ae. albopictus* සහ *Armigeres* (*Armigeres*) *subalbatus* (Coquillett) ය. වනාන්තරය තුල මොඩුන්ගේ විදීම් ක්‍රියාකාරීත්ව මට්ටම් පිළිබඳ මූලික විග්‍රහයක් සපයා ඇත. වෛද්‍ය විද්‍යාත්මක වශයෙන් වැදගත් වන *Aedes* (*Stegomyia*) *scutellaris* කාණ්ඩයේ මෑතදී වාර්තා වී ඇති විශේෂයක් වන *Aedes krombeini* මෙම ප්‍රදේශයේ බහුලව බෝ වුවද, මිනිස් ඇමට ආකර්ෂණය වූයේ විරළ වශයෙනි.

කොළඹ දිස්ත්‍රික්කයේ බෘසෙලෝසිස් රෝගය

යූ. ජී. ජේ. එස්. වික්‍රමසූරිය, එස්. කුමාරස්වාමි

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කොළඹ දිස්ත්‍රික්කයේ (වර්තමාන කොළඹ සහ ගම්පහ දිස්ත්‍රික්ක) කිරිපට්ටිවල බෘසෙලෝසිස් රෝග අවස්ථා, මිල්ක් රිං පරීක්ෂණය (එම්.ආර්.ටී) මගින් සමීක්ෂණය කර, සැකයට භාජනය වූ **ඔස්තු** සම්බන්ධයෙන් ප්‍රමිත ග්ලූටිනීකරණ පරීක්ෂණය (එස්. ජී. ටී.), අනුපූරක ස්ථායීකරණ පරීක්ෂණය (සි.එච්.ටී) සහ කුමිස් පරීක්ෂණය (සී.ටී.) බදු ප්‍රමාණාත්මක පරීක්ෂණ පැවැත්වීමෙන් තහවුරු කරගනු ලැබ ඇත. සමස්ථ වශයෙන් කිරි දෙනුන් 1478 දෙනෙක් සම්බන්ධ කරගනිමින් ගව පට්ටි 305 ක් පරීක්ෂාවට භාජනය කරන ලදී. පට්ටි ආසාදනය 1.6% ක් වූ අතර තනි සතුන්ගේ ආසාදනය 0.9% ක් විය. සන්සන්දනාත්මක වශයෙන් බලනකල ආසාදනය අඩුව පැවතීම, සැහීමකට පත් වීමට හේතුවක් නොවිය යුතුය. මෙම තත්ත්වය, පුළුල් ලෙස පැතිරිය හැකි ආසාදනයක ආරම්භය වීමට බොහෝ සෙයින් ඉඩ ඇත.

ශ්‍රී ලංකාවේ ඉල්මනයිට් වියෝජනය මීම පිළිබඳ අධ්‍යයන

එම්. ජී. එම්. යූ. ඉස්මයිල්, ජේ. අමරසේකර, ජේ. එස්. එන්. කුමාරසිංහ

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ශ්‍රී ලංකාවේ ඉල්මනයිට් සහ රූටයිල් තැන්පතු, නැගෙනහිර සහ වයඹදිග වෙරළේ වැලි වශයෙන් දක්නට ලැබේ. දැනට ශ්‍රී ලංකාවෙන් වාර්ෂිකව ඉල්මනයිට් සාන්ද්‍රණ ටොන් 65,000 ක් පමණ, කිසිදු යහකරණයකින් තොරව, ප්‍රධාන වශයෙන්ම වර්ණක නිෂ්පාදකයින් වෙත අපනයනය කරනු ලැබේ. දේශීය වශයෙන් ලබාගත හැකි අමු ද්‍රව්‍ය භාවිතයෙන් ඉල්මනයිට් වලින් කෘත්‍රිම රූටයිල් නිපදවීම සඳහා ලංකා විද්‍යාත්මක සහ කාර්මික පර්යේෂණායතනය මගින් පවත්වා ඇති රසායනාගාර අධ්‍යයනයන්හි ප්‍රතිඵල සමහරක්, මෙම ලිපිය මගින් සමාලෝචනය කෙරෙයි. මෙම ක්‍රියාවලියේ ප්‍රධාන ලක්ෂණය වන්නේ, ඉල්මනයිට් වල යකඩ අඟයන් අම්ල ක්ෂරණීය ස්වභාවයකට ඔක්සිහරණය කිරීම සඳහා යහකරණ ක්‍රමයකදී ඔක්සිහාරකයක් වශයෙන් ප්‍රථම වරට ලී කුඩු භාවිතා කිරීමයි. මෙසේ සකස් කරන ලද ක්‍රියාවලියේදී ඉල්මනයිට් ප්‍රථමයෙන්ම ඔක්සිකරණය කර පසුව ලී කුඩු භාවිතයෙන් ඔක්සිහරණය කරනු ලැබේ. ඔක්සිහරණය කළ ඉල්මනයිට් වල ඇති යකඩ ඉවත් කිරීම සඳහා ඒවා හයිඩ්‍රොක්ලෝරික් අම්ලයෙන් ක්ෂරණය කරනු ලැබේ. අවසන් සාන්ද්‍රණය, TiO_2 95% කින් පමණ යුත් රූටයිල් ඛවට පත්වන සේ හස්මීකරණය කරනු ලැබේ. ක්ෂරණය කළ දියරයෙන් හයිඩ්‍රොක්ලෝරික් අම්ලය ලබාගත හැක. මේ අතර, රතු වර්ණක සේ භාවිතා කළ හැකි යකඩ ඔක්සයිඩ අතුරු නිෂ්පාදනයක් වශයෙන් ලැබේ.

මෑතදී ශ්‍රී ලංකාවට හඳුන්වා දෙන ලද මින්ට් වර්ග දෙකක ශාක පරිණතභාවය ඒවායේ තෙල්වල සංයුතිය කෙරෙහි බලපාන ආකාරය

බෝ. ඩී. පිරිස්, එස්. බාලසුබ්‍රමනියම්, ඒ. එල්. ජයවර්ධන, එච්. එම්. ඩබ්. හේරත්

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මෙන්තෝල් විශේෂය (තාවකාලික වශයෙන් *Mentha arvensis* var. piperascens විශේෂය නමින් හඳුන්වා ඇති) යනුවෙන්ද, මෙන්තෝන් විශේෂය (තාවකාලිකව *Mentha arvensis* var. piperascens විශේෂය සහ *Mentha rotundifolia* අතර මූහුන් F_1 නමින් හඳුන්වා ඇති) යනුවෙන් ද නම් කර ඇති, එකිනෙකට වෙනස් මින්ට් වර්ග දෙකක් මේරීමේ විවිධ අවස්ථා වන් තුනකදී නෙලාගෙන, ඒවායේ තෙල්වල රසායනික සංයුතිය සොයා ගැනීම සඳහා ජී. එල්. සී. ක්‍රමයට විශ්ලේෂණය කරන ලදී. මෙන්තෝන් වර්ගයට වඩා මෙන්තෝල් වර්ගයේ මේරීමේ බලපෑම වැඩියෙන් දක්නට ලැබිණ. පරිණතභාවය මාස 2 වන අවස්ථාවේදී මෙන්තෝල් වර්ගයේ පැවති මෙන්තෝල් ප්‍රමාණය ඉතා පහත් වූ අතර තුන්මස් අවස්ථාවේදී (මල් හට ගන්නා අවස්ථාවේදී) උපරිම මට්ටමට වැඩි විය. එය මෙම කාල සීමාව තුල මෙන්තෝන් අන්තර්ගතයේ පිරිහීමට බොහෝ දුරට සම විය. මෙන්තෝන් වර්ගයේ ශාකය මේරීමත් සමග එහි මෙන්තෝන් අන්තර්ගතයේ වෙනසක් නොමැති තරම් වූ අතර, මෙන්තෝල් ප්‍රමාණයේ සුළු වැඩිවීමක් දක්නට ලැබිණ.

බහිර් පුප්ඵුසිය ක්ෂය රෝගයේදී ටකාමිගේ ප්‍රතිටියුබකල් ෆොස්ෆටයිඩ් කෙඔලින් ග්ලූටිනිකරණ පරීක්ෂණය (කේ. ඒ. ටී.) යොදා ගැනීම.

එම්. ආර්. එම්. පිත්ටෝ, එස්. එන්. අර්යකුලරත්න, එල්. වී. වැලිඅංග, සී. ජී. උරගොඩ සහ එන්. ගමගේ

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ආක්‍රමණික පෙළවෙක්ෂාවක් අඩංගු කරන සාම්ප්‍රදායික සනාත කිරීමේ පරීක්ෂණ වලට වඩා, සංවේදී මස්තු-රෝග-නිර්ණ පරීක්ෂණයක් පැවැත්වීම, බහිර් පුප්ඵුසිය ක්ෂය රෝගය නිර්ණයට, ප්‍රයෝජනවත් වේ. ක්ෂය රෝගයේ මස්තුවේදී නිර්ණයට වටිනා වන්නා වූ ප්‍රතිටියුබර්කල් පොස්පටයිඩ් කෙඔලින් ග්ලූටිනිකරණ, පරීක්ෂණය, බහිර් පුප්ඵුසිය ක්ෂය රෝගය ඇති රෝගීන් 210 දෙනකු පුප්ඵුසිය ක්ෂය රෝගය ඇති රෝගීන් 494 දෙනකු සහ සාමාන්‍ය සෞඛ්‍ය තත්වයේ සිටින ලේ දන් දෙන්නන් 315 දෙනකු සයදා බැලීමෙන්, විමර්ෂණය කර තිබේ. ග්ලූටිනිකරණ ටිටර් අඩු නිසාත් ඒ සමගම එම ටිටර්, ලේ දන් දෙන්නන්ගේ ටිටර් වලට සමාන නිසාත්, බහිර් පුප්ඵුසිය ක්ෂය රෝගය නිර්ණය කිරීමට, පොස්පටයිඩ් කෙඔලින් ග්ලූටිනිකරණ පරීක්ෂණය, වටිනා නොවන්නේය.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

பிற்செலவுப் பகுப்புத் தொடர்பில் முழு, முழுவல்லாத தரவுகளின் பயன்பாடு பற்றியது.

எஸ். வீரகந்தி

J. Natn. Sci. Coun. Sri Lanka 1982 10(1): 1—11

தேலின் (Theil's) தடுப்புற்ற இழிவு வர்க்கக் கொள்கையானது மடங்குப் பிற்செலவு மாதிரியுருப் பரமானங்களின் மீதியலும் கலப்பு ஒருபடி, இருபடி விகாரப்படை நேர்வு வகைக்கு, எடுத்துக்காட்டாக, ஏக பரிமாணமல்லாத மாதிரியுருக்களின் வகுப்பொன்றை மதிப்பிடும் போது எழுந்த வகைக்கு விரிக்கப்பட்டுள்ளது. பரமானங்களின் மதீப்பீடுகள் எந்தவொரு செப்ப முற்ற ஏகபரிமாணத் தடுப்பினையும் திருத்தியாக்க வேண்டிய நிர்ப்பந்தம் ஏற்பட்டபோதெல்லாம் தேல்-கோல்பேகர் 1961 இலும் தேல் 1963 இலும் கண்டுபிடித்த ''கலப்பு மதிப்பீட்டுப்பிரசினம்'' உம் ஆழ்ந்து ஆராயப் பட்டுள்ளது. அத்துடன் ''கலப்பு மதீப்பீடுசார் தடுப்புற்ற இழிவு வர்க்க மதிப்பிடுகைகளுக்கான'' வெளியார்ந்த சூத்திரங்களும் நிறுவப்பெற்றுள்ளன.

இலங்கையில் உடவளவே சர்ப்பன்றயினேற்று சார் புவிச்சரிதவியலும் புவியிரசாயனமும்

சி. பி. திசாநாயக்கா

J. Natn. Sci. Coun. Sri Lanka 1982 10(1): 13—34

இப்பொழுது உற்பத்தியாக்கப்படும் நிக்கல் உலோகத்தின் மூன்றில் இரண்டு பகுதி நிக்கற்சல்பைட்டு மூலம் பெற்றுவருவதாயினும் இலத்தறைற்று (செம்பூரான்கல்) நிக்கல் இருப்புவளங்களில் சல்பைட்டு மூலம் பெற்றுவரும் அளவினைவிட மும்மடங்கு நிக்கல் உலோகம் உண்டெனக் கணக்கிடப்பட்டுள்ளது. இப் பெரிய இலத்தறைற்று நிக்கல் இருப்புவளங்கள் புவியின் ஈர அயனமண்டலத்திணை நிலங்களில் அமைந்துள்ளன. இந்த உலோகம் தொடர்பில் இதுவரை இத்திணைநிலங்களில் மேற்கொண்டுள்ள பரிசோதனைகள் விரல் விட்டு எண்ணக்கூடியவை.

இலங்கையில் உடவளவே பிரதேசத்தைச் சேர்ந்த செம்பூரான் கல்லாகப் பரிணமித்த சர்ப்பன்றயின்யாக்கையொன்றின் புவிச்சரிதவியலினையும் புவியிர சாயனத்தையும் அறிதற்பொருட்டு ஆராய்ச்சி மேற்கொண்டுள்ளது. இதன் நிக்கல் அளவு 2% உயர்வினைக் காட்டுவதுடன் இரும்பொட்சைட்டு அவத் தையில் சிறிதளவாக அமைவதாகவும் உள்ளது. கோபாற்று மங்கனீசுடன் கன்கு தொடர்வு கொள்வதாயினும் மகனீசியம், சிலிக்கன் என்பவற்றுடன்

குறிப்பிடத்தக்க அளவில் நிக்கல் உலோகம் தொடர்வு கொள்வதில்லை எனத்தெரிகிறது. 300—3100ppm அளவினதான குரோமியம் பெரும்பாலும் சர்ப்பன்றயின் யாக்கையினுள் குரோம்சிபினல் வடிவத்தில் அமைந்திருந்த தென்பது கண்டறியப்பட்டது.

புவிச்சரிதவியற் கண்கொண்டு நோக்குகையில், மேல்நிலத்தொகுதி, கிழக்கு விசயன் தொகுவம் ஆகியவற்றின் எல்லையினுள் இருக்கக்கூடிய தகடோரத்தில் உடவளவே சர்ப்பன்றயினேற்று யாக்கை அமைந்துள்ளது. அத்துடன் அது பாம்புக்கல் தொடர்வினைவொன்றின் அதிகம் இடம் பெயர்வுக்குள்ளான பகுதியாகவும் இருக்கலாம்.

இலங்கையில் தூயவின, கலப்பினப் பன்றிகளின் பெண், ஓரீற்றுக் குட்டிச் செயல் நிறைவேற்றம்

ஆர். இராசமகேந்திரன், ஆர். எம். பி. பர்ணந்து

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இலங்கையின் மத்திய பகுதிகளில் வளர்க்கப் பெற்ற தூயவினக் கலப்பினப் பன்றிகளின் பெண், ஓரீற்றுக்குட்டிச் செயல்நிறைவேற்றத்தினை மதிப்பிடுதல் இந்த ஆய்வின் பிரதான நோக்கமாக அமைந்தது. இவ்வாய்வின் போது தூய பெரிய வெண் பன்றிகள், உள்ளூர் பன்றிகள், இவ்விரண்டு இனங்களின் தலைகீழ் கலப்பு இனப்பெருக்கத்தால் பிறந்த பன்றிகளும் பயன்படுத்தப்பட்டன. 1976 ஆம் ஆண்டு முதல் 1980 ஆம் ஆண்டு (இதுவும் உட்பட்டு) வரை விக்டோரியா பண்ணையில் பேணப்பட்ட பதிவுகளிலிருந்து தரவுகள் சேகரிக்கப் பெற்றன. பிறப்புக் காலத்திலும் 8 வார காலத்திலும் அமைந்த கலப்பினப் பன்றிகளின் ஓரீற்றுக்குட்டித் தொகையினை விட தூய வினப் பன்றிக் குட்டிகளின் தொகை அதிகமாக விருந்தது. தூய பெரிய வெண் பன்றிகளின் ஓரீற்றுக் குட்டித்தொகை — பிறப்புக் காலம் (9.92), 8 வாரக்காலம் (8.1) ஆகிய முறையில் மிகப் பெரிதாக விருந்தது. அதுபோன்று தூயவினப் பன்றிகளின் ஓரீற்றுக் குட்டித் தொகையின் எடையும் ஈன்ற பொழுதிலும் 8 வாரங்கள் சென்ற பொழுதிலும் கலப்பினக் குட்டிகளின் எடையினைவிடக் குறிப்பிடத்தக்க உயர்வினைக் கொண்டிருந்தது. பெரிய வெண் பன்றிக் குட்டிகளின் பிறப்புக் கால எடையினைவிடக் (12.76 கிலோ கிராம்) உள்ளூர்ப்பன்றிக்குட்டிகளின் பிறப்புக்கால எடை (14.09 கிலோ கிராம்) அதிகமாகும். ஆனால் இவ்விரண்டு பன்றிக் குட்டிகளுக்கிடையில் 8 வாரக்கால எடையில் எந்தவிதமான வித்தியாசமும் அவதானிக்கப்படவில்லை. தூயவினப் பன்றிகளின் பால் மறப்பு தொடக்கம் காம வெப்பம் ஏற்படும் காலம் வரையிலான இடைவெளி குறுகியதெனக் குறிப்பிடல் வேண்டும். இவற்றுள்ளும் பெரிய வெண் தூயவினப் பன்றிகளின் இடைவெளியானது (8.24 நாட்கள்) மிகக் குறுகியதாகவே காணப்பட்டது. பிறப்புக் காலத்துக் குரியதும் 8 வாரக் காலத்துக்குரியதுமான குட்டிகளின் எடை, பால் மறப்புக் காம வெப்பக் கால இடைவெளி என்பனவற்றுக்குரிய முக்கிய ஒப்புமை விளைவுகள் சிலவும் கண்டறியப்பட்டன.

தென்னந்தோப்புகளில் நடுகை செய்யப்பெற்ற சோயா அவரையின் (Glycine max. (L) merr.) வளர்ச்சி விளைச்சலின் மீது நைதரசன் இடைவிடல் என்பன ஏற்படுத்தும் விளைவுகள்

எம். பி. எல். டீ. மாற்றின்

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வடகீழ்ப் பருவக்காற்று மழைக்காலத்தில் இலங்கையின் இடைவலயத்து முதிர்வுற்ற தென்னை மரங்களுக்கடியில் மாற்றுப்பயிராக வளர்க்கப்பெற்ற சோயா அவரை (CV. Bragg.) யின் வளர்ச்சி விளைச்சலின் மீது நைதரசன் உர உபயோகமும் இடைவிடலும் ஏற்படுத்துகின்ற விளைவுகள் தரப்பட்டுள்ளன.

விதை விளைச்சல், ஒரு செடியில் உண்டாகும் நெற்றுக்களின் எண்ணிக்கை ஆகியவற்றின் மீது நைதரசன் குறிப்பிடத்தக்க தாக்கத்தை ஏற்படுத்தியது. பதிவான மிக உயர் விளைச்சல் (447.8kg ha^{-1}) ஆகவும் நெற்று எண்ணிக்கை 33.6 kg ha^{-1} ஆகவும் இருந்தது. நெற்று எண்ணிக்கை நீங்கலாக, செடியின் உயரம் சிறு கணுக்களின் தொகை, இலை பரப்புச் சுட்டி (LAI) உலர்ப் பொருள் விளைச்சல், புரத நூற்று வீதம், விதைகளில் அடங்கும் எண்ணெய் நூற்று வீதம் விளைச்சற் கூறுகள் ஆகியவற்றின் மீது நைதரசன் குறிப்பிடத் தக்க தாக்கத்தை ஏற்படுத்தவில்லை. அகன்ற வரிசை இடைவிடலிலும் பார்க்க நெருக்க முறு வரிசை இடைவிடல் வாயிலாக அமோக விதை விளைச்சல் கிடைத்ததென்பது குறிப்பிடத்தக்கது. ஆய்வுக்கு உட்பட்ட ஏனைய சிறப் பியல்பு எவற்றின் மீதும் இடைவிடல் காரணமாகக் குறிப்பிடத்தக்க தாக்கம் ஏற்பட்டிருக்கவில்லை.

இலங்கையின் உடவத்தைகெலே காட்டில் உள்ள நுளம்புகள் (Diptera Culicidae) பற்றிய அவதானிப்புகள்

எப். பி. அமரசிங்க

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இலங்கையின் உடவத்தைகெலே எனப்படும் காட்டொதுக்கத்தில் மேற் கொள்ளப்பட்ட களநிலை ஆய்வின் போது முப்பத்து ஆறு நுளம்பினங்கள் பதிவாக்கப்பட்டன. மூங்கில் அடிக்கட்டைகள், கித்துள் மர அடிக்கட்டை கள், மரப்பொந்துகள் தற்காலிக நில நீர்த் தேக்கங்கள் போன்ற இனப் பெருக்கலிடங்களிலிருந்து முதிர்வுறுத 17 இனங்கள் சேகரிக்கப்பட்டன. இவ் வற்றுள் இயற்கைக் கொள்கல வசிப்பிடங்களிலிருந்து *Culex* (*Lophoceraomyia*) *Uniformis* (*Theobald*), *Aedes* (*Stegomyia*) *Krombeini* Huang, *Aedes* (*Stegomyia*) *Albopictus* (Skuse), *Toxorhyncites* (*Toxorhyncites*) *Splendens* (Wiedemann) ஆகிய இனங்களும் நிலநீர்த்தேக்கங்களிலிருந்து *Hedes* (*Verrallina*) *pseudomediofasciatus* (*Theobald*) *Anopheles* (*Cellia*) *elegans* (James) ஆகிய இரண்டு இனங்களும் பெருவாரியாகச் சேகரிக்கப்பெற்றிருந்தன. இனப்பெருக்கலிடங்களிலிருந்து தனியினம் பல்லினம் சார்ந்த அறுபத்து நான்கு வகைகள் பதிவு செய்யப் பெறலாயின. மூங்கில் அடிக்கட்டை வசிப்பிடமாகக் கொண்ட *Ae. albopictus* க்கும் *Ae. Krombeini* க்கும் இடையில் நேர்நிலை இடைவினை உறவும் *Ae. albopictus* க்கும் *Tx. splendens* க்கும் இடையில் எதிர் நிலை உறவும் இருப்பது புலனாயது.

பகல் நேர மனித இரை மூலம் இருபத்து ஒன்று இனங்கள் பிடிக்கப் பட்டன. மிகப் பரவலாகக் காணப்பட்ட *Ae. albopictus*, *Armigeres (Armigeres) Subalbatus* (Coquillett) ஆகிய இரண்டு இனங்களுக்குரிய காடுசார் கடிப்புச் செயல் மட்டங்கள் தொடர்பில் ஆரம்பப் பொருள் விளக்கம் தரப்பட்டுள்ளது. மருத்துவ ரீதியில் முக்கியத்துவம் கொண்ட *Hedes (Stegomyia)* தொகுதியைச் சேர்ந்ததும் அண்மையில் விளக்கப்பெற்றதுமான *Aedes Krombeini*) என்னும் நுளம்பினம் இப்பகுதியில் இயல்பாகவே இனப்பெருக் கலடையும் தன்மையுடைத்தாயினும் மிகச் சில சந்தர்ப்பங்களில் தான் அது மனித இரையால் இழுக்கப்பட முடிந்தது.

கொழும்பு மாவட்த்தில் புருசேலோ வாதை **(Brucellosis)** பின் நிகழ்வு

யூ. ஜீ. ஜே. எஸ். விக்கிரமசூரியா, எஸ். குமாரசுவாமி

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கொழும்பு மாவட்டத்தில் (இப்பொழுது கொழும்பு, கம்பஹா மாவட்டங் களில்) உள்ள பால் பண்ணை மந்தைகள் மத்தியில் புருசெலோவாதையின் நிகழ்வு பால் வளையச் சோதனை (பா. வ. சோ.) மூலம் அளவாய்வு செய்யப் பெற்றுள்ளது. அதன் வழிக் கிடைத்த காண்புகள், ஐயத்துக்கிடமான சீரங் களைப் பயன்படுத்திச் செய்யப்பெற்ற நியம ஒருங்கொட்டல் சோதனை (நி.ஒ.சோ.) நிரப்பி பதித்தற்சோதனை (நி.ப.சோ.) கூம்ஸ் சோதனை (கூ.சோ.) போன்ற கணியச் சோதனைகளின் மூலம் உறுதிப்படுத்தப்பட்டுள்ளன.

1478 பசுக்களைக் கொண்ட 305 மந்தைப் பரிசோதனைகள் எல்லாவற்றி னதும் மந்தைத் தொற்று வீதம் 1.6% ஆகவும் தனி மாட்டுத் தொற்று வீதம் 0.9% ஆகவும் இருந்தது. இத் தாழ்ந்த தொற்று வீதம் ஒப்பு நோக்குங் கால் அபாயம் விளைவிக்காதென அக மகிழ்வு கொள்ள முடியாது. இந்த அறி குறிகள் எல்லா விடமும் இத்தொற்று நோய் பரவி வருகின்றதென்பதை எடுத்துக்காட்டுவனவாக அமையலாம்.

இலங்கையின் கிடைக்கும் இல்மனைற்றின் பிரிகை பற்றிய ஆய்வுகள்

எம். ஜீ. எம். யூ. இஸ்மயில், ஜே. அமரசேகரா, ஜே. எஸ். என். குமாரசிங்கா

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இலங்கையிலுள்ள இல்மனைற்று மற்றும் உரூத்தையில் படிவுகள் கிழக்கு, வட மேற்குக் கடலோரங்களில் கடற்கரை மணல் வடிவத்தில் கிடைக்கின்றன. எந்தவித நயந்தோய்வித்தல் முறைக்கும் உட்படா நிலையில் 65,000 தொன் இல்மனைற்றுச் செறியங்கள் இப்பொழுது ஆண்டுதோறும் இலங்கையிலிருந்து பெரும்பாலும் நிறப்பொருள் உற்பத்தியாளர்கட்கு, ஏற்றுமதியாகின்றன.

உள்ளூரில் கிடைக்கும் மூலப்பொருள்களைக் கொண்டு இல்மனைற்றிலிருந்து செயற்கை உருத்தயில் தயாரிப்பதற்கென, இலங்கை விஞ்ஞான கைத்தொழில் ஆராய்ச்சி நிறுவகத்தால் மேற்கொள்ளப்பெற்ற சில ஆய்வுகூட சோதனைகளின் பெறுபேறுகள் இக் கட்டுரையில் ஆராயப்பட்டுள்ளன. இல்மனைற்றிலுள்ள இரும்புப் பெறுமானங்களை அமிலக் கசியவூறல் வடிவத்திற்குத் தாழ்த்தும் ஒரு கருவியாக முதன் முதல் மரத்தூள் நயந்தோய்வித்தல் முறைக்கு உட்படுத்தப்பட்டமை இப்பதனிடல் முறையில் முக்கிய அம்சமாகும். இங்கு கண்டு பிடிக்கப்பட்டுள்ள பதனிடல் முறையின்படி முதலில் இல்மனைற்று ஒட்சியேற்றப்படுகின்றது. பின்பு மரத்தூள் மூலம் தாழ்த்தப்படுகிறது. அவ்வாறு தாழ்த்திய இல்மனைற்று ஐதரோக்குளோரிக்கமிலத்தில் கசியவூறலுக்கு உட்படுத்தப்பட்டு அதிலுள்ள் இரும்பு அகற்றப்படுகிறது. கடைசியாகப் பெறும் செறியம் சுமார் 95% T_1O_2 உரூத்தயில் ஆகும் வரை நீற்றுதல் செய்யப்படுகிறது. கசிய விடப்பெற்ற திரவத்திலிருந்து ஐதரோக்குளோரிக்கமிலம் திரும்பப்பெறலாம். பக்க விளைவாகக் கிடைக்கின்ற இரும்பொட்சைட்டு சிவப்பு நிறப்பொருளாகப் பயன்படுத்தப்படலாம்.

அண்மையில் இலங்கைக்குக் கொண்டுவரப்பெற்ற புதினவகைக் கீரை இரண்டின் எண்ணெய் அமைப்பிற்குத் தாவர முதிர்வு ஏற்படுத்தும் விளைவுகள்

பெ. டீ. பீரிஸ், எஸ். பாலசுப்பிரமணியம், ஏ. எல். ஜயவர்தனை, எச். எம். டபிள்யு. ஹேரத்

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Mentha arvensis Var. *piperascens* எனத் தற்காலிகமாக அடையாளம் காணப்பெற்ற Menthol எனப் பெயரிய இனத்துக்குரியதும் *Mentha arvensis* Var. *piperascens*, *Mentha rotundifolia* ஆகிய இரண்டின் இனக்கலப்பான F_1 எனத் தற்காலிகமாக அடையாளம் காணப்பெற்ற Menthone இனத்திற்குரியதுமான இரண்டு எண்ணெய் வகைகள் வெவ்வேறு மூன்று முதிர்வு நிலைகளில் அறுவடை செய்யப்பெற்று GLC (வாயு திரவ நிறப்படவியற்சோதனை) மூலம் அவற்றின் இரசாயனச் சேர்க்கையினை கண்டறிதற்பொருட்டு பகுப்பாய்வுக்கு உட்படுத்தப்பட்டன. மென்தோன் இனத்திலும் பார்க்க மென்தோல் இனம் சார்ந்த முதிவுத்தாக்கம் நன்கு தெரிகிற நிலையில் காணப்பட்டது. மென் தோல் இனத்தில் 2 மாத காலத்தில் மென்தோல் (கற்பூரம்) மிகக் குறைவாகவே அமைந்திருந்தது. 3 மாத காலத்தில் அதாவது பூக்கும் பருவத்தில் அம் மென்தோல் உச்ச நிலையில் அமைந்திருப்பதும் காணப்பட்டது. இக் காலப் பகுதியில் இந்த உச்சநிலை நிலைக்குப் பெரும்பாலும் சமமாக இவ் வினத்தின் மென்தோன் பதார்த்தம் குறைவுற்றிருந்தது. மென்தோன் இனம் சார்ந்த தாவரங்களிலோ மென்தோன் பதார்த்தத்தில் மாற்றமேதும் ஏற்படவில்லை எனலாம். ஆனால் தாவரம் முதிர்வு அடைய அடைய மென்தோல் பதார்த்தம் சற்று அதிகரித்ததெனத் தெரிந்தது.

நுரையீரல் சாராத தூபக்குளோசிசுநோய் தொடர்பில் தகாஹசியின் தூபக்கிள் எதிரி பொசுபேடைட்டு கயோலின் ஒருங்கொட்டல் சோதனை (KAT)

எம். ஆர். எம். பிந்து, எஸ். என். அரசகுலரத்தினு, எல். வீ. வெளிஅங்கே

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நுரையீரல் சாராத தூபக்குளோசிசு நோய் ஊடறிதற்கு மரபுவழி உறுதிப் பாட்டுச் சோதனைகளைப் பிரயோகிக்கும்போது உண்ணுழை உயிராய்வு வேண் டப்படுமாகையால் கூருணர் சீரவியல் ஊடறிவுச் சோதனையொன்று இருப்பின் பெரிதும் பயனளிப்பதாய் அமையும். நுரையீரல் தூபக்கிளோசிசு நோய் சம்பந்தமான சீரவியல் ஊடறிவின் போது மதிப்புக்குப் பாத்திர மான தூபக்கிள் எதிரி பொசுபேடைட்டு கயோலின் ஒருங்கொட்டல்சோதனை (KAT) முறை 210 நுரையீரற் சாராத தூபக்குளோசிசு நோயாளிகள் விடயத்தில் 494 நுரையீரல் தூபக்குளோசிசு நோயாளிகளுடன் 315 நல மான குருதிக் கொடையாளர்களை ஒப்புநோக்குவதன்மூலம் நுனித்து ஆரா யப்பட்டுள்ளது.

நுரையீரல் சாராத தூபக்குளோசிசு நோயாளிகள் சார்ந்த ஒருங்கொட் டல் நியமனங்கள் குருதிக் கொடையாளர்களது ஒருங்கொட்டல் நியமனங் களுக்குச் சமமானவையாகவும் தாழ்வானவையாகவும் காணப்பட்டமையால் கயோலின் ஒருங்கொட்டல் சோதனை (KAT) முறை நுரையீரல் சாராத் தூபக்குளோசிசு நோய் ஊடறிதற்கு பயனளிப்பதில்லையெனத் தெரிகிறது.

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