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The Sabaragamuwa University of Sri Lanka is pleased to present the second issue of the Sabaragamuwa University Journal. The journal provides a forum for Sri Lankan and International Scholars to publish high quality articles on original academic research as well as on innovative teaching practices. It is a refereed journal and accepts articles from all academic disciplines. A panel of Sri Lankan and international referees reviews the contributions. Senior Scholars from various faculties of the Sabaragamuwa University comprise the journal's Editorial Board. The Sabaragamuwa University Journal will be published annually.

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Colombo Institute

Editorial Note

Dayananda Somasundara

Thin Traded Capital Markets: An Empirical Investigation of Colombo Stock Exchange

W.M. Gunaratne Bandara, G. Abeyratna

An Empirical Study of Membership Participation in Trade Union Activities: Evidence from Selected Service Organizations in Sri Lanka

P.C.V. Jinadasa, H.H.D.N.P. Opatha

17

Redefining Parameters: The Case of Lankan Urban Bilingual Discourse

Chandana Dissanayake

35

Computer Applications in Medical Education and Training: A brief review

I.P. Goonewardene

47

Pulmonary Functions in Pregnant Sri Lankan Women

Deepal S. Weerasekera, D. Kusuma Ruberu, S. Sivayogan

57

A Note on the Chemistry and Mineralogy of Apatite Crystals of Eppawala and Ridigama Phosphate Deposits

A.L.T. Hewawasam, K. Dahanayake

61

Drying Characteristics of Potato Slices and Quality Parameters

V.P.A. Weerasinghe, A.R. Ariyaratne

69

Osmotic Adjustments and Associated Water Relations of Clonal Tea

P.M.A.S. Karunaratne, M.A. Wijeratne, U.R. Sangakkara

77

A Comparison of Different Models of Estimating Actual Evapotranspiration from Potential Evapotranspiration in the Dry Zone of Sri Lanka

R.P. de Silva

87

Socio-economics and Environmental Impact of Gem Mining Industry in Sri Lanka: A Case Study of Hunuwala Village in the Ratnapura District

H.M.S. Priyanath

101

Critical Evaluation of Fashioning of Gemstones in Sri Lanka

P.G.R. Dharmaratne

111

Cost Effective Building with Local Bricks

M.R.T. Jayasinghe

121

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Dedicated to

Late Prof. Sinnappan Sandanam

Prof Sinnappan Sandanam - An Appreciation

The late Professor Sandanam was clearly a man with a sense of mission, both in his mind and in his heart. This was the overriding impression of the person that I always had from my first meeting with him in the early seventies at the Tea Research Institute Talawakells and subsequently in our several associations at the Soil Science Society of Sri Lanka and also at the annual sessions of the Sri Lanka Association for the Advancement of Sciences (SLAAS).

Dr Sandanam was the "third man" in the team with Dr Joshua and myself that initiated the first studies on the water balance of the tea crop at Talawakelle. But he was in every sense the "first man" in the conduct and consummation of these studies using the then latest techniques of the neutron probe that enabled a study of the moisture profile of the tea crop over its entire root depth.

What impressed me most about Dr. Sandanam during the conduct of these studies was his keen perception of both long-term and short-term implications of the results arising from these studies. He was certainly not a man who was interested solely in short term gains. He had a large vision of seeing the outcome of his work in the broader setting of the total tea-growing environment. This is clearly reflected in the substance and quality of his early research publications at the Tea Research Institute.

A person of the spirit of Dr Sandanam could certainly, not have confined himself solely to the conduct of scientific research over the rest of his life span. He clearly recognized that building and fostering institutions for scientific education, and the preparation of minds for carrying out scientific research was as important as the conduct of research at research institutions. Hence his transition in later life to building up science faculties in Universities, and also handling the complex field of University Administration.

It was only a person of the selfless spirit of Dr Sandanam who could wrench himself from the comfort of a satisfying research station environment, and throw himself into hurly burly of building up Eastern University Faculty of Agriculture, and also sacrificing his safety and comfort in steering the University through its most turbulent period.

It was some kind destiny that diverted him into the Sabaragamuwa University in the last years of his life. It was almost a recompense for the preceding years of trouble and torment that he underwent in his final years at the Eastern University. He had the satisfaction of realizing a fulfillment of both a sense of mission and a vision, in joining hands with the Vice Chancellor of the newly created Sabaragamuwa University, where he made an enduring contribution both to the academic life of this new University, and also to the Environmental Sciences, in conceiving of the Environmental Research Centre that was supported by CEB. May this be a lasting monument to the memory of a person of his genre.

Dr. C.R. Panabokke
Chancellor

Message from the Vice Chancellor

It gives me great pleasure to send this message to the second volume of the Sabaragamuwa University Journal. It is most heartening to note that this issue would be released on the 25th July 2000, the day the University will hold its third convocation, in view of the fact that, the first issue of the journal was launched in 1998, the year Sri Lanka celebrated its Golden Jubilee of Independence. Besides, it also signifies the continuous progress in one of the innovative ventures initiated by the Sabaragamuwa University in our formative years.

In this new millenium, when knowledge and information go hand in hand, volumes of information can conveniently be assessed through the internet and perused via Computers. However, to the wider scientific community and to the general public, information is still largely mediated by means of the printed page, and therefore Journals still remain one of the major instruments for the dissemination of knowledge and especially of scientific results. Towards this end may the Sabaragamuwa University Journal contribute towards the exchange of knowledge even in a small way, for the greater good of the country in particular and that of mankind in general.

The Sabaragamuwa University Journal is not confined to a specific or a limited set of disciplines but instead encompasses all fields of human knowledge. Though review papers would be solicited from specialists in their fields, contributory papers, research and technical notes, papers on education would all be considered for publication after a stringent review process.

It is with profound sadness that I announce the sudden demise of our coordinating editor Prof. S. Sandanam who passed away after a brief illness in October 1999. In appreciation of his many contributions to our University, where he served since the year 1997, holding many positions, extending from Senior Professor & Head of Department of Export Agriculture, Director of the Career Guidance Unit, the Staff Development Centre and the Sabaragamuwa University Centre for Environment & Sustainable Development (SUCEDS), and eventually its Deputy Vice Chancellor, the Editorial Board unanimously decided to dedicate this issue in his memory.

I would also like to take this opportunity to profusely thank Prof I.K. Perera who took over from Prof Sandanam the role of the Coordinating Editor and assured the successful publication of this issue of the Journal.

Prof. Dayananda Somasundara
Vice Chancellor
25th July 2000

Thin Traded Capital Markets: An Empirical Investigation into Shares Traded on the Colombo Stock Exchange

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Introduction

The existence of a well-functioning domestic capital market has been recognised as a key factor in the economic development in Sri Lanka since, it provides a mechanism which facilitates the effective accumulation of capital and the efficient allocation of funds to those investment opportunities with the highest positive NPVs. The adoption of more open economic strategies in 1977 and the liberalisation of fiscal and monetary policies by successive governments during the last two decades have paved the way for the domestic financial development in the country. In particular, a number of specific steps have been taken by the government such as (i) the opening of the banking sector to foreign owners, (ii) repeal of the business acquisition act, (iii) abolition of 100 percent transfer of property tax on share transactions between non-nationals and (iv) privatisation of government owned business undertakings to develop the security market (Colombo Stock Exchange annual report, 1991). As a result of these measures the Colombo Stock Exchange (CSE) has expanded rapidly and trading activities has grown fast during the recent past¹.

According to Drake (1977), the existence of a well-functioning efficient security market positively influences domestic savings ratio of developing countries. Furthermore, it facilitates the inflow of large international capital flows into the domestic economy. However, the allocational efficiency, operational efficiency and pricing efficiency of a stock market² are heavily dependent on the thickness of the market. According to Gandhi et. al. (1980): A 'thick' capital market is one in which traded shares are liquid and divisible and the volume of daily trading is high and steady. Effective information flows and low transaction costs enable investors to react quickly to perceived changes in the 'value' of any company. Asset pricing in a 'thick' capital market will obviate excessive price adjustments as share values will reflect all relevant past and current information, thus limiting the effect on prices of new information flows. Low price volatility and high trading volume in the secondary security market should lower the cost of finance in the primary market and facilitate capital accumulation and economic development (p. 342).

¹ For example, in 1996 the market capitalisation stood at Rs.104.2 billion and the annual turnover amounted to Rs.7,403 million (of which almost 55 percent was contributed by foreign investors). There were 235 listed companies in the market and the volume of shares traded amounted to Rs.227 million. The comparative figures for 1988 were as follows: market capitalisation Rs.15.7 billion; annual turnover Rs.319 million; 176 listed companies; and trading volume Rs.12 million.

² When the market is allocationally efficient, it channels funds to those firms and organisations with the most promising real investment opportunities. If it is operationally efficient, the buyers and sellers of securities can purchase transaction services at prices that are as low as possible. However, when the market is efficient in pricing securities, share prices at any point in time are said to 'fully reflect' all available information that is relevant to the determination of value (Samuels et. al. 1990, pp. 247-248).

However, if shares in the stock market are thinly traded, it constraints the benefits to be gained from the market, impede the financial development and as a consequence hinder the economic growth of the country.

This paper investigates whether the shares traded on the CSE are thinly traded. The remainder of the paper is organised as follows. Section 2 describes the data used in the study while section 3 outlines the methodology. The results of the study are discussed in section 4. The last section of the paper offers a number of concluding remarks.

Data

As an emerging stock market in a developing country, the CSE does not possess computerised databases that can be readily used for research purposes³. The problems of undertaking research in such a situation have been documented by Russel (1972), Solnik (1973) and more recently by Dickinson and Muragu (1994). One possible strategy for overcoming this problem is to use the all share indices which are published for many stock exchanges and are therefore, readily available for empirical analysis. However, the use of a market index in share price studies may be inappropriate for two reasons. First, the market index only describes the average movements in the overall market; it does not show the price changes of sectors or of individual securities. Second, the use of the market index may introduce a serial correlation into the analysis depending upon the way in which the index is weighted. To overcome above criticisms and to enhance the validity of the analysis, this study employs data relating to all share price indices, sectoral indices as well as individual share prices.

A number of series of data ranging from all share price indices to individual share prices for the period from 1 January 1992 to 31 December 1994 have been used in the study. First, for the purpose of comparing return characteristics of the Sri Lankan market with those of the developed markets, daily values for all share indices for the USA (NYSE all share index), the UK (FT all share index), Japan (NICKIE all share index) and Sri Lanka (CSE all share index) were gathered. Second, to study the behaviour of share prices of different industries traded on CSE, daily indices for all the 14 sectors⁴ in the market were collected for the same period. Finally, a stratified random sample of 50 individual companies were selected to represent 25 percent of the total number of companies in each industry and daily share prices were again used in the analysis. However, the number of companies was reduced to 42 since 8 companies had to be dropped due to the non availability of data⁵.

³ For the purpose of this study, the researchers had to create their own database to have individual share prices compatible with CSE all share price index since the individual share prices were available only for the dates of actual trades of securities. Even though processed data may be available with private companies, the cost of obtaining such information is substantial.

⁴ Since 1995 the number of sectors has been increased to 16 introducing two more sectors namely diversified and plantations.

⁵ Data relating to NYSE all share index, FT all share index and NICKIE all share index were gathered from Datastream. All data relating to the Sri Lankan market were received from Forbes & Walker Ltd. And Asia Capital Ltd..

Methodology

The analyses that were undertaken in this study were based on daily returns earned by indices or individual securities, which were estimated according to the following identity:

$$R_{i,t} \equiv \ln \left[\frac{P_{i,t}}{P_{i,t-1}} \right] \quad [1]$$

where, $R_{i,t}$ is the return on index/share i for day t , \ln is natural logarithm, $P_{i,t}$ is the value of index i or the price of share i on day t and $P_{i,t-1}$ is the value of index i or the price of share i on day $t-1$ ⁶.

A battery of tests, based on the daily returns, was employed to examine different issues relating to thin trading problem for the CSE. First, the volatility of share returns of the CSE was compared with the return volatility of developed markets (the USA, the UK and Japan). For this purpose the coefficient of variation (standard deviation divided by mean) measure was employed on the daily returns of all share indices. Several researchers have argued that the emerging markets are more volatile than the longer-established developed markets since financial systems of such countries are more regulated and their financial structures are relatively immature (Peterson, 1994, p. 49). If the CSE is thinly traded, the return volatility of shares traded should be very high and in consequence, the coefficient of variation for CSE all share index should be greater than the coefficient of variation of other markets.

Second, the risk premium demanded by Sri Lankan investors is compared with that required by investors in developed countries. The risk-return trade-offs of markets and hence the attitude towards risk of the investors of respective markets are observed using the following equation:

$$\bar{R}_i = a + b(\text{STD}_i) \quad [2]$$

where, \bar{R}_i is the monthly mean return for the index i , a and b are the parameters to be estimated and STD_i is the standard deviation of monthly returns of the index i . To estimate the above model, monthly mean returns and their respective standard deviations were calculated using daily returns on all share indices, which had already been calculated⁷. If the shares of the market are thinly traded, uncertainty increases and as a result, the risk premium demanded by shareholders should be higher. In

⁶ Fama (1965, pp. 45-46) provides three reasons for using changes in log prices rather than simple price changes in share price studies. First, the change in log price is the yield, with continuous compounding, from holding the security for the day. Second, the variability of simple price changes for a given share is an increasing function of the price level of the security and taking logarithms seemed to neutralise most of this price effect. Third, for changes less than plus or minus 15 percent the change in log price is very close to the percentage price change, and for many purposes it is convenient to look at the data in terms of percentage price changes. Strong (1992, p. 535) suggests further two reasons why logarithmic returns are preferable to discrete returns. Theoretically, he argues, logarithmic returns are analytically more tractable when taking together sub-period returns to form returns over longer intervals (simply add-up the sub period returns). Empirically, logarithmic returns are more likely to be normally distributed and so confirm to the assumptions of standard statistical techniques.

⁷ This method had been used by Sharpe (1966), Briscoe et.al. (1969) and Gandhi et. al. (1980) for the USA, the UK and Kuwaiti markets respectively, in a different context, to examine the risk premium demanded by shareholders of above markets.

accordance with the above explanation, if the CSE is infrequently traded, we should be able to observe a higher value for the coefficient 'b' for CSE than that for the other markets.

Third, serial correlation and runs tests⁸ were employed on daily returns of 14 industrial sectors to study whether the market exhibits any systematic patterns over time. The serial correlation coefficient provides a measure of the relationship between the value of a random variable in time t and its value k periods earlier. Therefore, for the changes in log price for a given share from the end of day $t-1$ to day t (defined earlier as $R_{i,t}$), the serial correlation coefficient for lag k is given by:

$$r_k = \frac{\text{Covariance}(U_i, t, U_i, t - k)}{\text{Variance}(U_i, t)} \quad [3]$$

If the distribution of U_i has a finite variance, then for large samples the standard error of the serial correlation, $\delta(r_k)$, can be computed as:

$$\delta(r_k) = \frac{1}{\sqrt{(N - K)}} \quad [4]$$

where, N is the sample size (see Kendall, 1948, p. 412). The hypothesis tested in this study was that the correlation coefficients of successive daily changes of 14 sectoral indices on the CSE at lag k ($k = 1, 2, 3, \dots, 30$) were zero. For this purpose serial correlation coefficients, r_k , were computed for each sector over 30 lags and the hypothesis was tested using a two-tailed test. A coefficient was considered to be statistically significant if it exceeds ± 1.96 of its standard error, $\delta(r_k)$. A run is defined as a sequence of consecutive share price changes of the same sign; a plus run of length i is a sequence of i consecutive positive price changes preceded and followed by either negative or zero changes. For share price changes there are three different types of possible price changes – positive, negative and zero – and therefore three possible types of runs. If the assumption holds that the sample proportions of positive, negative and zero price changes are good estimators of the population proportions, and the independence hypothesis applies to the sequence of price changes, then the total expected number of runs of all signs for a share (m) can be computed as:

$$m = \frac{N(N + 1) - \sum_{i=1}^3 n_i^2}{N} \quad [5]$$

⁸ These two techniques have been widely used in the studies which have examined the randomness of share price movements. For example, see Cootner (1962), Fama (1965), King (1966) and Moore (1967) for US evidence, Kendall (1953) and Griffiths (1970) for UK evidence, Praetz (1969) for Australian evidence, Jennergren and Korsvold (1975) for Swedish evidence, Jennergren (1975) for Norwegian evidence, Niarchos (1971) for Greek evidence and Abeyratna and Power (1995) for Sri lankan evidence.

where, N is the total number of price changes and n_i ($i = 1, 2, 3$) are the number of price changes of each sign (i.e. positive, negative, zero). The standard error of m is given by:

$$\delta_m = \sqrt{\frac{\sum_{i=1}^3 n_i^2 \left[\sum_{i=1}^3 n_i^2 + N(N+1) \right] - 2N \sum_{i=1}^3 n_i^3 - n^3}{N^2 (N-1)}} \quad [6]$$

and for large N the sampling distribution of m is approximately normal. Since for large samples the distribution of the total number of runs is approximately normal with mean, m , and standard error, δ_m , then the difference between the actual number of runs and the expected number of runs can be expressed by means of the usual standardised variable, Z , as follows:

$$Z = \frac{(R + \frac{1}{2}) - m}{\delta_m} \quad [7]$$

where, R is the actual number of runs and $\frac{1}{2}$ in the numerator is a discontinuity adjustment. The computed value of Z is significant at 5 percent level if it lies beyond its critical value.

According to Fama (1970), if the movement of share prices shows a systematic pattern over time, then the market is imperfect and shares may be thinly traded. Accordingly, if the CSE is thinly traded, we should be able to observe systematic patterns in movements in the sectoral indices.

Finally, three alternative beta measures – (i) normal beta, (ii) Scholes-Williams beta and (iii) Dimson beta – were calculated in order to observe thin trading problem looking at the above measures at individual company level. In a thin traded capital market in which shares suffer from infrequent trading, the covariances of individual shares with the market are substantially underestimated. As a result, infrequently traded shares tend to have beta estimates which are biased downwards, while the figure for frequently traded securities is upward biased (Dimson, 1979, p. 198). This problem underestimates the actual market risk faced by a company. Scholes and Williams (1977) and Dimson (1979) suggest two alternative beta measures, both of which adjust for thin trading. Therefore, for the comparative purpose, these three beta measures were calculated as follows:

$$\beta_N = \frac{\text{Covariance}(R_i, R_m)}{\text{Variance}(R_m)} \quad [8]$$

where, β_N is the normal beta, Covariance (R_i , R_m) is the covariance between the returns of share i and the market and variance (R_m) is the variance of the returns on the market portfolio;

$$\beta_{sw} = \frac{\beta_{-1} + \beta_0 + \beta_{+1}}{1 + (2pm)} \quad [9]$$

where, β_{SW} is the Scholes-Williams beta⁹, β^N is an estimate of the slope coefficient in a simple regression of the return on the security on day t against the return on the market in day $t+n$ and ρ_m is an estimate of the first order serial correlation coefficient for the market index; and

$$\beta_D = \sum_{k=-3}^3 \beta_k \quad [10]$$

where, β_D is the Dimson beta¹⁰, β_k , $k = -3, -2, -1, 0, 1, 2, 3$ are estimates of the slope coefficients in a multiple regression of the return on the share on day t against the return on the market in periods $t-3, t-2, t-1, t, t+1, t+2$ and $t+3$. If the CSE is thinly traded, we should be able to observe that the normal beta is underestimated when compared to other two alternative beta measures. In other words, if the CSE is thickly traded we should not be able to detect a material difference between normal betas and other two beta measures.

Results

The results obtained from the analyses of the all share price indices are reported in tables 1 and 2.

Table 1

Return Volatility – 1992 to 94

Country	1992	1993	1994	1992-94
USA	30.3889	16.5172	47.2500	48.3636
UK	17.1698	6.6750	18.4103	23.0625
Japan	15.6923	11.9091	22.7917	70.6550
Sri Lanka	4.5072	4.3668	410.6667	43.0455

The table reports the coefficients of variation (STD/Mean) for the three-year period for the USA, the UK, Japan and Sri Lanka.

⁹ The Scholes-Williams (SW) beta estimator is based on two key assumptions. First, although trades are non-synchronous, a transaction takes place in every measurement interval. Second, price adjustment delays arise only through non-synchronous trading so that an observed transaction price is the true price at the time of the transaction. Under these assumptions, the SW beta estimator is a consistent estimator of the true beta.

¹⁰ The Dimson beta, which is normally called Dimson Aggregate Coefficients (DAC) Estimator does not require that a trade takes place in every return interval. This method has been employed by Dimson and Marsh (1986) with $k=-1, \dots, +5$.

Table 2
Risk Premium Demanded by Investors – 1992 to 94

Country	1992	1993	1994	1992-94
USA	0.2469	-0.2212	-0.4280	-0.1728
UK	0.3714	0.2303	-0.7206	0.1604
Japan	0.1499	0.1010	0.3001	0.0623
Sri Lanka	0.1449	0.8075	-0.2586	0.1831

The table reports ‘b’ coefficients of the markets for the three-year period ascertained using the equation of

$$\overline{R_i} = a + b (STD_i).$$

A visual inspection of these two tables indicates that the aggregate Sri Lankan market data do not show a marked difference from developed markets over the three-year period from 1992 to 1994. The coefficients of variation in table 1 indicate that the USA market has displayed the greatest volatility in 1992 followed by UK and Japan. On the other hand, Japanese market reported the highest volatility in 1993 followed by the USA and UK. In both these years the coefficients of variation for the Sri Lankan market were minimal. However, in 1994 Sri Lankan market exhibited the greatest volatility¹¹ in share returns. When the overall three-year period (1992-94) is considered the volatility of CSE is less than that of Japan and the USA. A similar picture emerges from table 2 which reports the risk premia demanded by the investors in the respective markets. With the exception of 1993, the risk premium demanded by Sri Lankan investors is either similar to or lower than those of the other markets; the attitude of the investors in Sri Lanka towards risk seemed not to be significantly different from the attitude of investors in developed share markets. These results indicate that at the aggregate level the CSE does not seem to suffer from a severe thin trading problem.

Tables 3 and 4 report the results of the statistical analyses, which were performed using daily returns of the indices of the 14 industrial sectors, traded on the Colombo Stock Exchange. The first-order autocorrelations for the 14 sectors are reported in table 3¹².

A brief analysis of table 3 indicates that, on average, the first-order serial correlations are large in magnitude; 40 out of 56 correlations (71.43 percent) are greater than 0.25. Most of the correlations are negative – 71.43 percent, and the majority of the negative coefficients are significant – 82.50 percent. This pattern was more prevalent in 1992 and in the overall period of three years (1992-94) where 100 percent and 92.86 percent of the autocorrelations were negative and significantly different from zero.

¹¹ This may be attributable to the uncertainty created among the stock market investors, specially among overseas investors, with respect to the economic policies of the government as a result of the transfer of political power from a right-wing government to a coalition government which consisted of few leftist parties.

¹² The serial correlation coefficients have been calculated for 30 lags and the rest of the coefficient values are available with the authors upon request.

Table 3**First-Order Autocorrelations – 1992-94**

Industry	1992	1993	1994	1992-94
Banking, Finance & Insurance	-0.499**	0.275**	0.437**	-0.497**
Beverage, Food & Tobacco	-0.449**	0.299**	-0.247**	-0.360**
Chemicals & Pharmaceuticals	-0.454**	0.057	0.242**	-0.355**
Construction & Engineering	-0.425**	-0.483**	-0.176**	-0.473**
Footwear & Textiles	-0.477**	-0.006	0.099	-0.438**
Hotels & Travels	-0.500**	0.249**	0.228**	-0.456**
Investment Trusts	-0.496**	0.031	0.117	-0.491**
Land & Property	-0.217**	-0.030	0.299**	0.077*
Manufacturing	-0.458**	0.273**	0.357**	-0.399**
Motors	-0.487**	0.087	-0.012	-0.470**
Oil Palms	-0.468**	-0.531**	-0.120	-0.499**
Services	-0.487**	-0.016	-0.495**	-0.494**
Stores & Supplies	-0.499**	-0.006	-0.055	-0.490**
Trading	-0.479**	-0.477**	0.087	-0.455**
Confidence Intervals at 99%	+ or - 0.1662	+ or - 0.1662	+ or - 0.1687	+ or - 0.0732
Confidence Intervals at 95%	+ or - 0.1263	+ or - 0.1263	+ or - 0.1281	+ or - 0.0964
No. of Significant Coefficients	14	7	8	14
% of Significant Coefficients	100.00	50.00	57.14	100.00

The table 3 reports the first-order serial correlations for the three individual years of 1992, 1993 and 1994 and for the overall three-year period of 1992-94.

The analysis of first-order autocorrelations over this three-year period indicates a greater degree of linear dependence in successive share price changes of Sri Lankan indices at the one period lag level. Statistically the vast majority of the coefficients are significantly different from zero at 5 percent level; the hypothesis that successive changes in share prices are independent can be rejected for 43 out of 56 coefficients – an overwhelming majority of 76.79 percent. The majority of the significant coefficients (which ranges from -0.531 to 0.437) are large in absolute terms which could be helpful for professional analysts who are attempting to predict future share price movements¹³.

¹³ However, the number of significant autocorrelations decreased for all the sectors as the lag length increased which means that the more recent price movements carry more weight in determining the next price movement.

An examination of the autocorrelation coefficients at the individual sector level indicates that for 5 industries (Banking, Finance & Insurance; Beverage, Food & Tobacco; Construction & Engineering; Hotels & Travels; Manufacturing) the first-order autocorrelations are significant for all the sub periods as well as for the overall three-year period. Moreover, for 5 more industries (Chemicals & Pharmaceuticals; Land & Property; Oil Palms; Services; Trading) the correlations are statistically significant for two individual years as well as for the overall period. If we apply a decision rule of number of significant coefficients ≥ 2 (out of 3 coefficients in three individual years representing 66.67 percent or more) for lack of independence, the hypothesis of independence could be rejected for 71.43 percent of the sectors traded on the CSE.

An examination of the test results of the runs reported in table 4, reveals that in an overwhelming majority of the instances the actual number of runs is less than the expected number of runs indicating an existence of a positive persistence in share returns; a share price change tends to be followed by further changes in the same direction. Out of the 14 sectors studied, 11 sectors (78.57 percent) in 1992, 12 sectors (85.71 percent) in 1993 and 13 sectors (92.86 percent) in 1994 showed this positive persistence. A similar conclusion can be drawn for the overall three-year period from an examination of the last column of the table where 92.86 percent (13 out of 14 sectors) coefficients are negative. Moreover, except in 1992, the majority of the sectors reported a significant difference between the actual number of runs and the expected number of runs; 50 percent in 1993, over 57 percent in 1994 and more than 78 percent for the overall three-year period.

Table 4

Differences Between Actual Number of Runs and Expected Number of Runs – 1992 to 94

Industry	1992	1993	1994	1992-94
Banking, Finance & Insurance	-34.33**	-45.34**	-38.79**	-110.39**
Beverage, Food & Tobacco	1.67	-10.40	-4.45	-33.98**
Chemicals & Pharmaceuticals	-10.62	-20.96**	-14.92*	-27.34*
Construction & Engineering	-12.13*	-23.32**	15.23*	-16.61
Footwear & Textiles	-19.34**	-8.22	-14.58	-38.93**
Hotels & Travels	-5.50	-25.59**	-18.00*	-43.52**
Investment Trusts	-7.55	2.51	-17.08*	-32.96*
Land & Property	9.75	-13.66	-14.99*	-13.72
Manufacturing	-11.75	-25.40**	-34.86**	-76.25**
Motors	-13.40	-17.52*	-12.99	-37.28**
Oil Palms	-1.79*	0.53	-0.79	0.91
Services	-8.25	-1.06	-3.77	24.34*

Stores & Supplies	1.61	-16.80**	-16.23*	-27.99**
Trading	-7.51	-13.15	-10.14	-30.58**
No. of Significant Coefficients	4	7	8	11
% of Significant Coefficients	28.57	50.00	57.14	78.57

The table reports the differences between the number of runs observed and the number of runs expected for the three-year period for the 14 sectors traded on CSE. An **(**)** denotes the statistical significance at 5% (1%) level where the hypothesis of 'non-systematic patterns in the movements of share prices over the time' was rejected.

Alternative beta measures for the randomly selected sample of 42 shares are reported in table 5. In accordance with the idea that the normal beta underestimates the actual market risk faced by the firm in thin traded capital markets, the majority of the shares in our sample have lower values for normal beta estimates compared with the beta estimates which are based on Scholes-Williams (1977) and Dimson (1979) approaches.

Table 5

Alternative Beta Estimates

(1) Share	(2) Beta _N	(3) Beta _{SW}	(4) Beta _D	(5) % of (2)-(3)/(2)	(6) % of (2)-(4)/(2)
1	0.2218	0.3071	0.4218	-38.4581	-90.1713
2	-0.2242	-0.2574	-0.3304	14.8082	47.3684
3	0.6483	0.7143	0.5443	-10.1805	16.0420
4	0.3392	0.5548	0.5503	-63.5613	-62.2347
5	1.3500	1.2849	1.2466	4.8222	7.6593
6	-0.0612	-0.0426	0.0094	-30.3922	-115.3595
7	0.8205	1.0283	1.2027	-25.3260	-46.5814
8	0.0244	0.0325	0.0280	-33.1967	-14.7541
9	0.3188	0.6708	1.7028	-110.4141	-434.1280
10	0.4286	0.5792	1.0834	-35.1377	-152.7765
11	0.1176	0.2633	1.0369	-123.8946	-781.7177
12	0.7488	0.7736	0.8460	-3.3120	-12.9808
13	0.7948	0.9120	0.9224	-14.7458	-16.0544
14	0.0234	0.01865	0.0054	20.9402	76.9231
15	0.9257	1.1592	1.2730	-25.2242	-37.5176
16	0.7377	0.8169	0.9992	-10.7361	-35.4480

17	-0.0180	0.0583	-0.0587	-424.7911	227.0195
18	-0.0426	-0.0194	-0.0114	-54.4601	-73.2394
19	0.3592	0.4122	0.5073	-14.7550	-41.2305
20	-0.0369	-0.0283	-0.0499	-23.3062	35.2304
21	0.6656	0.6832	0.3816	-2.6442	42.6683
22	-0.0029	-0.0048	-0.0063	65.5172	117.2414
23	-0.0026	0.0528	0.2567	-2130.7692	-9973.0769
24	0.9175	1.2928	1.2198	-40.9046	-32.9482
25	0.7160	0.4812	0.5192	32.7933	27.4860
26	-0.0358	-0.0994	-0.0961	177.6536	168.4358
27	1.6561	1.7927	1.2569	-8.2483	24.1048
28	0.0602	0.0573	0.0551	4.8173	8.4718
29	0.1748	0.3100	0.4598	-77.3455	-163.0435
30	0.2079	0.2378	0.2866	-14.3819	-37.8547
31	1.7925	1.9583	1.3018	-9.2497	27.3752
32	0.1041	0.1264	0.1672	-21.4217	-60.6148
33	0.4063	0.5167	0.5969	-27.1720	-46.9111
34	-0.0332	-0.0468	-0.0192	40.9639	-42.1687
35	0.5235	0.4841	0.6225	7.5263	-18.9112
36	1.7870	1.8547	1.6349	-3.7885	8.5115
37	-0.0644	-0.0910	-0.1026	41.3043	59.3168
38	0.6637	0.7385	1.4385	-11.2702	-116.7395
39	1.3328	1.3796	1.5389	-3.5114	-15.4637
40	1.5769	1.5894	1.5056	-0.7927	4.5215
41	1.5283	1.7576	1.3828	-15.0036	9.5204
42	0.6729	1.0108	0.7739	-50.2155	-15.0097

Table 5 reports normal beta, Scholes-Williams beta and Dimson beta for the sample of 42 shares for the three-year period 1992-94. The percentage difference between normal beta and Scholes-Williams beta and normal beta and Dimson beta are reported in columns 5 and 6 respectively.

As the fifth column of table 5 reports, the percentage difference between normal beta and Scholes-Williams beta is negative for an overwhelming majority of 76.19 percent of the sample companies in our study. These differences range from -0.79 percent to -2130.77 percent. On the other hand, the percentage difference between normal beta and Dimson beta is negative, as reported in the sixth column of table 5, for 59.52 percent of the companies in the sample. These differences range from -12.98 percent to -9973.08 percent. In summary, these results indicate that when the market risk is analysed at individual company level, it is clearly evident that the CSE is thinly traded

and therefore, normal beta is unable to represent the accurate level of the market risk faced by the companies traded on the market.

Conclusion

In this study we investigated whether the Colombo Stock Exchange suffers from infrequent trading using a number of series of data and employing a battery of statistical techniques. The analyses carried out at the aggregate market level revealed that the CSE does not seem to suffer from a severe thin trading problem when its return characteristics were compared with frequently traded markets such as the USA, the UK and Japan. However, the analyses undertaken at the sectoral level indicated some patterns in persistence of share returns. These sectoral evidences contradicted with the results of the analyses performed at the overall market level indicating an existence of a thin trading problem at the sectoral level. This problem was more prevalent at the individual company level where the results indicated that the normal beta measures substantially underestimated the market risk faced by companies compared with Scholes-Williams betas and Dimson betas which are adjusted for thin trading. This thin trading problem can be due to several reasons such as rumor driven share prices, leakage of company specific information before its official release, non active participation in share market activities by majority shareholders, illiquidity of the market, high return offered by other avenues of investment such as bank deposits, the dominance of the market by foreign investors, less developed security analyst service and non existence of a widespread share ownership.

This situation hinders the economic development of the country since it adversely affects the financial development as well as the existence of a well-developed capital market which are crucially important for the accumulation of funds (both domestic and overseas) and channeling of them among investment opportunities. Further, this thin trading problem has implications for security analysts and investors who use the beta coefficient as a measure of market risk and for finance researchers who use it in their studies (eg. event studies).

However, the results of this study should be interpreted with caution, because the period for which the data were gathered had a bull market demonstrating upward swing in share price indices. But, it was followed by a bear market, which was not captured by the period of investigation of this study. Future research will benefit from examining the return characteristics of the market for both bull and bear runs.

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An Empirical Study of Membership Participation in Trade Union Activities: Evidence from Selected Service Organizations in Sri Lanka

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Abstract

This study examines the membership participation in trade union activities. The empirical results discussed in this paper constitute the outcome of a study in five large-scale service organizations in Sri Lanka. Data on membership participation were gathered mainly through a survey of 500 randomly selected union members of these organizations using a structured questionnaire and an interview. Methods such as Percentage Analysis, Chi-square Test, Fully Saturated Hierarchical Log-Liner Model (HLLM) and the Qualitative Method were used for data analysis. The results indicate a strong need for trade unions for employees. Further the findings show that a collection of personal, job and perceptual factors like: age, sex and the number of dependents, political activism, job experience, and perception about union performance, union leaders and labour-management relations influence membership participation in trade union activities. The study attempts to gain insights and establish implications of practical significance to unions, union leaders and managers, and specially to those in service organizations.

Introduction

Management of human resources is an important and challenging function for every organization. Human resources cannot be utilized like machines because of their dynamic nature, they feel, think and act. Thus, they should be treated differently. According to Marx "labour is in the first place, a process in which man of his own accord starts, regulates, and controls the material re-actions between himself and nature" (1984, p. 173). Labour is no longer an article or commodity of commerce which can be bought and disposed of at the whims and caprices of an employer. However, this is not practised in most of the organizations. As a consequence, the labour class tries to combat these evils by organizing themselves. The end result is the formation of trade unions.

A trade union is a formal, voluntary organization of workers or employees, which aims to secure and improve the well being of members through collective actions. It is an association of workers working on the principles of unity, equality and security for the betterment of its members. A trade union engages in, any activities with the main objective of achieving the improvement of well being of its members. Ideally the activities of a trade union revolve around it. Unions are not only beneficial for the members, but also for the management, the organization and the society as a whole if they work efficiently.

Trade unions in Sri Lanka may be said to have commenced with the formation of the Ceylon Printers Union in 1893, perhaps the first workers' union in Sri Lanka (De Silva, 1978). Today the Sri Lankan labour movement is strong placed and there are a large number of trade unions functioning with a very large membership, the total membership being in the region of 1,500,000. These unions are widely spread in most of the areas of the country. In fact, there are trade unions in almost all the large organizations except in the armed forces and the police. These various trade unions are very powerful today with a large number of members. Even though there is a high union density in Sri Lanka, the salient feature is the lack of understanding and cooperation amongst management, government and trade unions.

Therefore, industrial disputes such as work to rule, go slow, boycott, work refusal, picketing, strikes etc. have become very common. Today, the Sri Lankan trade unions not only stay with their conventional demands of higher pay and better working conditions but they have also entered into a new arena where they directly interact with government policy decisions (for example CEB and Bankers strike against privatization).

Therefore, today's trade unions, are a very powerful force and, when thinking of the future of the country, trade unions will be playing a very significant role.

In this context unions need to be studied scientifically. Currently it is impossible to state that all trade unions are performing well. Even if there is no empirical evidence, which has been reported, general experience in the country shows that some unions are functioning effectively and efficiently satisfying the needs of their members and serving the relevant management. Some function at a moderate level, some at a lower level and others at very poor level and thus have been dissolved or canceled by the Department of Labour or abandoned by its members. The ultimate goal of an organization would be effectiveness through efficiency. A substantial number of trade unions in Sri Lanka are not effective or efficient, as they fail to satisfy members' needs and to achieve main objectives of the unions. Thus, what makes some unions efficient and effective and others less is an important question which needs discussion. Most of the empirical findings reveal that union leadership and membership participation are major determinants of union efficiency and effectiveness. According to Venugopal et al. (1991,p.77) the success or failure of a trade union depends upon the behaviour of its leaders who adapt to the requirements of the situation.

Moreover, membership is an inevitable and unique feature of any trade union. Unions rely on a growing and active membership for their survival. The effectiveness and strength of the union heavily depends on the degree of membership participation in union activities. A greater degree of membership participation in union activities reflects a higher level of support to the union and thereby adds strength and vigour to it. On the contrary passivity on the part of membership affects the union adversely and reduces its effectiveness and strength. Sharma, (1987, p. 454) and Gani (1992, p. 243) observe that the more active the participants, the greater the degree of strength. The more strong and intensively organized the union, the more distant it is from oligarchy and the closer it is to union democracy thereby, being able to exert a considerable degree of pressure on the management. Thus, the effectiveness of a trade union can be significantly influenced by the degree of member participation in trade union activities. The degree of participation is different from member to member. What makes this difference is an important question here. Exploration and determination of correlates of member participation become necessary to find a valid answer for this important question.

There are no research studies conducted on the membership participation in union activities in Sri Lanka, although a few research studies have been reported outside the country. There is a gap in the theoretical knowledge about the factors contributing to membership participation in trade union activities in Sri Lanka. The present study is, therefore, intended to address this theoretical lacuna in the Sri Lankan context.

This study attempts to accomplish four main objectives; (i) to understand the union members' perception about the need for a trade union, (ii) to identify the degree of membership participation in trade union activities, (iii) to identify the factors affecting participation behaviour of union members, (iv) to analyze and explain the correlation of the factors with membership participation.

Review of Literature

The available literature provides various modes of membership participation in trade union activities. Most of the research (eg. Spinrad, 1960; Glick et al, 1977; Anderson, 1979; Mcshane, 1984; Chacko, 1985; Gani, 1992; Nandakumar and Ravishanker, 1994) has identified some or all of the following modes of participation in trade union activities: attending union meetings, payment of union dues, voting in union elections, reading union literature, raising funds for unions, taking part in strikes, etc.

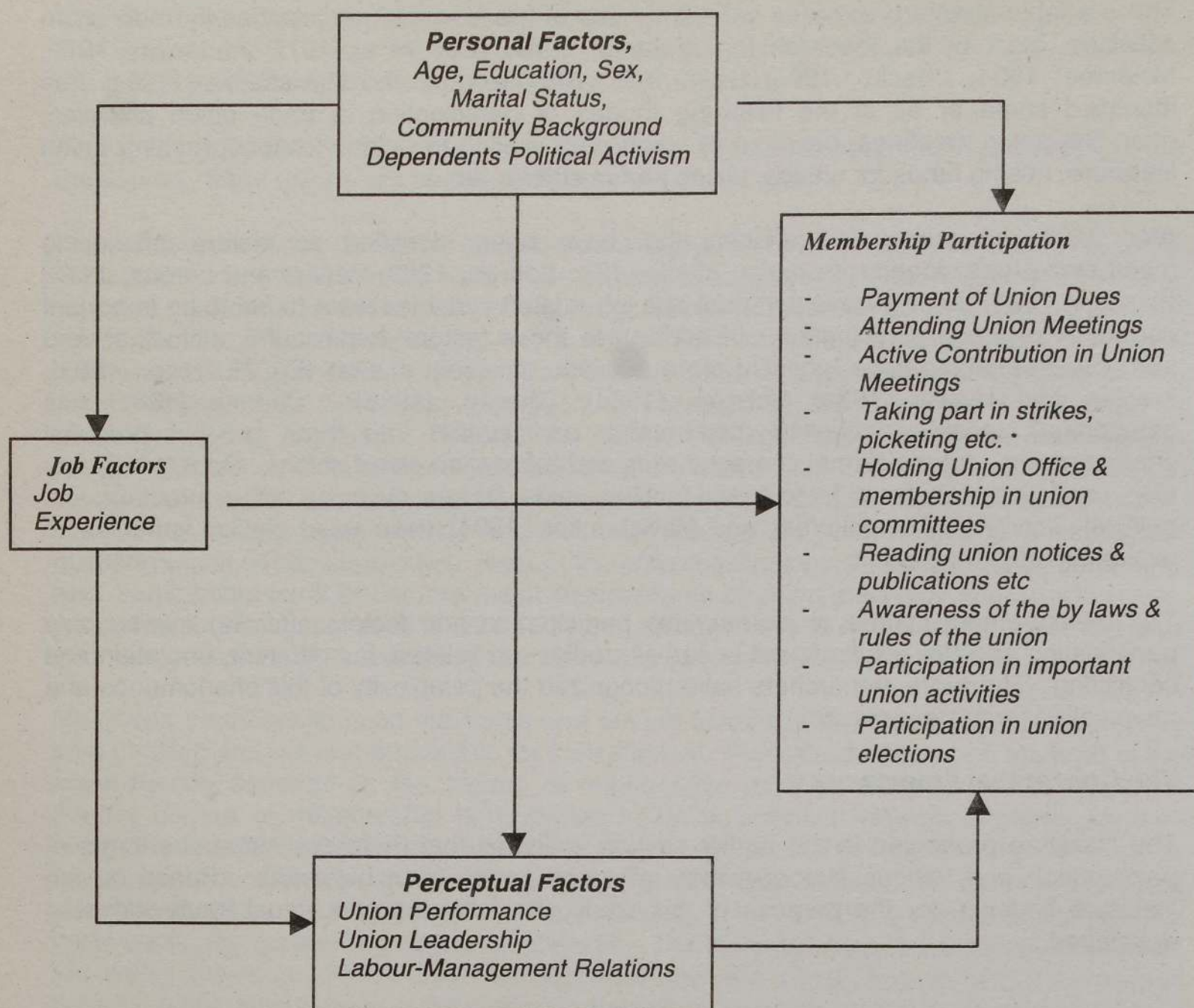
Also there are numerous variables that have been identified as factors influencing membership participation. In earlier studies (Eg. Sprinrd, 1960; Perline and Lorenz, 1970; Swanson, 1981) demographic personal and job related variables were found to be important correlates of union participation. In addition to these factors, behavioural, attitudinal, and perceptual variables have received more attention in recent studies (Eg. Huszczo, (1983); Kolchin and Hyclak, 1984; Mchane, (1984); Chacko, (1985). Sharma (1987) has categorized variables affecting membership participation into three groups: personal characteristics, organizational characteristics and perception about unions. Gani (1992) has also used three kinds of factors and politico-union factors such as union structure and political activism. Nandakumar and Ravishanker (1994) have used similar variables to explain union participation.

The measurement criteria of membership participation and factors affecting membership participation and the results found in earlier studies are related, but different, uncertain and conflicting. Therefore researchers have recognized the complexity of this phenomenon and have called for more research.

The Conceptual Framework

The literature presented in the earlier section indicates that there are numerous forms of participation and various factors, which influence participation behaviour. Based on the literature findings, for the purpose of this study, the following conceptual framework was developed.

Figure 1. Framework for Membership Participation in Trade Union Activities



The framework shows that membership participation is influenced by three major categories, personal, job and perceptual factors, and they were treated as the principle independent variables of the study. The principle dependant variable; membership participation, includes nine activities usually involved by the members of a union. The framework also indicates cross influences among dependant variables; personal factors may affect job factors and perceptual factors, while job factors may affect perceptual factors.

Hypotheses of the Study

Three hypotheses (two were descriptive and also relational) were constructed for the present study in order to get a useful direction and basis for future knowledge, and explain the social phenomenon associated with the study. Formulation of the hypotheses has been based on the evidence of empirical research, and the general assumptions and prediction in the society in the Sri Lankan context of trade union activities. The hypotheses were;

1. " Union members have a strong need for trade unions"
2. " Membership participation in trade union activities is considerably high"

3. " Membership participation in trade union activities is influenced by personal, job and perceptual factors"

Methodology

The research scope was limited to non managerial, and executive level trade union member participation. As the main sources in this research, five large scale service organizations in Sri Lanka; namely Sri Lanka Telecom (SLT), Bank of Ceylon (BOC), Ceylon Electricity Board (CEB), Sri Lanka Insurance Corporation (SLIC), and National Water Supply and Drainage Board (WSDB) were selected. The population for the study thus consisted of all members of all non-managerial and non-executive level trade union members working in these five organizations (about 42,000) union members). The units of observation of the study were at individual level; the individual union member. 500 union members representing more than 1% of this population were selected as the sample of the study. For the 500-member sample, 100 members from each of the five organizations were selected through simple random sampling.

Both primary and secondary data were collected for the study. The main source of collecting primary data was the union members of the selected organizations. To extract data from this primary source a pre prepared structured questionnaire was used. The questionnaire was pre tested using test- retest method for estimating the reliability. In addition, interview method were used with further clarifications as necessary.

Union members' responses for the questionnaire were scored using 3 Point Likert Scale or 4 Point Likert Scale depending on the nature of the question. Interval estimates, Chi-Squared test and fully Saturated Hierarchical Log- Liner Model were applied for data analysis.

Results and Discussion

The majority (85%) of the respondents in the sample was between 26 to 50 years old, and 7 percent were 25 or less, and 8 percent were 51 to 60 years old. In considering the respondents' sex and marital status it was found that 41 percent were females, 59 percent were males, 79 percent were married and 21 percent were unmarried. As regard to the education level, most of the respondents (about 86 percent) had GCE (O/L) or above. About 28 percent and 43 percent of the respondents had passed GCE (O/L) and GCE (A/L) respectively. Only 15 percent of the sample were graduates or had professional qualifications while 14 percent were in the range of grade one to GCE (O/L). About 40 percent of the sample had two or fewer dependents while 60 percent had three or more dependents. About 25 percent of the respondents were living in urban areas, 41 percent in semi-urban, and 34 percent in rural areas. Most of the respondents (91%) were not politically active, only 9 percent of the respondents were politically active.

Since this study was concerned with only non-managerial and non-executive union members, all the respondents in the sample were performing non-managerial and non-executive level functions in their organizations. These respondents worked under twenty different job titles.

As regards to the job experience of the respondents, most of them (65.2%) had more than 10 years experience in the relevant organizations. While 15.8 percent had less than 3 years experience, about 7.4 percent of the members had 3 to 5 years experience and 11.6 percent members had 5 to 10 years experience. Only 2.6 percent of the members were earning a very low monthly salary. But, in other salary categories there was no considerable difference, 24.4 percent of the respondents were earning more than Rs. 8,000 while 24.2

percent earned between Rs 6,000 – Rs 8,000. 48.8 percent of the respondents were earning between Rs 2,500 to 6,000 monthly salary. Interestingly, about 30 percent of the respondents were satisfied with their jobs and only 5 percent were not satisfied. About 65 percent of the respondents' job satisfaction was mediocre.

With respect to the perceptual characteristics, most of the members had no favourable perception about their union's performance, union leaders and labour management relations.

***Members' Perception about the Need for A Trade Union**

Members' responses for the fourth part of the questionnaire showing their need for a trade union are summarized in table 1.

Table 1. Members' Perception about the Need for a Trade Union

Organization	Members' Need for a Trade Union				
	Absolutely Needed	Needed	Nothing Special	Not Needed	Ab. Not Needed
SLT	18	56	24	01	01
BOC	50	41	08	01	-
CEB	40	33	27	-	-
SLIC	51	44	05	-	-
WSDB	33	42	22	03	-
Total	192	216	86	05	01
Percentage	38.4	43.2	17.2	1.0	0.2

Source: Sample Survey 1997

The results show that 81.6 percent of the members needed a trade union. Of these 38.4 percent absolutely needed a trade union and only 1.2 percent of the respondents' had no need for a trade union. There was no significant difference in the responses of the members of all the five organizations. At least 73 percent of the members of all organizations needed a trade union. To this large group of respondents, the relevant organizations failed to satisfy their needs. They needed to be willingly unionized in order to influence the management of the organizations.

The first hypothesis of this study states that union members have a strong need for a trade union. According to the research results, it is obvious that most of the respondents in the sample need a trade union. The calculated interval estimates ($S_p = 1.73$) support that members' perception about the need for a trade union is likely to apply to the population. Therefore it is possible to accept that the organization has tried to identify what their people need before the people demand them. Further, the individual influence has very little effect, and most of the time even to deal with the management a powerful mode is essential. Most of the respondents (78%) felt that the labour-management relations were relatively low, and also that the employees were not trusted by the management and hence, needed a trade union.

These findings are compatible with the results of the available research on this phenomenon in the Indian context; Nandakumar and Ravishanker's (1994) argument that members in Indian textile industry unions were emphatic on the need for a union. They express a similar idea, absence of unions means absence of a mechanism of representing grievances to the management and as such, difficult in dealing with the management.

***Degree of Membership Participation in Trade Union Activities**

Table 2 presents members' degree of participation in trade union activities under three columns designated as high, medium and low.

Table 2. Degree of Membership Participation in Trade Union Activities

organization	Degree of Participation		
	High	Medium	Low
SLT	24	60	16
BOC	49	46	05
CCEB	36	51	13
SLIC	41	47	12
WSDB	24	62	14
Total	174	266	60
Percentage	34.8	53.2	12

Source: Sample Survey 1997

The results show a high level of participation in union activities among the unionists under study. 88 percent of the respondents showed high or medium level participation. Only 12 percent showed low level participation. But, the present study observed that members were not highly involved in all union activities and the majority of the members were concerned on paying union dues, attending union meetings, participating in strikes, work to rule, picketing etc., voting at elections and fund raising. Members were not much interested in expressing their ideas and suggestions in union meetings, bearing positions in the union, intervening to solve problems etc. They always let leaders work for them. In the Sri Lankan situation, because of family problems, lack of time, political interventions etc., people hesitate to take part in responsible tasks in unions. Union leaders revealed that the leadership does not like to sacrifice their effort, time etc, on behalf of the union, or bear the risks attached to the position of a leader in a union.

The interval estimate ($S_p = 1.45$) verifies that the degree of participation identified in the sample is likely to apply to the population. Therefore according to the research results the second descriptive hypothesis, ie membership participation in trade union activities is considerably high, can be accepted. These are compatible with findings of Gani (1992), Nandakumar and Ravishanker (1994), but, contradicted with Sheth (1969), Sherma (1984), Pany and Vikram (1969) who reveal a low participation of members in trade union activities.

***Factors Influencing Membership Participation in Trade Union Activities; Personal Factors**

Age

The present study shows (refer table 3) a significant relationship between age and participation. It reveals that when people become older there is a tendency among them to participate in union activities showing a positive relationship between age and participation. According to the respondents, employees who have enrolled at an organization at their young age need only a job and salary to sustain them. But, when they mature, they need job security, social security and a lot of things, and hence they get involved in union activities more. These findings are collaborative with Anderson (1979), Sharma (1987), Arya (1980) who observed that older workers tend to be more involved in union activities. This is

however, not supported by Nandakuma and Ravishnker (1994) who observed that the factor which motivates membership participation is the commitment rather than the age of respondents (Nandakumar and Ravishanker, 1994). Sheth (1969) shows a considerable relationship between these two and that the workers' participation is low in the middle age compared to those who are young and old. He also found that non-unionists among the younger and older groups are respectively high as against the middle group. Sheth's views are compatible with Gani (1992) who says that workers who are either too young or too old show considerably lower degree of participation than the middle group.

Sex

The results indicate that sex has a significant influence on membership participation. Male members were more active participants than female members. There were no female union leaders or committee members in any of the 38 trade unions under study. It was also revealed in the discussions that female members very rarely expressed their ideas in union meetings, and their normal behavior was only attending meetings and signing the attendance sheet being passive participants. These results are supported by Sherma (1987) who says male members tend to participate more than female members. But, his argument that male voters may discourage or discriminate against female candidates in union elections and that they deprive them from active participation is not valid in this study. There was no interference from male members in this direction. These results are contradicted by Anderson (1979) who says that of the demographic variables only the age is significantly related to involvement in union activities.

Marital Status

The study did not find any significant relationship between person's marital status and his/her union participation. This argument is supported by Gani (1992) Sheth (1969), Matto and Gandhi (1989), and Pool et al. (1983). But Sharma (1987) and Nandakumar and Ravishanker (1994) give contradictory views about this finding. While Sharma shows higher participation from married members, Nandakumar and Ravishanker (1994) show higher participation from unmarried members. But, this study has not found any significant influence of marital status on participation. In addition, the traditional view that married members do not actually participate in union activities due to their added responsibilities and lack of time is not supported by this study.

Level of Education

The present study did not find a significant influence of a person's level of education on the degree of participation. This result does not support the argument that education enlightens a person and hence results in higher participation in union activities. Thus, Nandakumar and Ravishanker's (1994) argument that a positive relationship between these two variables exists is rejected as far as the present study is concerned. The present finding supports the findings of Anderson (1979), Arya (1980), Poole et al. (1983), Sharma (1987), and Gani (1992) who observed that there was no relationship between education level and participation.

Number of Dependents

The results show a significant relationship between the number of dependents and union participation. According to the results, in the situation where the number of dependents the worker has to support is very few or very large, the participation will be low, where as the number of dependents is moderate the participation is relatively high. Gani (1992), Nandakumar and Ravishanker (1994), and Seth (1969) give a similar view and show a positive relationship between these two variables.

Community Background

The present study did not find any significant relationship between community background and membership participation. This finding is compatible with the finding of Nandakumar and Ravishanker (1994), but contradictory with the findings of Sayles and Stauss (1953) and Gani (1992) who support the belief that urban members are more prone to participate than rural members.

Political Activism

As per results, politically active members are more likely to participate than politically passive members. Therefore, there is a positive link between these two. About 95 percent of the union leaders under study were active members of political parties. Further, it was found that there were at least two unions, which were political in all five organizations under study. As a result, members show the same commitment to unions as they show towards the political party, and thus participate in trade union activities more compared with those who do not have such a commitment. It is a common belief today in Sri Lanka, as well as in most other countries that politically active members who are involved in national political party activities, have greater influence on union participation. The finding supports the arguments of Ramaswamy (1977), Seth and Jain (1968), Gani (1992), and Nandakumar and Ravishanker (1994) who show a positive relationship between political activism and membership participation in trade union activities.

Job Factors

Job Experience

This study indicates that there is a positive relationship between job experience and degree of participation. This is compatible with the earlier finding of this study i.e., a positive relationship between age and participation. Therefore, it can be further revealed that the people getting older and more experienced lead to more participation in trade union activities. This observation gets further support from findings of Arys (1980), Canlon and Gallagher (1987), Sharma (1987), and Gani (1992) who observe that experience has a positive relationship with participation. In contrast Sheth (1969), Nandakumar and Ravishanker (1994) have not found any significant relationship between these two.

Salary

The present study shows that salary and degree of participation are not related. The result does not support the argument that members with lower wages participate in union activities more actively. Therefore, it does not support the findings of Duncan and Leigh (1980), Poole et al. (1983) and Gani (1992) who revealed that there is a positive relationship between low salary and union participation. This study found that low or high salary earners are independent of the degree of participation.

Job satisfaction

Interestingly this study does not show a significant relationship between job satisfaction and membership participation. While this finding is compatible with that of Nandakumar and Ravishanker (1994), it is contrary to available empirical findings which points towards a positive relationship between the degree of job dissatisfaction and union participation (e.g. Bernardin et al (1983), Block and Premack (1983), Fiorito and Gallagher (1986), Odewahn and Petty (1980), Sinha and Sharma (1982), Gani (1992).



Perceptual Factors

Perceptions on Union Performance

This study indicates that members' perception about their union performance influences on their union participation. The results support the belief that members who are satisfied with union activities are more likely to participate in union activities than members who are not satisfied with union activities. The results of Glick *et al* (1977) and Andersons' (1979) are also consistent with this finding.

Perceptions on Union Leaders

The results indicate that members' perception about union leaders influences their participation. A positive relationship was found between satisfactory perception about union leaders and participation in union activities. In the discussions most of the members revealed that because of the leaders faults, bad behavior and mismanagement of funds, they hated to participate in union activities. Further, union leaders of most of the unions worked for the benefit of their political parties and tried to spread their political power. This finding supports Sheth's (1969) findings which shows that there is a positive relationship between high quality of leadership of the union and the degree of participation. According to Sheth (1969, p. 286), if the leaders in a union have shown their ability to settle the problems of individual workers and groups to the satisfaction of the rank and file, we may expect a relatively higher degree of participation among workers.

Perceptions on Labour Management Relations

Sound labour management relations were found to be negatively related with membership participation in trade union activities. Members who are dissatisfied with labour-management relations are more likely to participate in union activities than members who are satisfied with labour-management relations. This result is compatible with Sheth's (1969) finding which shows a negative relationship between sound labour management relations and participation

In summary the research results show that age, sex, number of dependents, political activism, job experience; perceptions about union performance, union leaders and labor management relations have significant influence on membership participation in trade union activities. Therefore, the third hypothesis that membership participation in trade union activities is influenced by personal, job and perceptual characteristics can be accepted.

Conclusion and Implications

The empirical findings of the study indicate a strong perception of members on the need for a trade union. It also realizes a considerably higher degree of participation of union members in trade union activities. Though the degree of participation tends to vary across various union activities, the overall response pattern indicates a greater degree of participation in trade union activities. the study reveals that age, sex, number of dependents, political activism, job experience, members' perception about union performance, union leaders and labour management relations are significantly related with the participation in trade union activities. These findings confirm all formulated hypotheses of the study.

Remarkably the present study discloses a significant relationship between all perceptual factors considered and the participation. It shows that, significantly, perceptions about union performance and union leaders are negatively related with participation. The research results also reveal a positive relationship between unsatisfactory perceptions about labour-

management relations and participation, and conversely a negative relationship between satisfactory perception about labour-management relations and participation.

These findings have practical implications for both management and union. The study suggesting that unfavourable perception about labour management relations make the union members more active thus, by maintaining sound labour management relations, it is possible for the management to limit adverse trade union activities. Therefore, management must recognize and understand the employees and respect their dignity. Management should care about employee needs and should anticipate union problems and take affirmative and timely steps to minimize these problems rather than keep them waiting and postponing the discussion of their problems until they actually arise. Management should also consider unions as their supporters and not enemies. Through this process the management can develop a favourable attitude among employees towards the management. Such a process would contribute a lot to maintaining a sound industrial harmony in an organization

This study also suggests that unfavourable perceptions about the management of unions alone do not generate considerable membership participation. The perceptions about union performance and union leaders have a strong influence on the degree of participation. Consequently the union is supposed to work for the betterment of its members, and the leaders must be true leaders in the sense that they are genuinely interested in upgrading the standard of living of their members. The success of a trade union depends mostly upon its leaders. Leaders must have a commitment to the union and possess high leadership qualities to enhance members' commitment to the union. The findings of this study reveal that the members' commitment to the union is a crucial factor behind their participation. An effective and efficient union with such leaders will easily be able to gain its members' commitment. Therefore unions must initiate programmes for developing the members' commitment to the union to enhance their internal strength. As all members must be aware of the union purposes, functions, performance, the power etc. for building the commitment to the union, open communication becomes essential. Union leaders and members, therefore, have to play very important roles in uplifting their union performance. Further, both management and unions should recognize each other's role towards betterment of all parties concerned and should be aware of the significance of maintaining a sound and harmonious industrial relationship in the organization.

Moreover, in this study it is shown that personal factors have a greater influence on union participation. Even if management or union leaders cannot change members' personal factors directly they can behave in a specific manner to change members' perception towards a more positive state.

Further this study should draw more attention of future researchers towards this important field. This is an interesting field for research and has so far remained almost totally neglected by the Sri Lankan researchers. It is suggested that future studies be looked deeply into the factors influencing membership participation in different work environments, cultural settings, industries and in different trade unions. Further, attention should be paid to compare white-collar union with blue-collar union members' participation behavior in future studies.

Table 3. Factors Affecting Membership Participation in Trade Union Activities

Factor	Degree of Participation				Chi Squared Value	Degrees of Freedom	Remarks
	High (n=174)	Medium (n=266)	Low (n=60)	Total (n=500)			
<u>Age</u>							
25 Years or less	05 (14.3)	20 (57.1)	10 (28.6)	35 (100.0)	20.3	6	Significant
26-40 years	75 (31.5)	131 (55.0)	32 (13.5)	238 (100.0)			
41-50 Years	78 (42.2)	92 (49.7)	15 (8.1)	185 (100.0)			
51-60 Years	16 (38.1)	23 (54.8)	03 (7.1)	42 (100.0)			
<u>Sex</u>							
Female	44 (21.6)	128 (62.7)	32 (15.7)	204 (100.0)	27.1	2	Significant
Male	30 (43.6)	60 (56.6)	16 (15.1)	266 (100.0)			
<u>Marital Status</u>							
Married	144 (36.5)	206 (52.3)	44 (11.2)	174 (34.8)	3	2	Not Significant
Unmarried	30 (28.3)	60 (56.6)	16 (15.1)	266 (53.2)			
<u>Level of Education</u>							
Grade 1 to 8	06 (33.3)	07 (38.9)	05 (27.8)	18 (100.0)	10.8	8	Not Significant
Up to GCE (O/L)	21 (40.4)	25 (48.1)	06 (11.5)	52 (100.0)			
Passed GCE (A/L)	52 (36.9)	79 (56.0)	10 (7.1)	141 (100.0)			
Passed GCE (A/L)	70 (32.6)	113 (52.5)	32 (14.9)	215 (100.0)			
Degree/ Professional Exams	25 (33.8)	42 (56.8)	07 (9.4)	74 (100.0)			
<u>Number of Dependents</u>							
Zero	11 (19.3)	38 (66.7)	08 (14.0)	57 (100.0)	13.3	6	Significant
1 to 2	47 (33.8)	71 (51.1)	21 (15.1)	139 (100.0)			
3 to 5	105 (40.1)	133 (50.7)	24 (9.2)	262 (100.0)			
More than 5	11 (26.2)	24 (57.1)	07 (16.7)	42 (100.0)			

<u>Community Background</u>							
Urban	50 (40.3)	60 (48.4)	14 (11.3)	124 (100.0)	2.5	4	Not Significant
Semi-Urban	66 (31.9)	116 (56.6)	25 (12.1)	207 (100.0)			
Rural	58 (34.3)	90 (53.3)	21 (12.4)	169 (100.0)			
<u>Political Activism</u>							
Active	31 (67.4)	10 (21.7)	5 (10.9)	46 (100.0)	24.9	4	Not Significant
Passive	143 (31.5)	256 (56.4)	55 (12.1)	454 (100.0)			
<u>Job Experience</u>							
Less than 1 Year	05 (23.8)	11 (52.4)	05 (23.8)	21 (100.0)	30	8	Significant
1 to 3 Years	09 (15.5)	35 (60.4)	14 (24.1)	58 (100.0)			
3 to 5 Years	08 (21.6)	23 (62.2)	06 (16.2)	37 (100.0)			
5 to 10 Years	17 (29.3)	32 (55.2)	09 (15.5)	58 (100.0)			
More than 10 Years	135	165	26	326			
<u>Salary</u>							
Less than 2500	05 (38.5)	06 (46.1)	02 (15.4)	13 (100.0)			
Rs 2500 to Rs 4000	19 (30.2)	31 (49.2)	13 (20.6)	63 (100.0)			
Rs 4000 to Rs 5000	28 (31.1)	52 (57.8)	10 (11.1)	90 (100.0)			
Rs 5000 to Rs 6000	27 (29.7)	52 (57.1)	12 (13.2)	91 (100.0)			
Rs 6000 to Rs 8000	40 (33.1)	66 (54.5)	15 (12.4)	121 (100.0)			
More than Rs 8000	55 (45.1)	59 (48.4)	08 (6.5)	122 (100.0)			
<u>Job Satisfaction</u>							
High	59 (38.8)	82 (53.9)	11 (7.3)	152 (100.0)	8.2	4	Not Significant
Medium	106 (32.5)	176 (54.0)	44 (13.5)	326 (100.0)			
Low	09 (40.9)	08 (36.4)	05 (22.7)	22 (100.0)			
<u>Perception about Union Performance</u>							
Satisfactory	107 (59.5)	67 (37.2)	06 (3.3)	180 (100.0)	80.2	2	Significant
Not Satisfactory	67 (20.9)	199 (62.2)	54 (16.9)	320 (100.0)			

<u>Perception about Union Leaders</u>							
Satisfactory	99 (63.5)	51 (32.7)	06 (3.8)	156 (100.0)			
Not satisfactory	75 (21.8)	215 (62.5)	54 (15.4)	344 (100.0)	84.0	2	Significant
<u>Perception about Labour-Management Relations</u>							
Satisfactory	20 (18.2)	51 (46.4)	39 (35.4)	110 (100.0)			
Not Satisfactory	154 (39.5)	215 (55.1)	21 (5.4)	390 (100.0)	7.1	2	Significant

Note: Figures in Parenthesis represent Percentages to totals

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Redefining Parameters: The Case of Lankan Urban Bilingual Discourse

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Abstract

Spoken and written forms of discourse employed by English-Sinhala bilinguals at present call attention to certain significant factors which have served to condition the exponents of such forms at diverse levels. Research studies dealing specifically with English-Sinhala bilingualism are indeed few; more so any recent evaluations of extra-linguistic determiners applicable to the language behaviour of English - Sinhala bilinguals. In this study, I have attempted to deal with some of the significant features of extra-linguistic interest within the discourse patterns among present day urban English-Sinhala bilinguals in respect of spoken discourse. The main objective of this exercise happens to be the initiation of extensive discussion/research leading to the recognition of the functional aspects of some distinct discorsal features current within urban bilingualism. In addition, this study seeks to update the already available material with regard to new additions of many sorts to be noted within the vocabulary of the present day urban bilinguals which require an in-depth analysis.

My research in identifying these discorsal features and subsequent analysis involved direct and indirect interaction with urban English - Sinhala bilingual representatives of several age groups as well as educational, socio-economic and cultural backgrounds and extensive recording of their use of both languages in question. Special attention was paid towards ascertaining how representative each exponent was of a particular group thus divided, since the quality and the effectiveness of the language functions of certain bilinguals often lead to questions rather than definitions based on the in-group identity of the speakers in question. The focus of this research was also concerned with capturing the aspirations, emotions and attitudes of selected bilinguals as they are framed in language, since interpreting the extra linguistic and social significance of such features would enable one to grasp the character and complexities of language behaviour of present day language users belonging to the urban sector.

Further, it has been attempted to examine some of the attitudes, past and present of linguists and discourse analysts towards the language use of individuals, through reference to discourse patterns among the urban English - Sinhala bilinguals. The value of such attitudes has been questioned by analysing these discourse patterns, considering the very many controlling factors affecting the utterances and writing of these bilinguals within the present day context. It has been argued that extra-linguistic factors governing the language behaviour of the urban bilinguals can hardly be placed in perspective in relation to their discourse acts through some unproblematised theoretical notions of modern discourse analysis.

Introduction

Discorsal features both established and of recent origin used by urban English - Sinhala bilinguals well deserving in-depth analysis happen to be many. Often, a word or phrase among these features, when closely examined, can be made to reveal the multidimensional nature of a variety of influences presently governing the language behaviour of these bilinguals. The fundamental process of employing language in communication, when subjected to socio - linguistic refraction, portrays the varying shades of historical, social, educational, economic, situational, personal and other factors influencing the formation and use of the vocabulary of the language user, and it is such refraction of the linguistic database of the bilingual that can truly yield extensive information on the functional and other aspects of English - Sinhala bilingualism in its current form.

How this process of analysis or refraction can lead to a better understanding of the functions of discourse among the urban English - Sinhala bilinguals can best be illustrated by examining thus some of their expressions of recent origin employed in day-to-day interaction with peers. For instance, among the multi-varied expressions used by the upper and upper middle-class young male urban English - Sinhala bilinguals in informal discourse are the inter-related terms "bit" and "Bitscene". These render meanings entirely different from the lexical meanings that come to mind when giving the two words involved a standard (British) English interpretation, having treated them in isolation. "Bit" within the code of the younger males (mostly teenagers) of upper and upper middle-class bilinguals is employed to refer to a young female, belonging to the social class and age group of the speakers themselves. This expression could be treated as the Lankan equivalent of the American "gal", yet unlike the American expression employed to refer to women of different age groups and classes (and even animals at times!), "bit" is strictly confined to identifying females in terms of a particular age group or class;

A female of the same age group from the urban lower middle class or under class, or from the rural upper/lower middle classes would not be identified as "bit"; rather they would be referred to as "dame" or even "*baduwa*" (this latter term is given two shades of meaning by its users: (a) a female having more than one male partner (b) an attractive female of any class).

"Bitscene" is a combined form used to express ideas associated with the number of "bits" to be found in any particular environment/locale: eg. "I was at the College carnival; heavy bitscene and all". This would, in effect, mean that while the speaker was at his college carnival, scores of desirable females of his own class and age group were to be noted within that environment. I say "his college carnival" since for an urban upper or upper middle-class male bilingual "college" would almost always mean a privileged public or private educational institution where he has received his primary/secondary education. The same is true of his female counterpart. These comprise only a fraction of a wide range of expressions that reveal the attitudinal aspects pertaining to extra-linguistic determiners - age, gender, class and region of present day English-Sinhala bilingualism.

There are other not-so-recent features of the discourse patterns among the urban English - Sinhala bilinguals that have not received adequate attention of studies conducted so far. Take for instance the language based oppression of the lower / under - classes by the socially superior, manifesting itself through subtle forms of expression within discourse. Often, the learner talk of a lower/underclass bilingual eager to master the educated variety of Lankan English would be tolerated by the socially superior up to a point. Beyond this point, such learners would be victimized by the patronising attitude of his/her superior participants in discourse by a special type of code switching¹, aimed at discouraging learner talk and challenging the learner's attempt to include himself / herself within the group of the socially and educationally advanced speakers. More often than not, this code switching would take the form of a response in Sinhala by the superior speaker to a question framed in learner English by the socially disadvantaged person. Note the following for instance :

- A: They gave you ?
 B: Yes, I just went in.
 A: What is your results?
 B: D *Pahai C thunai*.

In this conversation which took place outside the premises of an urban private owned school for males, the first speaker's violation of the subject-verb agreement through the misuse of "is" in his second utterance in extra-linguistic terms serves as a class marker. The second speaker who first responds to his interlocutor in the code of the interlocutor's choice, on noticing this class marker immediately code switches into Sinhala, conveying to the former

¹The use of different languages by a single speaker at different times, different intervals in a particular discourse act.

the message "you cannot possibly speak the way I do, so use the code of your own class". Here it must be noted that the in-group identity among the participants in discourse is often questionable. Both speakers in this example belonged to the same age group and school, and during the recording of their conversation it became apparent that they together with peers used Lankan English as a locale-related code within the school environment. Yet, despite this shared identity, a type of in-group favouritism was seen to be in operation, based on the overriding powers of a class factor in existence **within** that identity. As perceived through this example, no rule governed definitions in terms of in-group identity can accurately explain on all occasions the language behaviour of the members of a particular group; hence the significance of examining the extra-linguistic determiners encountered within discourse.

The reverse of this phenomenon of class-based code switching in discourse is also to be found among the present day bilinguals. The socially disadvantaged learner bilingual, on noticing the condescension of his/her partner in discourse, would often continue to use learner English throughout the conversation without resorting to code switching or mixing², by way of protest, no matter the extent of use of the other code (Sinhala) by the other speaker.

Here, the learner English of the bilingual becomes a marked code³ seeking the rejection of the notion that his/hers is an inferior sub variety of English vis-a-vis the 'educated' standard form. This use of a marked code can also be linked to a psychological process active within some learner bilinguals, which is governed by a desire to neutralize manifestations of social and educational inferiority reflected through their use of language.

At this stage, it is also necessary to distinguish between some special features of the bilingual's use of a marked code and his/her employing of accommodation strategies⁴. The following example reveals the manner in which these features condition speech events of the urban English - Sinhala bilinguals.

This example comprises a recording of a telephone conversation, this time between a journalist and a ministry secretary. Both speakers are urban male English-Sinhala bilinguals.

A: Could I speak to Mr.....

B: (after a brief pause) *kathaa karanawa.*

A: *Mama 'Daily News' eken kathaa karanne.*

B: *Ovu?*

A:*me maase siyayata thihakin vedi karanava kiyanne eththada?*

B: You see, the Cabinet has agreed only in principle to increase and up to now, the percentage has not been specified. Prior to implementation, we'll have to go into a number of issues...

This exchange comprises several aspects of extra-linguistic interest that reveal as to why the two speakers react to each other the way they do. The journalist's already available information on the language background of the bureaucrat in the first instance is seen to lead to his code selection-to speak in the educated variety of Lankan English. Nevertheless, in this particular speech event, he is also aware of his interlocutor's strong 'nationalist'

²The use of different varieties of language by a single speaker within a single utterance.

³A variety of language which serves as a marker of social status, education etc.

⁴Strategies employed by a speaker to keep up with the code of his/her interlocutor, or to compensate for his/her inability to do so.

sentiments pertaining to the use of Sinhala as 'Swabhasha', though the bureaucrat is perfectly capable of communicating in the code he (the journalist) has selected. The brief pause of the bureaucrat denotes indecision, stemming from a conflict between an emotional bias and his knowledge of conversational conventions as well as of what leads to efficiency in communication. Finally, the dictates of emotion are given precedence, and this in turn leads to the bureaucrat's code selection, denoting the national and cultural significance of Sinhala; by implication, the journalist is indirectly indicted for failing to recognise this significance.

However, once the journalist in the example employs the accommodation strategy of reverting to the bureaucrat's own code, the latter's attitude towards his mother tongue is seen to alter, at least momentarily, presumably due to two reasons. Through the information furnished through discourse ("*Mama 'Daily News' eken kathaa karanne*"), the journalist is seen to reveal his professional links with a state run English daily and in his role-relations with the bureaucrat he seeks to fulfil a professional requirement - i.e. news reporting for publication in the English medium. As for the bureaucrat, being a fluent speaker of educated Lankan English, he is now called upon to perform the function of an informant (source), preferably in English. In addition, established social norms require him on this occasion to assert his identity (official/social) which is inalienably linked with English, this language being a status- symbol for those of his calibre in addition to others. Though his first utterance, once the journalist has revealed his identity, is still in the mother tongue ("*Ovu?*"), the next utterance of the former which continues in Sinhala at length immediately leads to the bureaucrat's code switching into English, which for him is a situational requirement. Clearly then, the process of code selection in discourse among the urban bilinguals is seen to be conditioned by a variety of extra-linguistic determiners-class, profession, cultural and emotional ties among them.

One of the controversial areas in the field of discourse analysis stems from the distinction drawn by some analysts between what they term 'transactional' and 'interactional' talk. According to this division, transactional talk is usually aimed at changing the status quo pertaining to one or more situations, such as getting another to accomplish some task, carrying out commercial transactions etc. Interactional talk aims, primarily, at "the lubrication of social wheels" (McCarthy 1991), assisting in the confirmation and consolidation of relationships. As made apparent by day-to-day interpersonal communications, however, these categories are not strictly mutually exclusive. Transactional talk can at times accomplish, at least partially, the role of interactional talk. The following exchange between two urban bilinguals at an exclusive leatherwear sales centre in a plush supermarket complex in Colombo, would illustrate this:

Salesperson: What can I do for you?

Customer : I'm looking for a travelling bag.

(Parakrama, Arjuna :Field notes)

Here, the customer who was shabbily dressed was thus questioned by the salesperson as soon as he stepped into the sales centre and did not even have sufficient time to glance at the available products. What he noticed later in this particular locale proved that other customers, well dressed, were not questioned on entering the premises by the salesperson in such a hurried manner. The salesperson's question, then, rather than being framed to assist the customer, could be said to have had an interrogatory function in this particular context, his attire in the salesperson's terms having been inferior to that of the average customer that she usually came in contact with. Her question, therefore, can be attributed to a combined interactional-transactional purpose-i.e. class-based interrogation of an undesirable customer who at first glance did not bear signs of sufficient "purchasing power", and the initiation of a remotely possible commercial transaction which **might**, after all, result in the sale of some item or other.

A communicative act of a speaker or writer can often be an access-code for interpreting his/her identity and behaviour. When an English-Sinhala bilingual female tells another "I'll give you some; but the thing is the fellow came drunk yesterday and plucked, and it's neither *kos* nor *polos* so how to use for your pickle?", she is not merely referring to the value of temporance or to temporary insanity but, due to whatever reason, asking the other to leave aside any hopes of sharing the fruit in question! The speaker's use of Sinhala loan words *kos* and *polos* instead of the Lankan common substitute 'jak', tells us of her ethnicity - that she most probably belongs to the Sinhalese community, and probably to the middle class, the members of which often use such loan words and also phrases like "so how to use for your pickle" than any other group within the Lankan social hierarchy. In addition, the subject-matter of this text of discourse, through its association with home-grown fruit and a home-made traditional culinary preparation usually attended to by females, conveys some idea of the gender of the addressee as well as that of the speaker. It would be assumed through the words employed that this conversation would have emerged during interaction between the speakers within the domain of friendship. An utterance or written text then, when closely examined with reference to linguistic/extra-linguistic factors and contextual parameters often turns out to be an informative preface vital for understanding the multidimensional character of participants in discourse and their physical and non-physical⁵ environment. I shall now discuss a variety of features currently apparent within the discourse patterns of urban English-Sinhala bilinguals that serve to highlight the extra-linguistic value of words and phrases which are indeed informative in a socio-linguistic sense. Further, the discussion seeks to assert the identity of these units of language as truly Lankan in character, ie. truly Lankan 'property' of Lankan English.

During the research activity that provided material for this study, speech patterns and written forms pertaining to discourse among urban English-Sinhala bilinguals were recorded extensively. Particular attention was paid to capturing as many speech acts as possible in 'natural' informal contexts. While some interlocutors were unaware that their words were being processed either on tape or paper, others undertook to converse as 'naturally' as possible, disregarding the necessity of assisting in research (their very assistance was in fact based on this attitude). This led to the availability of segments of 'language-in-action' produced under little or no interlocutory constraint which enabled the close analysis of certain distinctive features within the discourse patterns among these bilinguals. Such material may not have emerged through marked self conscious attempts of subjects at providing information for a researcher. Yet, I shall proceed by leaving behind the rule and considering an exception - an occasion in which a speaker on noticing the presence of the researcher, produced an expression due to a particular type of interlocutory constraint, not merely to achieve her stated objective, but chiefly to declare her identity as a member of a particular group constituent of the urban community of English-Sinhala bilinguals.

Effacement of Identity as Reflected through Discourse

This speaker, a Sinhalese English-Sinhala bilingual female aged 36, had been brought up, as was revealed later, in a westernized urban family residing within the Colombo municipality. In the family domain, from childhood she had been exposed to extensive use of Sinhala and frequent code-mixing involving a few English expressions such as nouns referring to objects, items of food, illnesses etc., while her primary and secondary education at a private owned Colombo school for females had been in the Sinhala medium. With regard to social/economic status, this speaker belonged to the westernized upwardly mobile middle-class.

⁵ Socio-cultural, political, economic etc.

Married to a state sector executive using Sinhala as an L₁ to communicate with the family, the speaker had two children who had been trained to identify their parents with the Sinhala expressions *Ammi* and *Thaththi* within and outside the family domain. Yet, as contained in the recorded text, in the presence of a stranger, (in this case the researcher) the speaker was heard to employ the following expression to instruct her children:

Ask Dada to come

By analysing this expression with reference to the context of communicating in the presence of a stranger, it could be given a problematised reading which would serve to highlight a variety of factors of extra-linguistic significance, lying beyond the stated intent of the speaker. Firstly, the expression *Dada* contained within the utterance could be defined as an extremely Anglicized upper-class term, still prevalent within the family domain of a few users of Lankan English as L₁ as part of the British colonial inheritance. Given the speaker's social standing, quality of discourse within the family domain and the educational background as well as the language choice of her spouse, it would be most unlikely that this term would fit into her vocabulary (and that of her children) under normal circumstances.

What then would be the stimulant, which triggered off this expression within the given context? My reading would point to a strong underlying class factor leading to an attempt at complying with a psychological obsession, requiring the speaker to consciously seek the alteration of her identity before another. The speaker, belonging to the upwardly mobile middle-class as was noted earlier, in this instance is indeed a victim of cultural falsity, arising through social aspiration of acquiring at least a few elements of the language behaviour of the Anglicized upper-class. Thus, in the presence of the stranger who presumably had been unaware of her genuine identity, the speaker could be said to have engaged in a deliberate attempt at placing herself at an upper rung of the Lankan social hierarchy considered superior to her own, through a unit of discourse.

This example serves as an index to certain larger-than-personal (i.e. social) areas concerning the lifestyle, thought processes and discourse of urban English-Sinhala bilinguals. Currently, many bilinguals among the middle and lower-middle classes using Sinhala as L₁ seek to upgrade their social status and gain access to relatively beneficial avenues of employment through what is more than a mere "working knowledge" of English. In attempting to meet this requirement, the bilinguals mentioned not only learn the language at the primary, secondary, tertiary levels through schools, courses of study conducted by individuals and institutions such as the universities, The British Council etc., but also attempt at imitating the language behaviour of whom they consider to be 'role models' among English users. These 'role models' (if there can be such beings considering the multiplicity of factors governing the choice and use of language among individuals) for them are persons who are necessarily Anglicized, belong to the upper stratum of the social scale, and whose spoken (and written) variety of Lankan English, in Lankan terms is closest to Standard (British) English. (Since the 1980s with the introduction of American television programs and an increased number of American films, some bilinguals have begun to veer away from this trend and move closer to the American variety.) Some among the in-group and out-group expressions of these trend-setters are in actuality direct borrowings from the British Standard, and are markers of the idiom and other linguistic as well as extra-linguistic features found among mother tongue speakers of English in Britain. As pointed out by **Thiru Kandiah [(1978)1981]** too, this entire process involving 'role models' and their followers is linked with the bilinguals' own irrational rejection of the very identity of the Lankan English speaker as a 'Symbiotic personality' with a distinct variety of that language at his/her command which embodies his/her own linguisticocultural norms.⁶ Similar to the speaker in the example, these lower-middle and middle-class and in some cases the upper middle-class bilinguals in most urban locales resort to such speech strategies to shade their

⁶ See Kandiah[(1978)1981].P.79

feelings of social insecurity, albeit unsuccessfully; infrequent and imitated use of a limited number of expressions in selected contexts could never qualify a speaker as a proficient user of the code to which such linguistic features in actuality belong.

And, as in the given example, among the lower, lower-middle and upper-middle classes, these imitators cannot very well master (and their need to do so is indeed problematic) the discourse patterns among the upper-class English speakers of Lankan English as L₁, leave alone those of the Standard (British) English speakers. This is basically due to the operation of certain linguistic, personal/social factors such as the phonological inheritance of some members of these groups {as pointed out by **Chitra Fernando**[(1976)1982] and **Kandiah** [(1978)1981] }, the extent of the influence of Sinhala as a mother tongue on their English, the lack of an Anglicized family/ancestral and educational background etc.

Having discussed some of the attitudinal aspects of urban English-Sinhala bilingualism, which serve to reinforce my previous related arguments, I shall now proceed to illustrate through units of data how the urban bilinguals within given domains interact as interlocutors using Lankan English in order to achieve a variety of objectives-aided, governed, altered and at times even violated by the language that they use.

Novelty Amidst Established Usage

The variability in patterns of discourse among the urban bilinguals is further illustrated by the language behaviour of upper-middle and middle-class bilinguals, who use Lankan English as a first language within almost all domains despite Sinhala being their mother tongue. The code used by them in informal discourse with peers, depending on the extent of their allegiance to the Anglicized lifestyle is characterized by code mixing and code-switching with the use of Sinhala. Particularly, the younger bilinguals of this group(it is a group that can be included in **Chitra Fernando's** [(1976)1982] Group Two, provided that the latter group is redefined)are prone to use Sinhala expressions increasingly than their older counterparts. Given below is a text transcribed from a tape recording made at the 1995 Royal-Thomian cricket match in Colombo, Sri Lanka. The participants were Sinhalese male upper-middle class English-Sinhala bilinguals aged 16-17 years who use Lankan English as an L₁. Only one participant(C) was aware of the presence of recording equipment.

- A: These buggers are mad *machang*. Look where he lifted that.
Thava podden athey caught. At this rate there'll be no match on Saturday. We'll be all out before close.
- B: Buggers are feeling down *machang*. But the other thing is, considering their batting we can't afford to *thattufy*.....
- C: Mm
- B: at this stage. So the buggers must be thinking hit out or.....
- C: Yeah
- B: get out and whacking. *Naththang ithin*.....
- A: Yeah, but the one he lifted now was too dangerous.
- C: True
- A: Peiris won't usually miss one like that. We're lucky. Last time....
- B: Same with his bowling .The bugger is well seasoned. What were you saying *machang*?
- A: Last time.....I told you! there! he's gone. That one was lifted to the same spot. *Illang parippu kanawa*. This is the end *machang*, this is theeeeeee end. The rest of our guys will do nothing with this kind of bowling. *Heta wenakangallan hitiyoth pudumai*. Aa..they are bringing the drinks. *Machang* shall we go down and have.....
- B: O.K.
- A:something? This heat is a bloody killer.
- C: Here, are we leaving the bags or..
- B: We'll leave them and go. Otherwise some bugger might...

- A: Shit *machang!* I was hoping that we'd be well into the game and full *dayma gahai kiyala*.
 B: Don't cry you bugger. If no match on Saturday, we'll go for a swim or something. Or we can....
 A: Swim *koheda*?
 B: Mount or somewhere.

What becomes apparent through the code of each interlocutor in this conversation is that while each could habitually (effortlessly?) communicate in English, code-mixing and switching here is clearly aimed at reinforcing an informal register appropriate for establishing friendship/intimacy and asserting in-group identity. There are more instances of code switching than mixing to be noted, for most of which the speaker A is responsible. This could be attributed to a strong influence of Sinhala as mother tongue, yet considering the overall performance of the participants, A happens to be the most communicative and consequently possesses a wider linguistic repertoire at his command in discourse.

The fact that code switching takes precedence over code mixing throughout the speakers' interaction would indicate a conscious effort on their part to preserve the quality of their L₁ English as 'English' and not ⁷'Singlish', since this spoken language qualified as "better" is indeed a status symbol. Nevertheless they are not reluctant to introduce certain day-to-day expressions within this 'superior' variety which are characteristic of the Lankan consciousness of the 'symbiotic personalities'⁸ that they are. The expressions *thattufy* (to bat on slowly) and *illang parippu kanawa* (asking for trouble) are typically used in discussing cricket by the bilinguals; while the former (which in L₁ Sinhala is known as *thattu*) is employed by both young and older male bilinguals alike, the second is 'endemic' among the middle and upper-middle-class young urban bilinguals.

The element of code-mixing in A's utterance:

I was hoping that we'd be well into the game and full *dayma gahai kiyala*

needs to be analysed closely, since it brings out a commonly shared feature of most discourse acts of urban English-Sinhala bilinguals - the employing of grammatical structures/syntactic arrangements of Sinhala in code-mixed elements included within discourse that happen to be predominantly English-oriented. The expression "full *dayma gahai kiyala*" (would play throughout the day) cannot be treated as a mere code-mixed item facilitating communicative efficiency alone. Granting that it does achieve this purpose, one needs to be aware that it is linked with wider social implications that condition the language behaviour of the speaker, emerging from the terrain of the subconscious while participating in discourse.

Such expressions often convey a sense of protest against Anglicized linguistic hierarchy and a desire within the speaker to alter the language-related status quo, possibly due to one or more extra-linguistic reasons. As mentioned, the speaker A who employs this expression could be one influenced considerably by the operation of Sinhala as a mother tongue.

Though English is his L₁ within the domains of family and friendship, it is possible that he had been exposed to the use of Sinhala from childhood among neighbours and later among fellow students at the primary and secondary levels of education. His use of Sinhala within English in the above manner, then, would mark a necessity to award recognition to a mode of expression prevalent among other speakers within his communicative environment, a mode which despite its 'otherness' in the light of his own code, is associated in his mind with a notion of shared racial inheritance, the overriding powers of which alter his speech acts

⁷ See Chitra Fernando [(1976)1982].P.200

⁸ See Kandiah (1981).PP.96-97

wherever possible. Thus, it is vital to emphasize the necessity for looking beyond the established definitions (such as code-mixing) and parameters if one were to accurately interpret the extra-linguistic complexities situated within the discourse patterns of urban English-Sinhala bilinguals and other speakers.

The speakers here alternately employ the expression *machang*, which literally means 'brother-in-law'. An expression markedly in-group in character, *machang* is currently employed by both young and older English-Sinhala bilinguals (but not by those who are above the age of seventy or so) belonging to all levels of the social hierarchy, in informal discourse. A very special and interesting feature of its employment in discourse which emerged during my research activity was that having remained a male prerogative expression until recent times, *machang* was now being used by some upper-middle and middle-class urban *females* aged around 16-26 - schoolgoers, undergraduates, and commercial sector employees (shop assistants, stenographers etc) among them. They were heard employing this expression along with Lankan English while travelling in buses, during "shopping-sprees" and in informal discourse at locales ranging from universities to carnivals. The fact that they were clearly 'violating' an established, gender-related norm did not seem to deter them at all, since the term was being employed quite audibly in the presence of out-group members of many types.

Having discussed some aspects of the influence of Sinhala expressions and language structures on Lankan English, I shall now analyse some features of linguistic and extra-linguistic interest noted within the Sinhala-oriented discourse patterns of middle-class English-Sinhala bilinguals. Speech acts contained within informal discourse of this group are characterized by the frequent inclusion of English lexical items, some of which happen to be well established at present within L₁ Sinhala of most speakers. This combined use of the two languages in the present day context can be illustrated by the following informal discussion between three middle-class female bilinguals aged 33-46, at a Colombo private sector commercial institution in December 1994. Participants were aware that their conversation was being recorded.

- A Notice *eka daalada ane?*
 B: *Thaama na. Nathnam melahakatath aaranchiya gihin.*
 A: Notice board *eke baluwada?*
 B: *Ovu.*
 A: *Kohomath pay ekath ekka gevai. Pereda news walatath kivva..*
 C: *Me paara tikak vediyeri dunnanang....*
 A: *Pereda news walata kivva private sector ekatath denna oona kiyala.*
 B: *Hm..*
 C: *Ape increments hadalada? Mata nam dan ahala ahala epaa wela. Giya sumaane...*
 A: Computer section *eke Nishanthi kivva eyaalata okkoma details evalalu.*
 Feed *karanna witharalu thiyenne.*
 B: *Eyaala feed karanakota labana avurudda vei. Dan kavada indalada*
 A *Kohomath me month eka ivara venna kalin hadai. Indranige wedding ekath langai....*
 C: *Ovu.*
 A *Needa? List eka patan aragenada?*
 B: *Thaama na. Monavada ithin present ekata denne? Lalanita wage porcelain....*
 C: *Ae set eka dan ae gaanata ganna ba. Langadi prices vedi vuna. Api cake tray ekakui...*
 A: *Cake tray ekakata vadaa gedarakata oona deyak...*
 B: *Plates, tea set ekak wage deeval thamai honda. Colpetty paththe giyoth ceramics showroom eken prices check karanna puluvan.*
 C: *Lunch eke giyoth velaa madi. Saturday withara?*

- B: *Ovu. List eke wade kaata hari baaraganna vei.*
 C: *Andung laasthi karagannath oona. Mage hatteta material ekak balannath thiyanawa.*
 B: *Eka gamaninma okkoma kaloth lesiy.*
 A: *Koheluda wedding eka thiyenne?*
 B: *Thaama invitation deela nane. Habai gedera thamai gannava kivve.*

The speakers here are representative of the upwardly mobile middle-class, some members of which, contrary to Chitra Fernando's definition of Group Two bilinguals, are in fact competent users of Lankan English as L₂. In informal discourse among peers (with similar status, education, age and of the same age group) they often use L₁ Sinhala, a code substantially influenced by their knowledge of English, gained outside the family domain in most cases, through primary, secondary and tertiary level education. The loan words from English included in their code belong to several categories - kinship terms (husband, wife, brother-in-law); terms referring to meals (lunch, tea); terms associated with profession (pay, increment, advance, short leave, absent, C.C meaning Chief Clerk and the ubiquitous boss); reference to illnesses, bodily functions (flu, fever, malaria, measles, menses, labour-pains - Sinhala equivalents are almost never used for these last two terms, presumably since the English terms carry a certain neutrality which is absent in the Sinhala equivalents which sound awkward to most speakers); references to occasions in life (birthday, wedding, funeral, welcome, farewell - these terms are used with the Sinhala suffix "eka", and a most notable term referring to young female children reaching puberty: attained. Often mispronounced as "attend" and used together with the Sinhala suffix "welaa", it is a derivation from the English expression "attained age". Yet another term for which a Sinhala equivalent is almost never used is pregnant); references to places (shop, hospital, supermarket, annex meaning a section of a private residence given on rent by the owner, library, hotel, pool, town hall) and many other terms.

To turn to the example, as mentioned the utterances of all the participants carry a distinct flavour of English and the expressions used such as *notice board, pay, news, private sector, list, porcelain, material invitation* etc. can be described as terms well assimilated into the code of these middle-class speakers through long association with Sinhala. The expressions "feed karanna" (to "feed" or process data) and "computer section eka" are relatively new comers but are well on their way towards established usage since computer technology is currently present in many spheres within the urban context.

Conclusion

The outcome of the analyses of different patterns of discourse among the urban English-Sinhala bilinguals in each section of this discussion calls for the recognition of the fact that the prevailing language standards/interpretive criteria should be reformulated to suit the varying forms and levels of expression currently serving the communicative requirements of the different strata of urban bilinguals. Validating their 'non-standard' expressions subject to well developed levels of coherence and efficacy in discourse has to be awarded priority in any constructive attempts at truly improving the quality of the individual and collective language behaviour of urban language users. The use of Lankan English and Sinhala in informal/formal discourse, through levels of synthesis determined by context and extra-linguistic determiners applicable to the urban community, has to be viewed in a truly Lankan perspective leaving aside some standard British notions that are hardly helpful in correctly interpreting the language behaviour of this particular community.

Given these facts and the undeniable truism that the language behaviour of any community is subject to constant evolution, it is necessary to emphasize the need for future extensive research studies/publications that would reveal many other aspects of urban English-sinhala bilingualism well deserving recognition, acceptance and promotion. Such constructive

attempts should also lead to awareness, seeking the elimination of certain undesirable elements of language behaviour among bilinguals, ranging from standard-based irrational intransigence of purists to totally unacceptable features of usage among certain bilinguals. Openness of academic minds probing discourse patterns and socio-linguistic transition among bilinguals, must lead to the formulation of new paradigmatic values serving to strengthen the healthy, innovative aspects of language behaviour prevalent among all urban/rural groups subdivided under linguistic and extra-linguistic parameters. Only then would it be possible to substantially diminish and perhaps totally negate the language-based stigmatising of some sections of the Lankan people in terms of vocabulary, pronunciation and acts of discourse.

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Computer Applications in Medical Education and Training: A Brief Review

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Abstract

Computers have been used in medical education during the past three decades. It has however, gained wider applicability and acceptance during the past decade. Today, powerful microcomputers and user friendly computer software are increasingly being used in many areas of medical education such as simulations in basic sciences during undergraduate training, training simulations in surgical procedures during postgraduate education, medical curriculum development, evaluation procedures and in continuing medical education.

Computer assisted instruction (CAI) is increasingly taking on a new role as an alternative or an adjunctive medium of instruction at all levels of medical education. Because of the increasingly important role the information technology plays in different aspects of medical education, there is at present a growing need for the medical students to become computer literate early in their undergraduate careers. However, there are still many limitations of the use of CAI in medical education such as the initial cost of computers and software packages as well as the maintenance cost of this equipment, which is especially true for third world countries. The development of new low cost powerful microcomputers and global networks such as the Internet and the World Wide Web, Computer Technology is likely to be more widely applicable in several areas of medical education in the ensuing decade.

Introduction

Although the number of students entering the medical schools today with some computing experience is few, the academic staff of the faculties of medicine are increasingly becoming aware of the importance and the vital role played by computer software in assisting their academic and research activities.

With rapid advances in medical education and the radical changes in the undergraduate medical curricula, it was found opportune to outline some important applications of computers in medical teaching and learning and its future prospects. The field is advancing so rapidly that no book can be up to date for long, and keeping abreast of the developments in computer applications in medicine is becoming increasingly difficult. It is evident that we are in a transitional phase in the application of computers in medical education. Except for the past decade, their use has been largely confined to specialised units manned by enthusiasts, who have advanced the application of computers in their own field of practice (Pradham & Dev; 1993). Now that the cost of powerful personal microcomputers has become affordable, it is becoming a common place utility.

The use of computers in medical education has been in evolutionary development since the early 1960s (Piemme; 1988). Its adoption however has been less widespread than was warranted. Computer Assisted Instruction (CAI) enhances learning, allowing the student the discretion of time, content, place and pace of instruction (Piemme; 1988). Information conveyed may be applicable to undergraduate, post graduate and continuing medical education (Pradham & Dev; 1993).

Background to Computer Education

The call for medical students to become literate in the use of information technology has been in existence for over a decade now (Koschmann; 1995). It was over 10 years ago that the Association of American Medical Colleges Report recommended that medical schools incorporate into their curricula, the use of computer technology for medical students to become computer literate (Koschmann; 1995). It will not only enable them to use information technology competently, but will assist in post-graduate and continuing medical education.

It was in the 1970s that computers were first made use of in teaching basic sciences using computer based programmes (Friedmann; 1995). These early results have been encouraging and it prompted the educationists to use CAI more widely in the following two decades. With the advent of low cost microcomputer technology, CAI has received wide spread applications such as clinical simulations (Chew and Smirniotopoulos; 1995).

Information technology has been introduced to medical students in several countries already. Most studies have found that men were more computer literate than women (Gouveia-Oliveira et al. 1994, Sancho et al. 1993, Kidd et al. 1993). However, without a gender bias, the majority identified CAI to be useful as a teaching medium to students and in future medical practice (Kidd et al. 1993). Therefore, the undergraduate curriculum should seek to promote a more self-educative approach, which was suggested by the General Medical Council in Britain in 1990 (Chessell; 1994;). One of the main proposals was the introduction of self-directed learning to reduce didactic teaching during the course, partially with the introduction of CAI (Chessell; 1994). A recent questionnaire based study, which was carried out in Portugal found that the medical students' attitudes towards CAI were favourable (Gouveia-Oliveira et al; 1994). The majority of students (with no significant gender difference) identified the need for the introduction of computer education in their undergraduate medical curriculum, even though only about half those questioned had any exposure to computers (Gouveia-Oliveira et al; 1994). However, the medical schools and teachers in them were late in adapting to the changing teaching techniques, which resulted in a delay in the use of CAI in teaching and training technology and were thus late in introducing computers as a day-to-day teaching aid (Chessell, 1994; Levy, 1989).

Early years of computers and teaching

Computers and the concept of Computer Assisted Instruction (CAI) were introduced into medical teaching almost three decades ago. Since then it has made great strides, particularly during the last decade (Piemme; 1988). Although, computer technology has progressed rapidly during the last decade, the use of CAI as an adjunct to traditional methods of medical education has made limited progress globally (Levy; 1989). However, the advent of cheap and powerful microcomputers has opened the possibility of CAI in medical education to be more widespread by the beginning of the 21st century (Clayden and Wilson; 1988). It has been found that CAI in medical education can be of help to liberate students from the burden of learning of facts and enhance the role of reason and imagination in the learning process.

One important aspect of computer applications in teaching and training at both undergraduate and postgraduate education has been the development of computer models and simulations (Stocking and Mo; 1995; Ostrow et al. 1975; Prentic and Kenny, 1986; Fingert and Schneider 1994). Simulations as an instructional technique are being utilized for the learning of clinical skills in the training of medical students and doctors. It was as far back as 1975 that simulations on pulmonary function tests were introduced in USA (Ostrow et al., 1975). Significantly, CAI in clinical teaching and diagnosis was found to be more acceptable and favoured compared to other teaching methods in surveys

conducted more than 10 years ago (Prentic and Kenny; 1986; Fingert and Schneider; 1994).

The Internet World Wide Web and Interactive Multimedia in Medical Education

Technology is revolutionizing education today. Global networks, powerful personal computers and user friendly graphically oriented software are creating an environment, which gives rapid access to information (McEnery; 1995). The Internet, World Wide Web (WWW) and Mosaic are such networks, which have made a significant impact on CAI.

There are now several interactive multimedia software available for medical education. Such packages are distributed over compact disk-read only memory (CD-ROM), floppy disks and laser video disks (Quinn *et al.*, 1984). The target audiences are usually medical students, doctors, health administrators as well as patients. Recent research has found that such multimedia textbooks, when compared to printed textbooks and standard lectures, prove to be an educationally sound alternative instructional method with a promising future in undergraduate medical education (Poses *et al.*; 1992). A major limitation of the use and popularity of their use has been the high cost and relative non-availability of these software in most countries outside the developed world (Clayden and Wilson; 1988), and the inexperience of the teaching profession to use them (Piemme; 1988). The multimedia textbook was found to be more effective than the standard lecture and as effective as the printed textbook (Santer *et al.*, 1995). However, much needs to be done to improve the reliability and dependability of the contents of information presented in the new multimedia systems (McEnery *et al.*; 1995). Methods have also been devised to utilize the WWW for interactive teaching in some disciplines such as Radiology in USA (McEnery; 1995).

The practicing clinicians in hospitals do not have the same computer based facilities for CAI as those based in the universities. The Internet, which contains a vast amount of medically relevant information, has been employed to link universities with such off campus sites in USA and in future proves to be a useful link between the university hospitals and clinicians (Constantinou *et al.*, 1995). However, even in the developed countries such as USA, where CAI was introduced nearly three decades ago, its use is still limited due to the fewer WWW site available for users in medical education (Constantinou, *et al.*, 1995), and also due to insufficient incorporation of reliable information on topics of medical relevance (Stocking and Mo; 1995).

CD ROM and MEDLINE in Medical Education

Computerized literature searching system was introduced to the medical profession in the 1980s (Markert *et al.*, 1989). Since then it has seen a very rapid development with the culmination of the compact disc-read only memory (CD-ROM), which has been used to store medical literature (MEDLINE). The CD-ROM is a striking new development. These disks have the capacity to hold up to 550 megabytes of digitally stored information. That amount of storage is roughly equivalent to six complete sets of Encyclopedia Britannica (Piemme; 1988). Medically relevant information is now commercially available on National Library of Medicine's MEDLINE on CD-ROM disks.

Several studies have been conducted to assess the usefulness of MEDLINE and CD-ROM in assisting medical students education (Schwartz *et al.*; 1995, Pao *et al.* 1993, Haynes *et al.*, 1993). These studies have consistently found that once the students are exposed to the MEDLINE search, the frequency of use by the students increases significantly. However, these studies have all been carried out in countries where multimedia facilities have been available for sometime. It will be very difficult for such a study to be carried out in a developing country due to the lack of exposure to such information technology (Piemme; 1988, Levy; 1989). Therefore, more exposure to

MEDLINE during medical school could play an important role in developing effective literature searching skills for not only in undergraduate medical education, but also in post graduate and continuing medical education, the last being essential for today's health professionals (Pao *et al.*, 1993). However, the cost of such software would still be a major limiting factor in the world wide use of this information technology (Levy; 1989, Clayden, and Wilson; 1988).

Computer Assisted Instruction (CAI) and Simulations in Medical Education

Computer based clinical simulations have been used in medical education during the past 25 years. During this period, the technology has evolved from mainframe computers to microcomputers to multimedia. The CAI fulfills an important need for pictorial representation of the functions of organs and systems. Various computer techniques of animation (simulation) are now available in medical educational technology (Habbal and Harris; 1995). Basic science subjects such as Anatomy, Physiology and Biophysics are increasingly being taught using computer simulations (Schubert *et al.*, 1994; Lilienfield *et al.*, 1994; Samsel *et al.*, 1994).

In anatomy, computer models have been designed for situations such as teaching of cardiac anatomy and thoracotomy (Champman *et al.*, 1994; Stanford *et al.*, 1994). However, it was found that CAI should not replace dissection in teaching anatomy, but should be used as an adjunct to it, because computer instruction after dissections was found to dramatically improve the testing performance of students (Stanford *et al.*, 1994).

Physiology is increasingly being taught using CAI (Lilienfield and Broering, 1994; Samsel *et al.*, 1994; Mangione *et al.*, 1991; Boyle *et al.*, 1991). Multimedia presentation of lung sounds in undergraduate teaching has been found to be useful for learning and understanding of lung sounds in a study in Chicago, USA (Samsel *et al.*, 1994). The digitalised lung sounds were played and the corresponding waveforms were commented on and displayed on a computer. The great majority of students found the association of the acoustic signals with their visual image more useful than the physical examination of the chest only (Samsel *et al.*, 1994). Comparisons of computer simulations versus animal demonstrations in Cardiovascular Physiology teaching were found to be highly rated by students at the University of Chicago medical school (Samsel *et al.*, 1994). However, CAI received a higher rating. It is likely that CAI facilitates learning in many situations or as equally effective to traditional teaching methods given sufficient exposure (Lilienfield and Broering; 1994), which however is lacking in most parts of the world (Piemme; 1988, Levy; 1989, Clayden and Wilson; 1988). A comparison of CAI and small group teaching of cardiac auscultation to medical students found that CAI is at least as effective as small group teaching of cardiac auscultation to third year medical students in USA (Mangione *et al.*, 1991). Similar results were obtained when ventilator control simulation was introduced to second year medical students (Boyle *et al.*; 1991). It is quite possible that this approach using computer simulations provides a number of additional benefits that are normally lacking in a lecture based practical session.

Although the use of CAI in the medical undergraduate curriculum is increasing, little was known regarding the acceptability of CAI among medical students. A study carried out at the University of Sydney, Australia has found that computer anxiety among medical students was negligible when using CAI and, that there was a high level of acceptance of this type of instruction (Khadra *et al.*, 1995). This is encouraging for medical educators involved in producing multi-media packages for teaching medicine and surgery. Even among intern doctors, it was found that following exposure to CAI on clinical information system use, the computer anxiety was significantly reduced (Brow *et al.*, 1994). However, most medical educators, who are involved in the development of such software packages have not yet integrated themselves into a team, which has inputs from different segments

of the medical education and informatics sectors to develop user friendly reliable software packages (Levy; 1989, Brow *et al.*, 1994, Ota *et al.*, 1995, Goonewardena; 1997).

Virtual reality (VR) is an emerging technology that can teach surgeons new procedures and can determine their level of competence before they operate on patients (Ota *et al.*; 1995). Medical applications of VR are just beginning to emerge. These include surgical simulators, beginning telepresence surgery etc (Ota *et al.*; 1995). Such simulators are being used to train doctors in various surgical techniques such as arthroscopy (Dumay and Jense 1995), endoscopic surgery (Scott-Conner *et al.*, 1994) and laparoscopic surgery (Dubois *et al.*; 1995) and in training in eye surgery (Sinclair *et al.*, 1995). VR also allows the trainee to return to the same procedure or task several times later as a refresher course. Laparoscopic surgery is one of those skills for which VR is used. The major teaching/ training limitations identified with such techniques at present are the high cost of software, lack of experienced training staff and the initial acceptability by trainees (Goonewardena; 1997, Curry *et al.*, 1984). These techniques will have limited use, especially in developing countries and the third world (Levy: 1989, Clayden *et al.*, 1988, Curry *et al.*, 1984).

Medical Curriculum Development

Another application of computer software is in the development of undergraduate medical curriculum content and in the development of integrated curricula (Burrows *et al.*, 1989). This allows for quick and multiple access to the information and allows each department or teaching block to review the complete curriculum quickly, identify redundancies and more fully integrate new or existing material. The curriculum integration is gaining acceptance as an effective approach to teaching information skills and computerized bibliographic databases can be made use of for development of such an integrated approach (Young; 1995). However, most medical schools still have departmental barriers, and are resistant to change, which has resulted in slow progress of the process, despite the knowledge that blurring of boundaries between disciplines continue to occur (Koschmann, 1995, Chessell; 1994).

Continuing Medical Education

Continuing Medical Education (CME) is a key feature of ensuring quality delivery of health care by doctors. In a rapidly changing technological environment, it is important that medical education is undertaken in an effective and efficient manner. Physicians can use personal microcomputers for CME. Advantages of computerized CME include local control over the topic, time, place and pace of instruction (Goonewardena: 1997). Computers can be interactive, providing selected information that depends on the desires and needs of the physician. Learners have different preferred styles of receiving information and computer programmes can be written to appeal to a particular style of learning which will result in the development of programmes and packages much more dependable and attractive to the inexperienced in multimedia use (Goonewardena; 1997, Burrows *et al.*, 1989).

Computers in Evaluation

The computer's role in evaluation is equally significant (Worthley; 1985). Computer programmes have been used to develop files of multiple choice questions (MCQ) and in the correction of MCQs. It allows an examiner to review the student's answers individually or collectively, updating the item discrimination or difficulty indicating each time a student performs the test. It also provides the option of answering the question with or without review of the correct answer and reference (Worthley; 1985).

Conclusions

Already computer technology has found numerous applications in the field of medical education. The past decade has witnessed most of these prolific developments. With the increasingly important role computers play in different aspects of medical teaching, the need for medical students to become computer literate is becoming a growing need as we prepare to enter the 21st century. Today, CAI is assisting in training at undergraduate, postgraduate and continuing medical education levels, and is likely to contribute significantly to the production of tomorrow's doctors globally.

However, there are still significant limitations in the use of computer information technology. They are the initial cost of computers and computer software packages, the maintenance cost of the equipment, training of staff to man such units, the lack of experience of medical educators with the new technologies associated with Informatics and the initial reluctance of the users. All of these have significantly hampered the growth of this new medium of instruction in the developing or the third world.

With the advent of global communication networks such as the Internet and the World Wide Web and low cost powerful microcomputer technology, it is likely to provide a much wider exposure, usage and applicability, resulting in a significant impact in the field of medical education in the coming decade.

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Pulmonary Functions in Pregnant Sri Lankan Women

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Abstract

The objective of this study is to determine the changes in vital capacity and peak expiratory flow rate during the course of pregnancy in Sri Lankan women. This is a cross-sectional study done on 238 pregnant women recruited from antenatal clinics at different periods of gestation. Subjects were divided into eight groups according to their period of gestation. In each subject the vital capacity was obtained by using the vitalograph and PEFR by blowing into the peak flow meter, three times and the best value obtained. Predicted value for vital capacity and PEFR of each mother was calculated by using the regression equation for the Sri Lankan women using the height and age of each mother. For each group mean predicted value and the mean observed value were calculated and the difference in these two values were compared among groups. Also the mean FEV₁ and FEV₁/FVC ratio was determined for each group. There was no significant difference in FVC, FEV₁/FVC and PEFR among the eight groups depending on the period of gestation. Therefore, FVC and PEFR are two useful lung function tests, which can be performed on pregnant women throughout the course of pregnancy, as performed in the non-pregnant state for early diagnosis of pulmonary dysfunction.

Introduction

The results of most of the studies done on western populations indicate that vital capacity and peak expiratory flow rate do not change significantly throughout the course of pregnancy (Weinberger et al. 1980, 559-577; Gilroy et al 1988, 669-672). Similar studies done on Indian populations show that the vital capacity and peak expiratory flow rate tend to increase in the later stages of pregnancy (Chhabras et al. 1982: 56-60; Shaikh 1983:459-499). A previous study done on a Sri Lankan population comparing lung function tests on a group of pregnant women at a gestation of 36-40 weeks, with a group of non pregnant women showed that forced vital capacity was low in the pregnant group, but there was no change in the peak expiratory flow rate (Jayawardene 1992: 21-25).

In view of these conflicting results the present study was undertaken to study the changes of these two parameters in Sri Lankan women during pregnancy.

Methodology

The study group consisted of 238 pregnant women at different periods of gestation. Only women with clinically normal respiratory and cardiovascular systems were selected for the study. Women with a past history of wheezing in childhood, bronchial asthma and those with antenatal obstetric complications were excluded from the study. Women were recruited to the study from antenatal clinics in the Piliyandala area during a three-month period beginning from April 1997.

Their age, height, weight, period of gestation, and symphysio-fundal height were recorded and instructions in the use of peak flow meter and vitalograph were given. Each mother was made to sit comfortably on a chair and was asked to blow three times into the peak flow meter with maximum effort and the values were recorded. The best of the three recordings was used for calculation of peak expiratory flow rate. The forced vital capacity and FEV₁ was measured using the vitalograph and FEV₁/FVC ratio was calculated. The

subjects were allowed three trials and the best value was taken for data processing. Then these matters were divided into 8 groups according to the period of gestation. Group 1 consisted of women with a period of gestation between 9-12 weeks, group 2 – a period of gestation between 13-16 weeks, group 3 – a period of gestation between 17-20 weeks, group 4 – a period of gestation between 21- 24 weeks continuing up to group 8 – a period of gestation between 37-40 weeks. FVC and PEFR of these groups have also been compared.

Results

Expected value for the vital capacity of each mother was calculated by the regression equation for the Sri Lankan women using the height and age of each mother (Udupihille, 1995: 53-58).

$$VC=-1.42 + 0.028 \text{ Ht} - 0.012 \text{ Age} \pm 0.4207$$

For each subject, expected VC and the best value obtained by using the vitalograph were calculated and the difference in these two values were obtained. FEV₁ and FEV₁ /FVC ratio was obtained for each subject. The mean value for each group was determined and is shown in Table 1 for the 8 considered groups. Expected value for PEFR for each woman was calculated by the regression equation for the Sri Lankan women using the height and age of each mother (6).

Table I: Mean deviation from expected FVC (1) and FEV1/FVC (%)

Group	Gesta- tion (weeks)	No. of women	Mean deviation from expected FVC (1)	SD	FEV1/ FVC (%)
1	9-12	28	0.341	0.435	84
2	13-16	29	0.392	0.358	80
3	17-20	32	0.357	0.488	81
4	21-24	30	0.264	0.296	82
5	25-28	31	0.267	0.265	79
6	29-32	31	0.283	0.325	76
7	33-36	30	0.339	0.273	83
8	37-40	27	0.315	0.352	78

F statistic -0.49
P value - 0.8442

For each subject the difference between the expected value and the obtained value was determined and the mean value for each group was calculated and these are shown in Table II. The statistical analysis was performed using F statistics.

Table II - Mean deviation from expected PEFR (1/ml) in 8 groups.

Group	Gestation (weeks)	No. of women	Mean deviation from expected PEFR (1/ml)	SD
1	9-12	28	137	37.86
2	13-16	29	138	43.68
3	17-20	32	142	35.61
4	21-24	30	138	42.31
5	25-28	31	148	29.33
6	29-32	31	147	38.25
7	33-36	30	149	29.96
8	37-40	27	140	33.52

F statistic -0.54
P value -0.8049

Discussion

In Sri Lanka pulmonary function testing is increasingly being used in the management of respiratory illnesses. In this paper we studied the FVC and PEFR changes during pregnancy as these two parameters are considered relatively good indicators for early detection of deteriorating ventilatory capacity (Shaikh et al 1983:495-499). Since these tests are easily done and are fairly repeatable they can be used in antenatal clinics to assess the ventilatory capacity of pregnant mothers (Puranil et al, 1995:137). As there is no consensus of opinion in most of the western and Indian studies done on airway function in pregnant women the present study was undertaken to study these parameters in Sri Lankan pregnant women.

Analysis of data in this study shows that FVC and PEFR do not change significantly in pregnancy. As pregnancy state is associated with complex physiological and anatomical changes, maintenance of FVC and PEFR may be related to these changes (Milne et al, 1977:448-451).

Hormonal alternation in pregnancy causes a reduction in the tracheo-bronchial smooth muscle tone and the increasing thoracic width may be compensating for the rise in the level of the diaphragm which occurs as a result of the enlarging uterus (Singh et al, 1995: 162). Therefore, results of this study show that a large airway function is not impaired throughout the course of pregnancy and FVC and PEFR are two useful lung function tests to assess ventilatory capacity in pregnant women as it is used in the non-pregnant state for the diagnosis of pulmonary dysfunction.

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A Note on the Chemistry and Mineralogy of Apatite Crystals of Eppawala and Ridigama Phosphate Deposits

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Abstract

The mineralogy, chemistry and solubility of apatite from two rock phosphate deposits in Sri Lanka were studied. The larger deposit is located at Eppawala in the North Central Province, and the newly discovered smaller deposit is at Ridigama, in the North Western Province. Both ores show enrichment of phosphorous by way of primary and secondary components, developed in two stages. The primary component consists of coarse, primary apatite crystals, whereas the secondary component has a finer matrix. The primary apatite crystals of both deposits contain at least two types of apatite: chloro-fluoro-hydroxylapatite (CFHA) as the major type and fluorapatite (FA) as the minor one. Although the mineralogical composition of the primary apatite of the two deposits is similar, their a-axis dimensions are different. Further, it was revealed that the crystal structure of the primary apatite from Eppawala is more stable than that of Ridigama. Therefore, a greater chemical reactivity is expected of the primary apatite from Ridigama than that from Eppawala. This explanation is consistent with the solubility data obtained for the primary apatite of two deposits, primary apatite from Ridigama being more soluble than that from Eppawala. In addition, chemical studies show that the primary apatite from both locations, with low Fe and Al contents, has a better potential as a fertilizer than that of their finer matrices.

Key Words : Apatite, Phosphate, Solubility, Mineralogy

Introduction

A large and important phosphate deposit was discovered in 1971 at Eppawala, in the Anuradapura District, about 200 km north of the Sri Lankan capital city of Colombo (Figure 1). This deposit is being currently mined as fertilizer for direct application with a product having an average P_2O_5 content of 30 per cent. The Eppawala phosphate deposit occurs as a thick, weathered profile underlain by a apatite-rich carbonate rock. Due to intensive weathering conditions, the parent apatite-rich carbonate rock has been weathered and leached, and in the process the capping material has been enriched with mineral apatite and other secondary products. Essentially, the deposit consists of yellowish green, sub-hedral, large apatite crystals as a primary mineral in the fine matrix. The matrix itself is composed of finer primary apatite and still finer secondary phosphatic matrix (Dahanayake and Subasinghe, 1988). The deposit is a leached, apatite-bearing phoscrete type phosphorite, which has developed on an apatite-bearing carbonate rock with a possible igneous origin. However, it should be noted that the apatite-bearing rock is interbanded with gneisses, which form a series of hillocks directing in a N-S direction across the Eppawala-Talawa road (Jayawardena, 1976; Dahanayake and Subasinghe, 1989). The parent carbonate rock contains yellowish green apatite, calcite and dolomite as major minerals and spinel, pyrite, ilmenite and magnetite as important accessories.

Another rock phosphate deposit was recently discovered at Kawisigamuwa, near Ridigama, on the Mallawapitiya - Ridigama road, south-east of the town of Kurunegala, 105 km away from Colombo (Figure 1). The phosphate occurrence at Ridigama is restricted to a smaller area, in comparison with the surficial distribution of the Eppawala deposit. The deposit is overlain by a lateritic crust. Field evidence suggests an extension to the ore body along the NS direction up to a distance of one kilometer along the NS direction.

As at Eppawala, yellowish green apatite crystals with high amounts of hematite and magnetite are embedded in a secondary, fine-grained matrix (Hewawasam and Dahanayake, 1995). Near the deposit, some igneous intrusions with primary apatite, hematite and magnetite have been emplaced into the surrounding Precambrian terrain (Hewawasam and Dahanayake, 1996). The mineralogical, chemical and solubility characteristics of the yellowish green primary apatite and their associated matrix in both deposits are studied and compared in this paper.

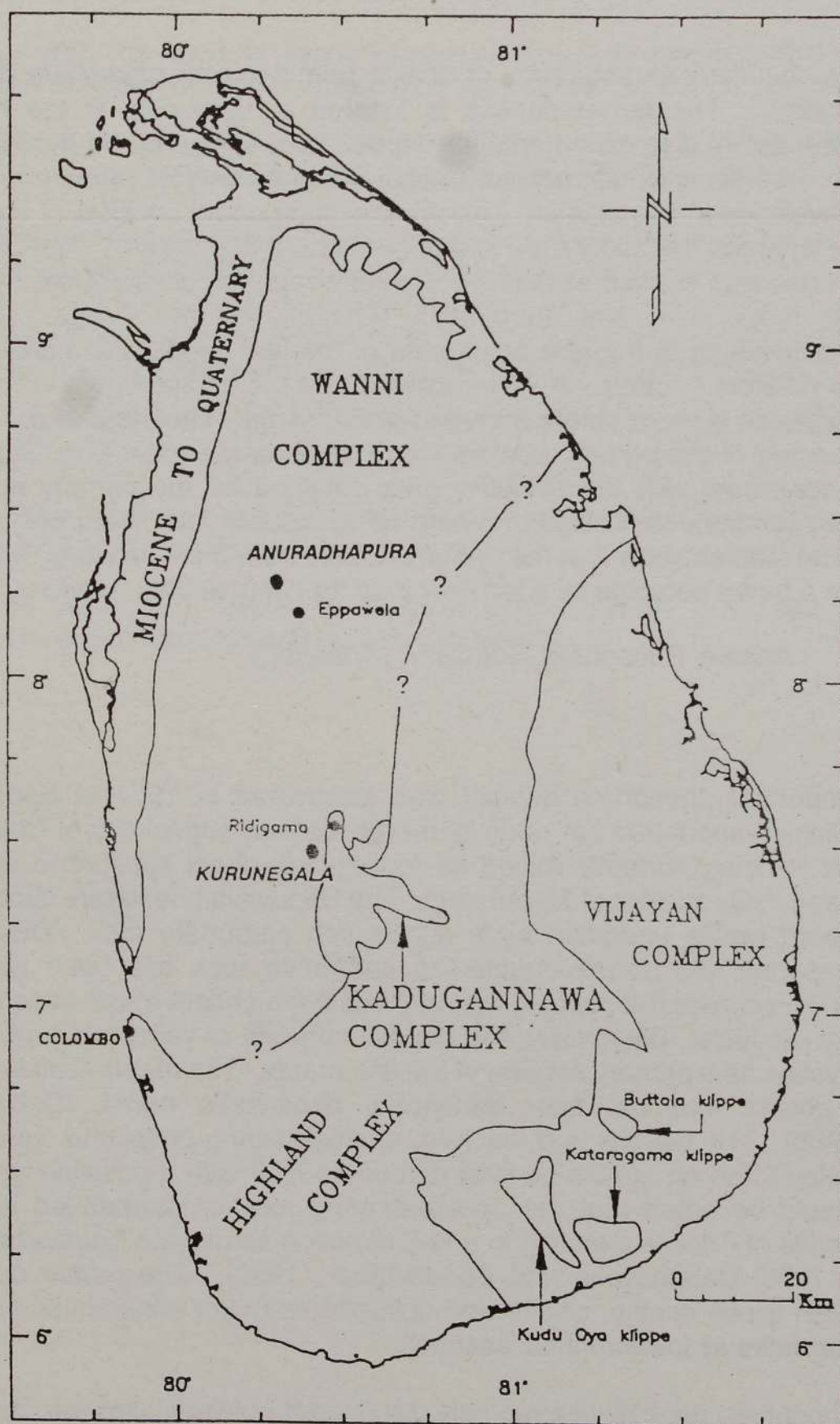


Figure 1 Geological Subdivisions of Sri Lanka and Locations of Phosphate Deposits (Kroner et al., 1991)

Materials and Methods

X-Ray Diffractometry: Apatite varieties and mineralogical compositions in the primary crystals and the fine matrix were detected by X-ray powder diffraction method (Moore and Reynolds, 1989; Whiston, 1987).

Wet Chemical Analysis : Chemical composition of the dissolved samples was determined by atomic absorption spectrophotometry(AAS), inductively coupled plasma spectrophotometry(ICPS) and colorimetry. For solubility analyses, the powdered samples were dissolved in relevant solvents and filtrates were used (Jeffery and Hutchison, 1981; Yoshida et al., 1976; Watanabe and Olson, 1965).

Mineralogy and Chemistry of the Deposits

1. Eppawala

In the Eppawala deposit, yellowish green, euhedral, primary apatite crystals are distributed in the brown coloured matrix. According to XRD studies, these apatite crystals contain chloro-flour-hydroxylapatite (CFHA) and flourapatite (FA) as major and minor components (Figure 2). The unit cell a-dimensions of CFHA and FA are 9.46A° and 9.37A° respectively (Table 1). The finer matrix of the Eppawala deposit is rich in minerals such as carbonate fluorapatite (CFA), CFHA, goethite, kaolinite, crandallite and quartz (Table 1).

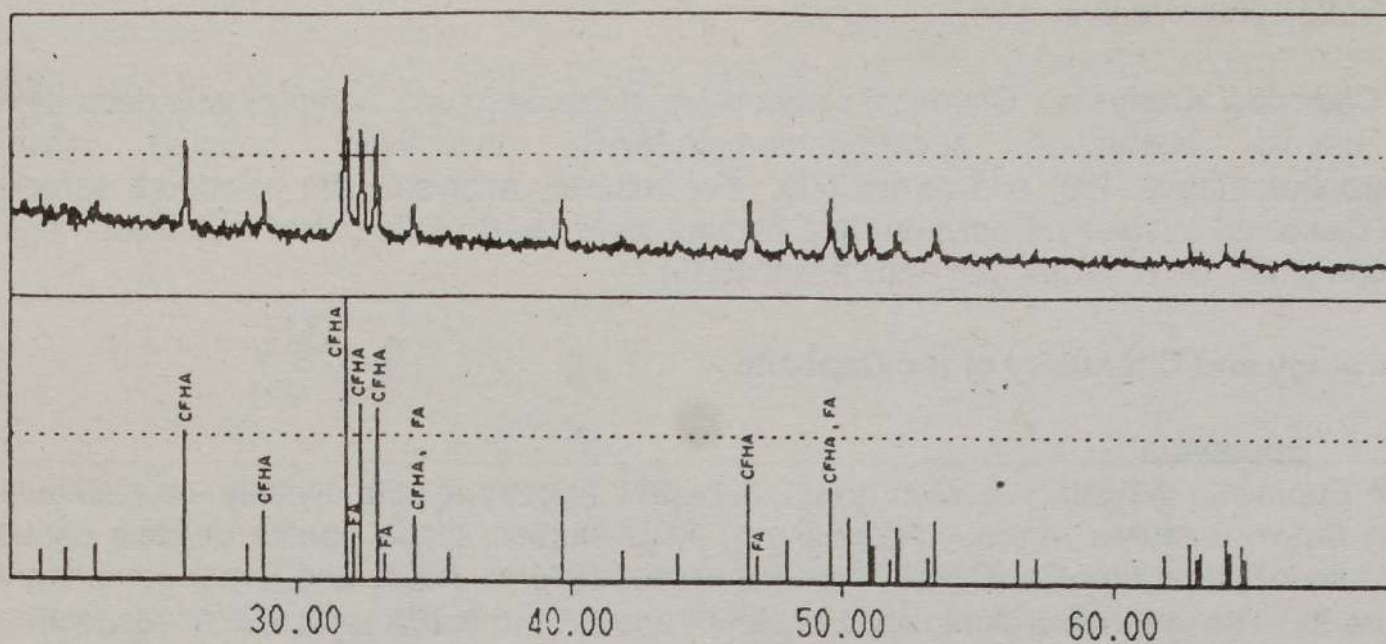
Table 1 Comparison of mineralogy of two apatite varieties in two phosphate deposits

Location	Mode of Occurrence	Mineralogy
Eppawala	Yellowish green primary apatite crystals occur in fine grained matrix.	Primary Apatite major - CFHA (<i>a axis</i> : 9.46A°) minor - FA (<i>a axis</i> : 9.37A°). Fine Matrix CFA, CFHA, goethite, kaolinite, crandallite, quartz
Ridigama	Yellowish green primary apatite crystals occur in fine grained matrix .	Primary Apatite major - CFHA (<i>a axis</i> : 9.48A°) minor - FA (<i>a axis</i> : 9.35A°) Fine Matrix CFA, CFHA, randallite, hematite, goethite, kaolinite

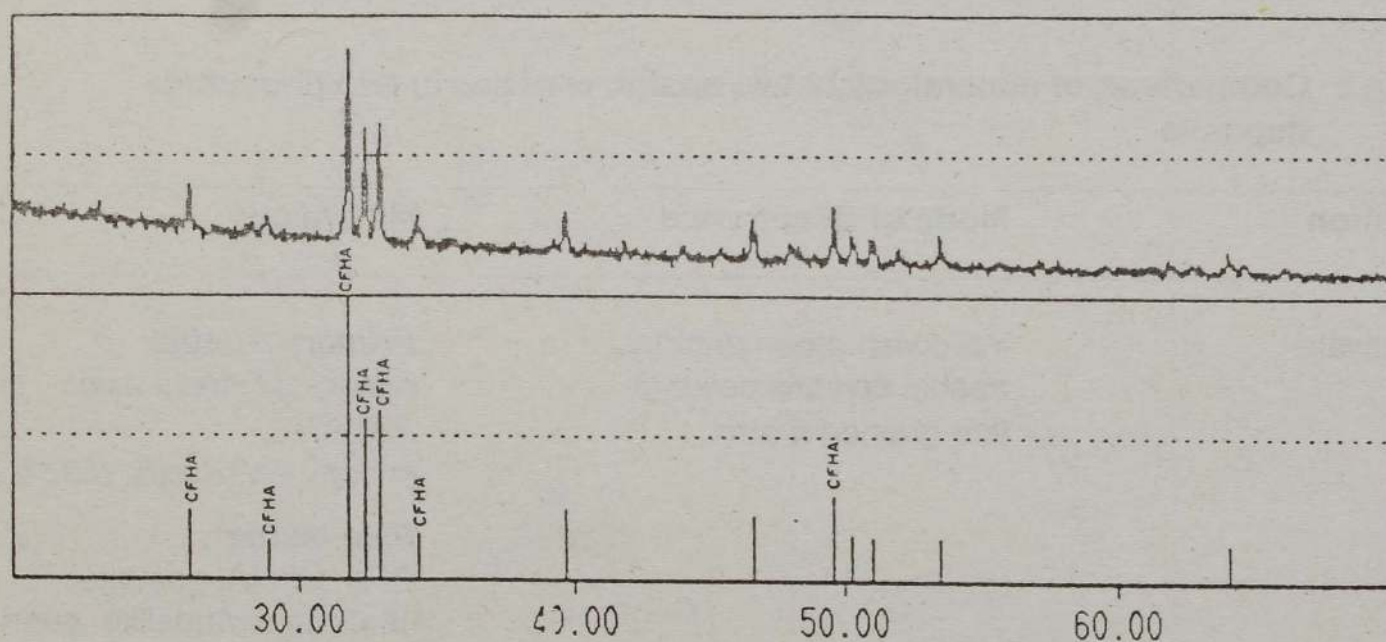
CFHA - Chlor-fluor-hydroxylapatite, FA - Fluorapatite, CFA - Carbonate fluorapatite

The average P₂O₅ of primary apatite lies between 38 to 40 per cent based on analysis of randomly selected samples, and it varies from 30 to 35 per cent in the matrix. The 2 per cent citric acid solubility is around 6 per cent for primary crystals and it ranges from 3 to 5 per cent for the matrix (Tables 2 and 3). The water solubility of primary apatite and the fine matrix is around 0.06 (P₂O₅ by weight) and 0.04 (P₂O₅% by weight), respectively.

A Note on the Chemistry and Mineralogy of Apatite Crystals of Eppawala and Ridigama Phosphate Deposits..., 63



(A)



(B)

Table 2 Chemical composition of primary apatite and fine matrix from Eppawala and Ridigama phosphate deposits

	Eppawala Primary Apatite %	Eppawala Fine Matrix %	Ridigama Primary Apatite %	Ridigama Fine Matrix %
P ₂ O ₅	40.18-38.72	33.22-28.26	40.73-39.63	30.26-24.39
CaO	53.80-51.38	43.19-34.90	54.62-53.21	38.36-32.32
F	02.39-02.09	02.72-02.06	01.48-01.29	01.32-01.28
SiO ₂	00.19-00.11	00.79-00.14	00.19-00.12	00.43-00.23
Al ₂ O ₃	00.05-00.02	02.02-01.38	00.26-00.18	02.72-02.06
Fe ₂ O ₃	00.38-00.32	12.21-10.78	00.76-00.42	22.33-14.56
Na ₂ O	00.16-00.11	00.19-00.12	00.15-00.05	00.23-00.19
K ₂ O	00.05-00.02	00.04-00.02	00.05-00.02	00.08-00.04
MgO	00.18-00.11	00.19-00.13	00.11-00.03	00.16-00.11
Cl	01.98-01.84	01.41-01.16	02.31-02.12	01.52-01.29

2. Ridigama

Yellowish green, subhedral, primary apatite crystals are found in a secondary, fine grained sedimentary matrix, which is composed of secondary phosphate minerals, aluminous, ferruginous and siliceous materials. The size of the primary apatite crystals varies from a few mm to several cm. In the matrix, high amounts of hematite and magnetite are present. The colour of the secondary matrix varies from yellow and yellowish brown to dark brown. The XRD studies revealed that CFHA and FA are the major components in the primary crystals (Figure 2). The unit cell a-dimension of CFHA is 9.48Å° whereas that of FA is 9.35Å° (Table 1). According to XRD analyses of the fine matrix, it contains CFA, CFHA, hematite, crandallite, goethite and kaolinite (Table 1). The total P₂O₅ of primary apatite is around 40 per cent (by weight) whereas it varies from 25 to 30 per cent (by weight) in the matrix. The 2 per cent citric acid solubility of primary crystals is around 7 per cent (P₂O₅ by weight) and it is around 3 per cent (P₂O₅ by weight) for the matrix. The water solubilities of primary crystals and matrix are around 0.05 (P₂O₅% by weight) and around 0.04 (P₂O₅% by weight) respectively (Tables 2 and 3).

Table 3 Solubility of primary apatite crystals and fine matrix from Eppawala and Ridigama Phosphate deposits

	Eppawala Primary Apatite	Eppawala Fine Matrix	Ridigama Primary Apatite	Ridigama Fine Matrix
2% Citric Acid Solubility (as P ₂ O ₅ %)	6.32-5.81	4.72-2.85	7.32-6.64	4.21-2.32
Water Solubility (as P ₂ O ₅ %)	0.06-0.04	0.04-0.03.	0.06-0.05	0.04-0.03
Neutral Ammonium Citrate Solubility (as P ₂ O ₅ %)	2.20-2.10	2.10-1.90	2.70-2.60	1.60-1.70

The chemical studies reveal that the total P₂O₅ content in the primary apatite of Eppawala and Ridigama exceeds 40% (Table 2). In the fine matrix of both deposits, relatively low P₂O₅ content was recorded and it ranges from 25 to 35 per cent P₂O₅. The chemical studies show that the CaO content of all the primary apatite samples exceeds 50 per cent whereas that of the fine matrix ranges from 30 to 45 per cent. The F content of the primary apatite from Eppawala (2.0-2.4%) is higher than that of the Ridigama ore (1.25-1.40). A low SiO₂ content was observed in the primary apatite but that value is higher in the fine matrix. The contents of Al₂O₃ and Fe₂O₃ of primary apatite of both locations are very low when compared with their fine matrices. Higher values of Al₂O₃ and Fe₂O₃ were observed for primary crystals of Ridigama than that of Eppawala (Table 2).

The values of the Fe₂O₃ for the matrix of Ridigama are significantly higher than those of Eppawala, due to the abundance of Fe rich minerals. The 2 per cent citric acid, neutral ammonium, citrate and water solubilities of these deposits were compared (Table 3). This study reveals that the 2 per cent citric acid and neutral ammonium citrate solubilities of primary apatite crystals from Ridigama are higher than those of Eppawala. The solubility and the total phosphorous content of the fine matrices are low, due to the presence of high amounts of non-phosphatic materials.

Discussion and Conclusions

It is noted that both the Eppawala and Ridigama residual sections have developed through several stages of weathering, both physical and chemical, followed by precipitation, deposition and consolidation, resulting in the present stage of the profiles. The existing profiles are characterized by a number of horizons, starting from the parent rock to loose unconsolidated top soil. Primary phosphate minerals have been subjected to weathering, forming new components, and the nature of the new minerals depends on the composition of the parent rock and the weathering environment.

Primary apatite crystals from both deposits have CFHA and FA as major and minor components, respectively. However, the ratio of abundance of CFHA to FA in the primary crystals ranges considerably for the two deposits. It was noted that when the content of FA increases, the solubility, or the reactivity of the primary crystals also increases significantly. This shows that the minor apatite mineral component (i.e., FA) is more soluble than the major apatite mineral component (i.e., CFHA). Therefore, the abundance of FA is much more important than that of the CFHA in determining the reactivity of the primary apatite crystals.

Although FA is present as a minor component in the yellowish green crystals, their a-axis dimensions are different for the two locations. The length of the a-axis (9.37\AA) of the primary apatite from Eppawala corresponds closely with that of the pure fluorapatite (9.372\AA), whereas this value is lower for the primary crystals from Ridigama (9.35\AA). Therefore, the crystal structure of primary crystals from Eppawala is more stable than that of the Ridigama crystals. In addition, mineralogical investigations have revealed that the abundance of FA in the primary crystals of Ridigama is higher than that of Eppawala. This evidence suggests a greater chemical reactivity and, thus, an increased solubility of the primary crystals from Ridigama compared to Eppawala. This explanation is consistent with the solubility data and it was noted that the primary apatites from Ridigama have higher solubilities than Eppawala.

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Drying Characteristics of Potato Slices and Quality Parameters

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Abstract

Preservation of potato when the market price is low has been considered as a means of improving farmer income. Dehydration of potato as slices is an alternative method for preserving it. The re-hydrated product should be a replacement to fresh potato used in preparation of food items. This study was conducted to understand the drying characteristics of potato slices and re-hydration properties for the variety Desiree.

Slices having thickness of 3, 5 and 7 mm were considered with or without combinations of heat and chemical treatment. Drying temperature was maintained at 60 °C at initial 100 min. and then reduced to 50°C for the rest of drying. The air velocity was maintained between 5.64 m/s and 5.46 m/s. The drying characteristics of potato slices can be expressed by the exponential function $Y = ae^{bt^2}$.

The lowest drying time was required by the samples of 3mm thick, which is the smallest thickness considered in the experiment. Potato slices subjected to blanching and dipping in potassium metabisulphite resulted in the highest acceptability in colour and shape. The rehydration property varied with the thickness and other heat and chemical treatments. The highest rehydration ratio was shown by the 3 mm thick sample with 1 min. blanching.

Further studies are recommended to investigate the effects of other slice thicknesses, nutritional aspects and also the effect of other varieties.

Introduction

Potato (*Solanum tuberosum*) is an annual herbaceous, decotyledonous plant, which produces tubers as economic yield. In Sri Lanka, the local production and the imports from neighbouring countries meet the annual requirements. The consumption of it is mainly in the form of traditional dishes. In other parts of the world, potato is used in many preparations as value added products. But, in Sri Lanka, very little attention has been paid to develop technology for potato based products.

The price of potato in the local markets varies throughout the year due to seasonal supplies of Sri Lankan farmers or imports. Imports by the private sector prior to the impending harvest have resulted in very low farm gate prices. The ensuing effect has been the farmers refraining from potato cultivation.

Storage of the crop and development of value added products are some steps that can be taken by the farmers (Fennema et al, 1975). Storage of potato crop as fresh produce is necessary for even supplies during off-seasons. Development of technology for converting (processing) to other products is necessary to ease the drawbacks on potato farming in Sri Lanka.

This study was conducted to investigate the drying characteristics of potato slices. Drying time requirement and re-hydration properties are the important parameters in establishing a process for production. Satisfactory re-hydration is necessary in preparation of dried products for consumption as a moistened food. An understanding of potato drying

characteristics is also necessary in designing the processes and processing equipment. The specific objectives of the study were to investigate:

1. effect of thickness, steaming and potassium metabisulphite treatment on drying rate and quality parameters, and
2. re-hydration characteristics.

Materials and Methods

An experimental dryer was constructed at the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya. It consisted of a drying chamber, a heating unit, a blower and an air temperature regulator unit.

Initially, potato slices of 3, 5 and 7 mm thick (variety-Desiree) were dried at three different temperatures of 50, 60 and 70°C in three tests. Drying at 70°C resulted in potato slices with poor appearance while tests at 50°C and 60°C were satisfactory. Therefore, further testing at 70°C temperature was not done. It was observed that the drying rate became equal after 100 minutes of drying irrespective of the temperatures tested at 50 and 60°C. Therefore, in all tests, the drying temperature of 50°C was maintained after a drying time of 100 minutes.

An axial flow blower used in the experimental dryer produced an air stream at 0.51m/s velocity at ambient conditions. The air velocities were measured at different drying temperatures.

Since the experiment was designed to study effects of steaming and treatment of potassium metabisulphite (KMS) on slices, it consisted of five treatments including a control as given below.

TREATMENT	PROCEDURE
T1	Potato sample without any treatment
T2	Sample was subjected to steaming for 1 min.
T3	Sample was subjected to steaming for 2 min.
T4	Sample was dipped in KMS 1.5 g of KMS/kg of potato (personal communication, 1996) for 2 min. Then it was steamed for 1 min.
T5	Sample was dipped in KMS 1.5 g/kg of potato, solution for 2 min and then steamed for 2 min.

These five treatments were repeated for three slice thicknesses of 3, 5, and 7mm.

Rehydration characteristic, which is an indication of cells damaged during drying was studied by boiling in distilled water for 5 min. A sample of known weight was boiled and then kept in a buchner funnel until dripping of water from the funnel was over. Then the sample weight was taken. The rehydration ratio was calculated with the following equation (Perera, 1994).

$$\text{Rehydration ratio} = W_r / W_d.$$

where, W_r = drained weight of the rehydrated sample, and

W_d = weight of the dehydrated sample which is used for the test.

Results and Discussion

The drying behaviour was represented by variation of moisture content (wet basis) of the potato samples with time. Drying rates were studied for different thicknesses of potato slices and different treatments to which the material was subjected.

Effect of thickness of potato slices on drying time

Drying time was observed when the moisture content (wet basis) reduced from 75% to 6%. To determine the relationship between the drying time and the drying rate, statistical analysis was performed on the data set that contained 30 observations on moisture contents with time as the dependent variable.

The results from the analysis of variance procedure show that the probability $>F$ value is lower than the standard probability value of 5% significant level. Therefore, thickness effect on drying time is significant. When the thickness is increased, interior moisture removal is restricted due to higher number of cell layers. Therefore, the total drying time will increase with the increased slice thickness. R^2 value of 0.937810 shows that 93.78% of the variation can be explained by thickness effect.

Effect of treatments of potato slices on drying time

Statistical analysis was done on data containing drying time and moisture contents (wet basis) between 6% and 75% in different treatments. The number of observations in the data set was 30. The drying time as the dependent variable, the Analysis of Variance procedure was performed. The probability $> F$ value is more than the standard probability value of 5% significant level. Therefore, treatment effect on drying time is not significant. This may be due to blanching treatment. Blanching time is an important factor that influences the drying rate. But, the time should be varied with the thickness of potato slices.

In this experiment, equal blanching times were used for all thickness values of potato slices. Therefore, samples of low thickness may be over blanched and higher thicknesses may be under blanched. This may result in different degree of starch gelatinization during blanching.

Interactive effect of thickness and treatment on drying time

Statistical analysis was performed on drying time for changes in moisture content (wet basis) from 75% to 6%. No. of observations in the data set was 30. The dependent variable was time. Results from the analysis of variance procedure were obtained. Probability $> F$ value was more than the standard probability value 5% significant level. Therefore, interaction effect is not significant.

Effect of thickness and treatment of potato slices on rehydration ratio.

Three treatments and three thicknesses were tested for rehydration properties. The number of observations made was 18. According to the Analysis of Variance procedure, results were obtained with dependent variable as rehydration ratio. Probability $> F$ value for, treatments, thicknesses and interaction are less than the standard probability value 5% significant level. Therefore, treatment effects, thickness effects and interaction effects are significant.

Mathematical formula

For the drying process, the remaining moisture content (wet basis) % with time (h), are plotted to obtain the drying curve. The study was conducted on five levels of treatments, and three levels of thicknesses. Almost all the drying curves were in the same pattern (Figure 1). Therefore, by using the Sigma Plot software package, curve fitting was done for non-linear relationships. The ensuing function is shown in Equation (1).

$$Y = ae^{-bt^2} \quad (1)$$

Where,

Y = Moisture content (wet basis) %

t = time (h)

a, b = constants

Linear regression was performed to find the unknowns a and b with the following linear model.

$$\ln Y = \ln a - bt^2$$

This regression procedure was followed for all data sets, and found the a and b values for each case. According to these values, a is the initial moisture content of the sample. But, the values b changed with the thickness. Statistical analysis was done by using b values, to find out whether there is an effect of treatments or thickness or both on b values. - With the 15 observations in data set and the b value as dependent variable, the Analysis of Variance procedure was performed. The results showed that the probability > F value for treatment was more than the standard probability value 5% significant level. Therefore, the treatment effect is not significant.

The probability > F value for thickness was less than the standard probability value 5% significant level. Therefore, the thickness effect is significant.

Then the mean values of b were found for different thicknesses as given below.

For 3mm thickness; $b = 0.398$

5mm thickness; $b = 0.179$

7mm thickness; $b = 0.045$

The drying rate function was obtained by taking the first derivative of Equation (1). The resulting drying rate function is shown in Equation (2).

$$dY/dt = -2abte^{-bt^2} \quad (2)$$

Equations (1) and (2) can be used to predict the drying function of potato slices which are within the sizes considered in the experiment. If the drying function is known, the drying time can be predicted.

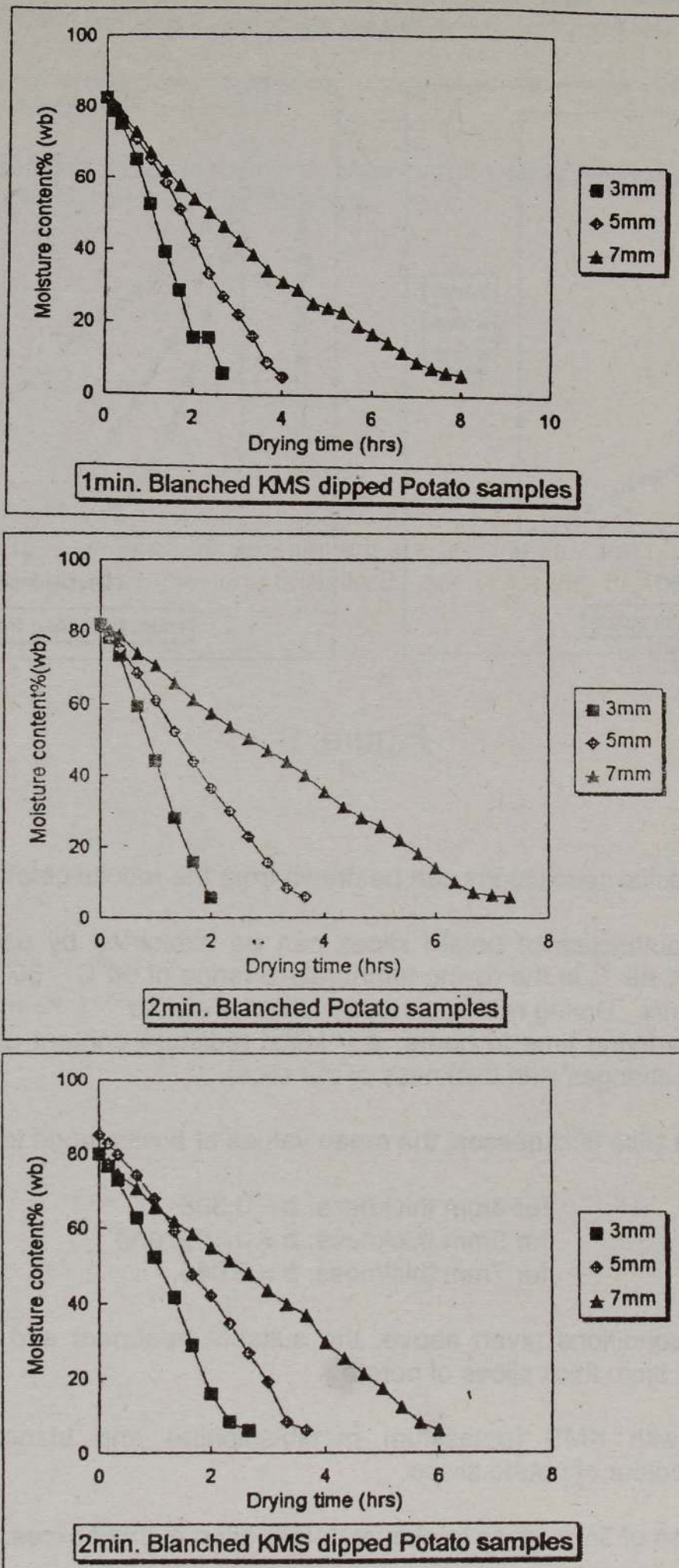


Figure 1

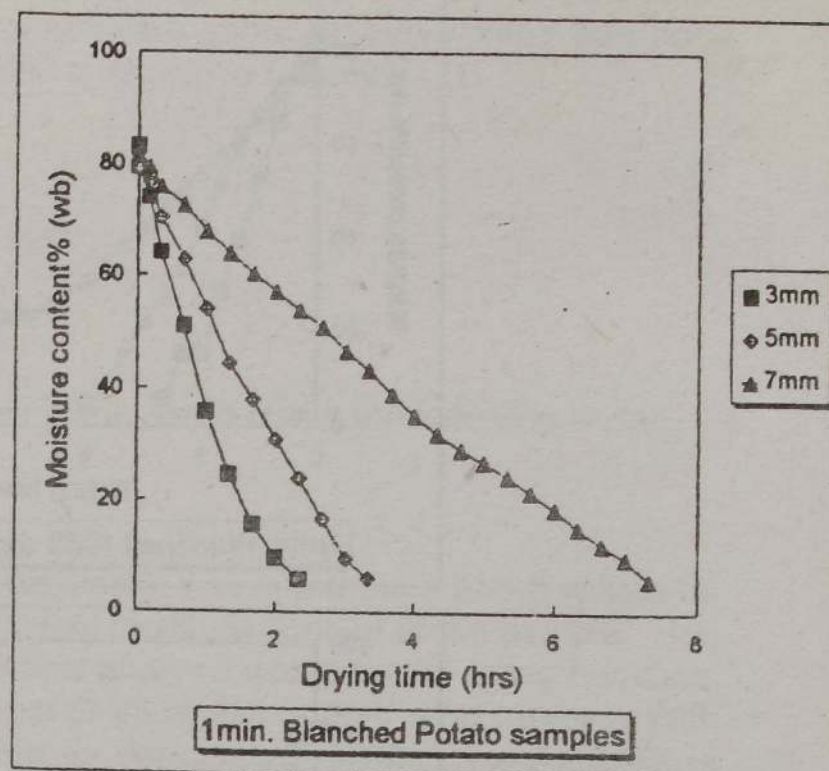
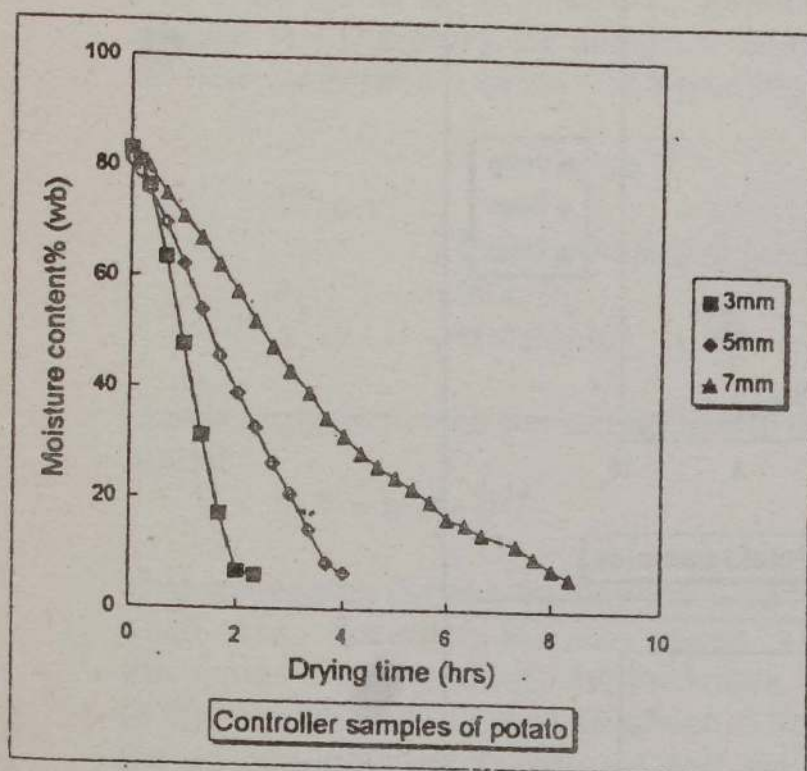


Figure. II

Conclusion

The following specific conclusions can be drawn from the results obtained in the study.

1. Drying characteristics of potato slices can be explained by using the exponential function, $Y = ae^{-bt}$, in the drying temperature range of $60^{\circ}\text{C} - 50^{\circ}\text{C}$ and air velocity of $5.64 - 5.46 \text{ m/s}$. Drying rate is given by $dY/dt = -2abte^{-bt}$ (Y = moisture content (wet basis) %, t =drying time in hours, a = initial moisture content of the sample, b = a factor which changes with thickness of the slice).

For different slice thicknesses, the mean values of b was found to be

for 3mm thickness; $b = 0.398$
 for 5mm thickness; $b = 0.179$, and
 for 7mm thickness; $b = 0.045$.

2. For drying conditions given above, the suitable treatment and thickness are 2min blanching of 3mm thick slices of potato.
3. Treatment with KMS (potassium metabisulphite) and blanching results in an acceptable colour of potato slices.
4. The thickness of 3mm gives minimum deformation in dried slices.
5. The 3mm thickness with 2min. blanching treatment produces high rehydration ratio in dried slices.

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Osmotic Adjustments and Associated Water Relations of Clonal Tea (*Camellia sinensis* (L.))

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Abstract

Soil moisture stress associated with high saturation vapour pressure deficits during drought causes adverse impacts on water economy of tea plants. Transpiration rate and stomatal conductance are generally used as indices for screening tea clones for drought resistivity. However, accumulation of osmotically active solutes, leading to osmotic adjustments play a major role in drought tolerance.

Green house studies were conducted to rank recently recommended tea clones for drought tolerance. Feasibility of using osmotic adjustments as a criterion for drought tolerance was studied and identified as a key factor. The treatments consisted of 5 TRI '3000' series clones, 5 TRI '4000' series clones and TRI 2025 which is a well known drought tolerant clones. Artificial induction of drought modified transpiration rates and diffusive resistance resulted in lower leaf water potential at zero turgor, and were higher in most of TRI '4000' series clones while that of TRI '3000' series clones were approximately similar to that of TRI 2025/6. Hence, TRI '3000' series clones can also be considered as drought tolerant clones. Wider osmotic adjustments together with more negative water potential at zero turgor of TRI '4000' series clones revealed more capability to tolerate dry conditions than the other tested clones.

Key words: Tea, osmotic adjustments, drought, transpiration, diffusive resistance

Introduction

Tea (*Camellia sinensis* L.) is primarily grown as a rain-fed crop in tropics. Although monsoonal rains bring in sufficient amounts of rainfall to both wet and intermediate zones, erratic distributions within a year can result in moisture stress on tea plants during the months of January, March and August. Tea lands in the Low Country are especially subjected to moisture stress together with temperature and high saturation vapour pressure deficits during these dry months (Wijeratne and Ekanayake, 1990).

Drought is a serious environmental hazard globally and its damage to cultivated crops has become a frequent phenomenon (Navaratne, 1992). Tea is no exception. Under prolonged dry weather conditions the growth of tea plants is adversely affected by water deficits. This is created by lack of soil moisture and high saturation vapour pressure deficit in the air (Wijeratne and Ekanayake, 1990). Mature tea bushes with well developed root systems withstand drought better than young tea plantations. However, during the first 3-4 years after field planting, bushes are prone to drought effects. Although irrigation during dry periods is a reliable solution, there are practical limitations such as lack of water resources, high costs, etc. Therefore, the use of drought tolerant tea clones with a higher water use efficiency in drought prone regions is of utmost importance.

Transpiration rate and stomatal conductance of leaves are some indices generally used for screening clones for drought tolerance (Sandanam et.al., 1981; Wijeratne, 1986). However, accumulation of osmotically active solutes in plant tissues leading to osmotic adjustments, plays a major role in adapting plants to drought. Moreover, experimental results have shown

that the pressure volume curve which explains the relationship between the relative water content and shoot or leaf water potential can be used as a key factor for screening plant species for drought tolerance and shoot or leaf (Wijeratne, 1984).

Most of the clones recommended by the Tea Research Institute of Sri Lanka have been ranked according to their capacity for drought tolerance on the basis of field performance. However, in depth studies have not been conducted on newly released TRI "3000" series and TRI "4000" series clones. Hence a green house experiment was conducted at the Tea Research Institute (Low Country Station) at Ratnapura to rank recently recommended tea clones for the Low Country based on osmotic adjustments and transpiration / diffusive resistance.

Materials and Methods

The experiments were conducted under green house conditions at the Tea Research Institute – Low Country Station, Ratnapura (6° 40'N, 80° 25'E and 60m above m.s.L.). A group of eighteen month old vegetatively propagated (vp) plants was selected from the Tea Research Institute nursery (St. Joachim Estate). Eleven clones including TRI 2025 as a control were used for the experiment. They were as follows.

TRI "3000" SERIES CLONES:

- a. TRI 3058
- b. TRI 3025
- c. TRI 3041
- d. TRI 3057
- e. TRI 3052

TRI "4000" SERIES CLONES:

- a. TRI 4042
- b. TRI 4052
- c. TRI 4049
- d. TRI 4033
- e. TRI 4014

CONTROL: TRI 2025

These plants were transplanted in plastic pots (41) filled with top soil (Red Yellow Podzolic ultisol). At the beginning of the experiment all the plants were thoroughly watered, and kept for 24 hours to drain out excess water. These potted plants were exposed to moisture stress condition without watering until they were permanently wilted. Plants were arranged in three blocks according to their size. Each block consisted of 33 potted plants (3 plants * 11 clones). One month after transplanting, treatments were imposed.

Measurements of relative water content and leaf water potential (pre dawn) were taken between 6.00 am - 8.00 a m daily. For the determination of relative water content 3 mature leaves were excised from three different replicates. Leaves were weighed separately and floated on distilled water for three hours at room temperature under a light intensity of 90 mol/cm²/s supplied by two 100W bulbs, mounted approximately 30 cm above the water surface (plate 3). After floating, the surface water was removed by placing the turgid leaves between several layers of soft tissues and the turgid weight was recorded. Leaf dry weight was determined by oven drying the leaves at 90° c for 24 hours (Sandanam et al., 1981). The relative water content (RWC) was estimated as reported by Weatherly (1950).

$$RWC = \frac{(FW - DW)}{(TW - DW)}$$

where FW, TW and DW are the fresh weight, turgid weight and dry weight respectively.

Leaf water potential was measured on a similar set of mature leaves sampled from the same plants used for relative water content assessments. They were the opposite leaves to that removed for relative water content determination. The leaves were so selected that the effect leaf age on the water relations was minimized (Kozlowski, 1979, Sandanam et al.

1981). The leaf water potential measurements were taken inside the green house using a Pressure bomb (Plant water status Console - Model - 3005, USA). Soil samples were collected at the beginning and at the permanent wilting point of each plant for the estimation of soil moisture. A soil sample of 100g was placed in the oven at 105° c for 24 hours and dry weights were recorded (Sandanam et al 1981).

At the end of the experiment fresh and dry weights of leaves, stems and roots (oven dried at 90° c for 24 hours) and fresh and dry weights of soils of tagged plants were recorded. The daily soil moisture content was estimated as follows.

$$\text{Soil moisture \%} = \left[\frac{(\text{FW of soil} - \text{DW of soil})}{\text{DW of soil}} \right] * 100$$

where FW of soil in the pot = TW - PW - PMW

and FW = fresh weight, DW = dry weight, TW = total weight of the potted plant, PW = pot weight, and PMW = weight of the plant materials.

Daily minimum and maximum temperatures (using a minimum and maximum thermometer), dry and wet bulb temperatures (Assman Hygrometer) were also recorded inside the green house at 9.00 hrs and 16.00 hrs during the experimental period.

Data were analyzed using SAS statistical package and the means were separated using Duncan's New Multiple Range Test (DNMRT).

Results and Discussions

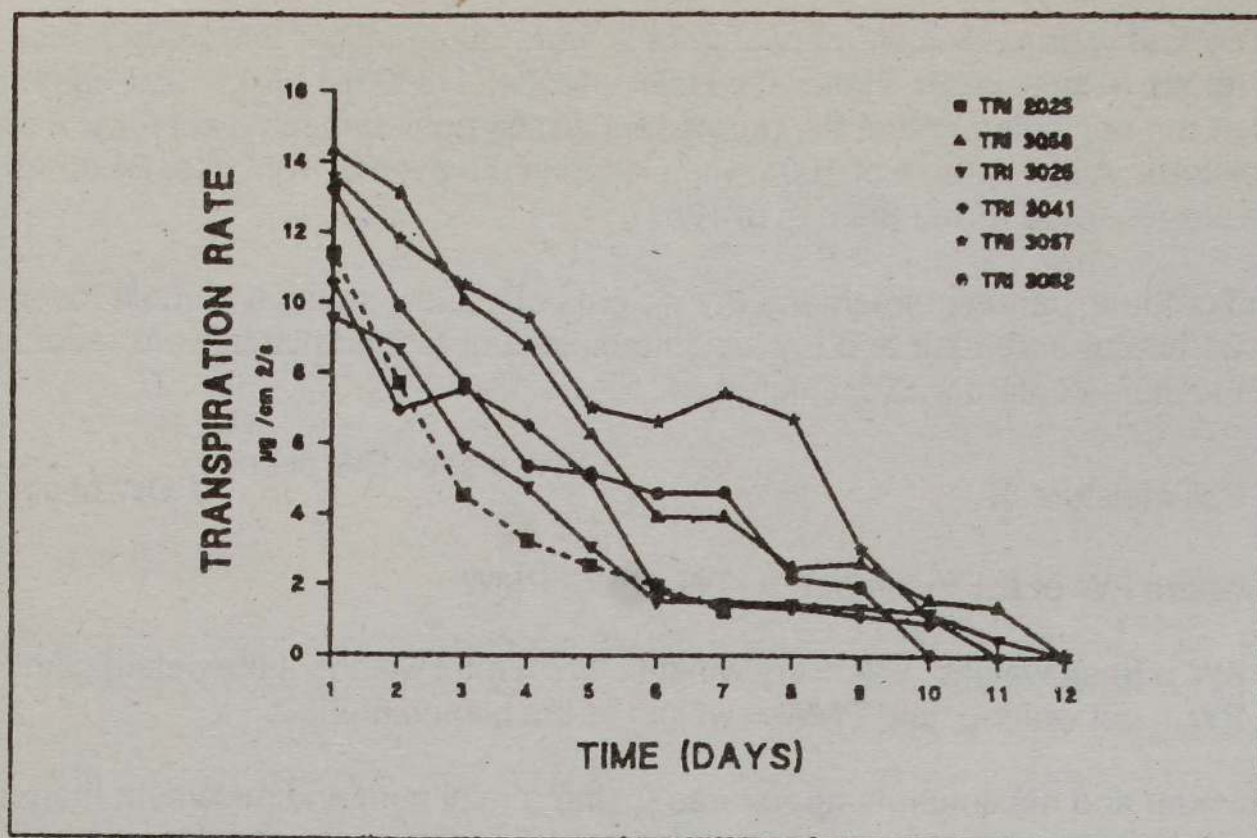
During the drying cycle the sequence of wilting among tea clones was different. Although the age of the plants was the same, the total number of leaves per plant and the leaf area were markedly different among clones. The first signs of wilting was observed in clones having a larger leaf area. TRI 4049 and TRI 4014 started wilting 9 days after withholding watering; on followed by TRI 4033. At the eleventh day of the drying cycle TRI 2025, TRI 4042 and TRI 4052 had wilted. The other clones were wilted twelve days after imposing moisture stress. Moreover, TRI 3025 wilted after 14 days. As wilting depends largely on the leaf area, ranking of tea clones according to their drought resistant capabilities had to be done with utmost care considering the soil moisture content at wilting point and osmotic adjustments.

The variation of transpiration rate of stressed plants is shown in Figure 1. Diffusive resistance recorded an inverse relationship to transpiration. Transpiration rate reduced gradually over the drying cycle (Figure 1) while diffusive resistance increased. A drastic reduction of transpiration up to the sixth day was common for all the clones used in the experiment.

The daily averages of leaf water potential (Figure 2) and relative water content of drying plants show similar patterns of variation. Soil drying has resulted in a reduction of leaf water potential and relative water content. All stressed plants used for assessments were permanently wilted (ie, remained wilted by the morning) by the fourteenth day and recording was stopped.

The pattern of variation of leaf water potential over the drying cycle was similar to that described by other workers. Maintenance of higher water potential may be due to stomata during development of a drought (Kozlowski' 1981). It was evident that TRI '3000' series clones maintained a higher leaf water potential and a relative water content, even at latter stages of the drying cycle (figure 2) due to its moisture conserving ability. Maintenance of higher water potential may be a result of the rapid closure of stomata.

(a)



(b)

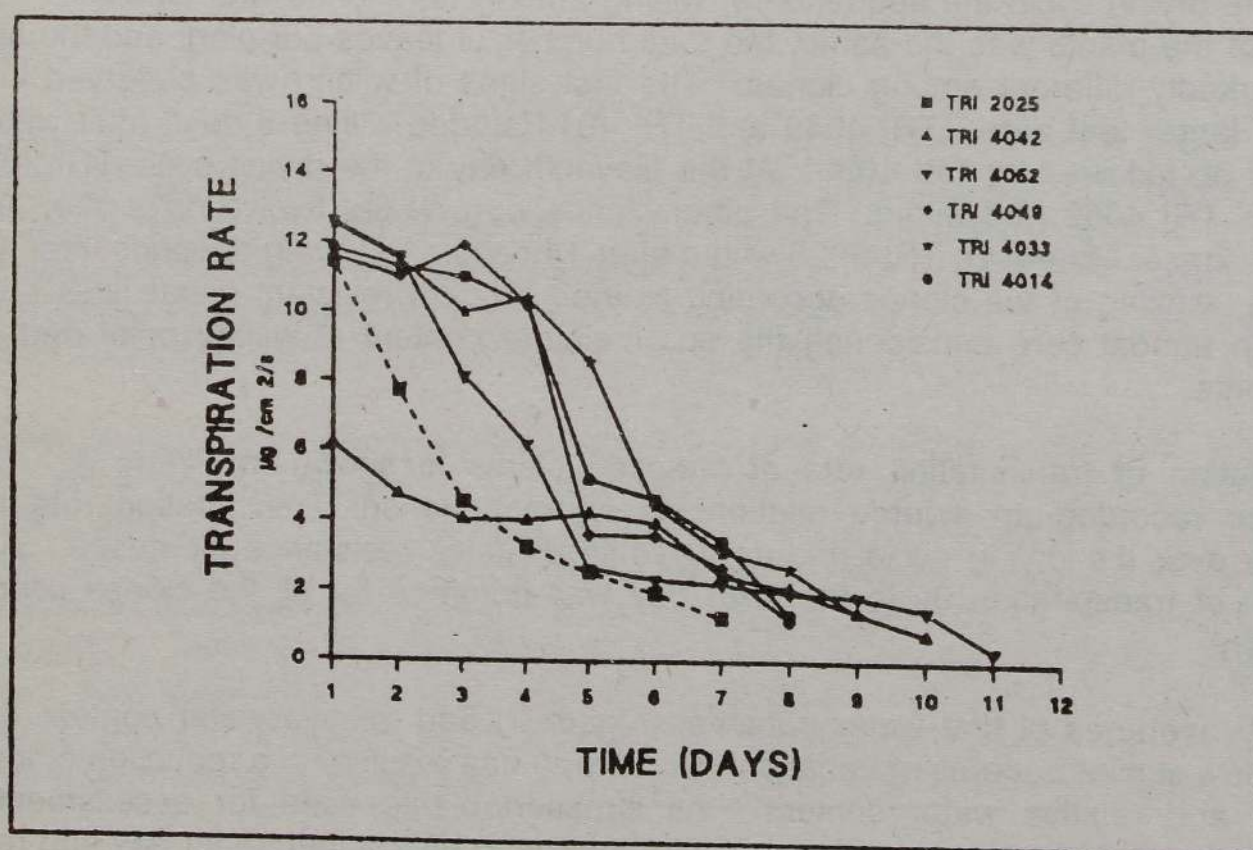
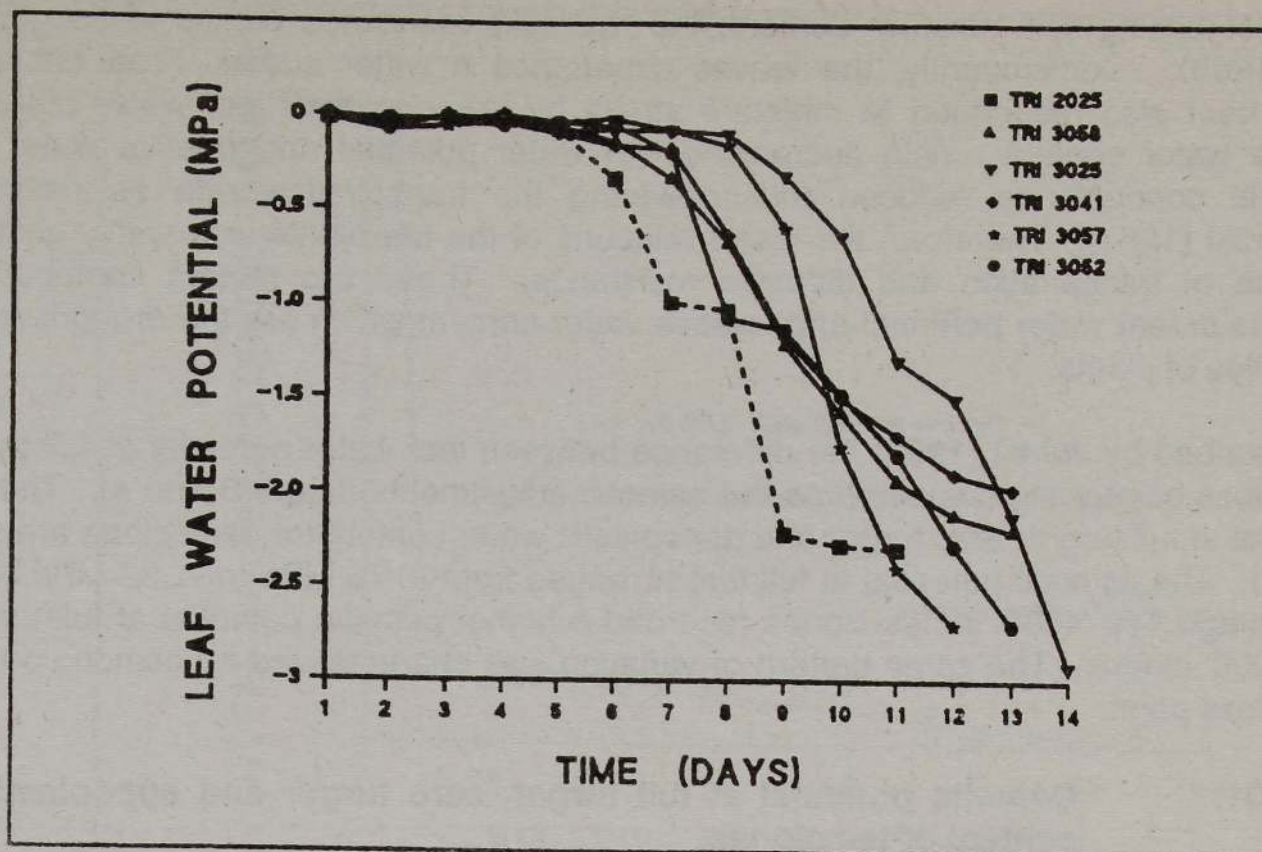


FIGURE 1. The transpiration rate of droughted plants (a) TRI '3000' series clones and (b) TRI '4000' series clones.

(a)



(b)

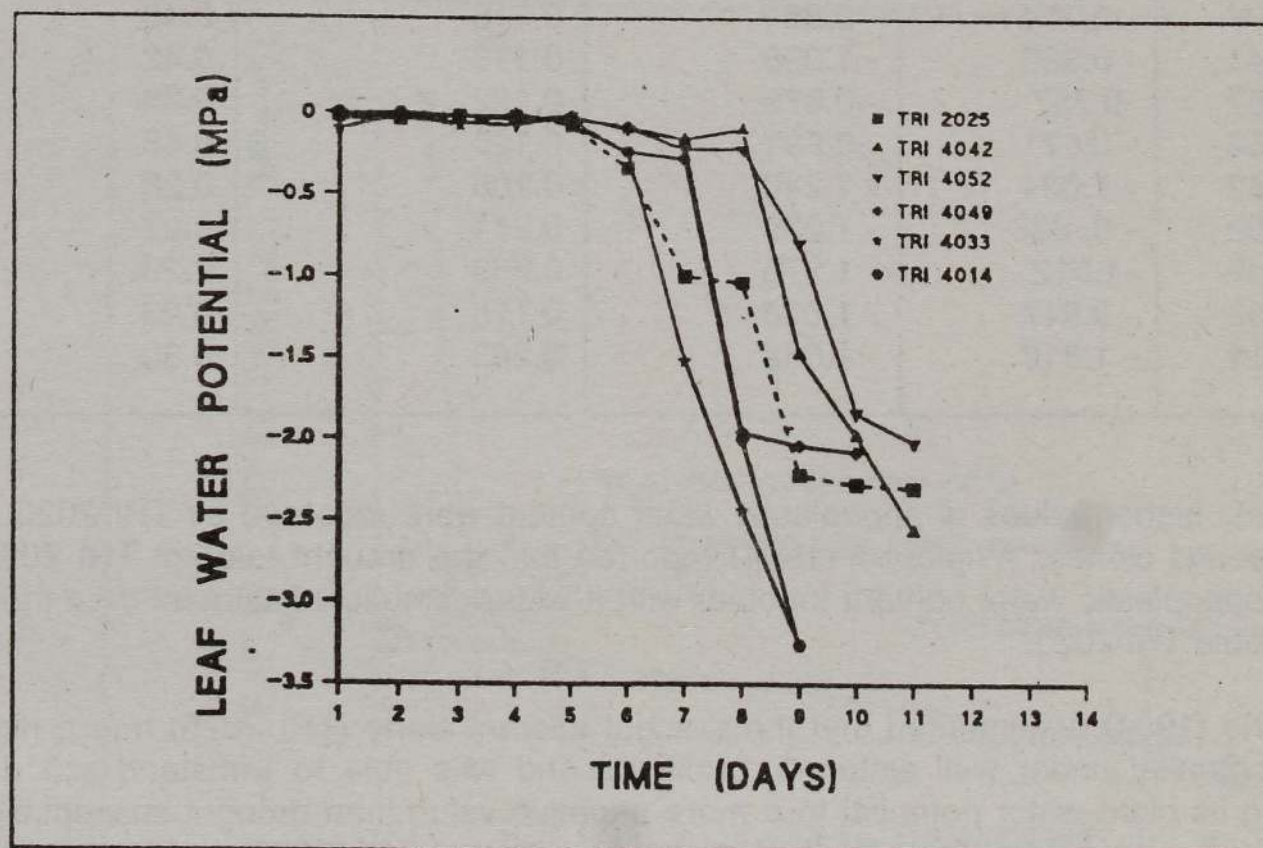


Figure 2. Leaf water potential of droughted plants (a). TRI '3000' series clones and (b). TRI '4000' series clones.

With decreasing soil moisture content, the hydraulic resistance begins to rise (Fitter and Hay; 1983). Consequently, the leaves experience a water stress. Tea plants of this experiment also responded to moisture stress by lowering their leaf water potential and relative water content. With decreasing leaf water potential and relative water content, stomatal conductance reduced thus, lowering the transpiration rate as described by Kozlowski (1981). Therefore, the water relations of the tea plants are mainly governed by the rate of transpiration and diffusive resistance. These two factors contribute to the changes in leaf water potential and relative water content which are the drought resistance properties of plants.

As described by Jones (1992) the difference between leaf water potential at full turgor and turgor loss point was considered as the osmotic adjustments (figure 3 and 4). The osmotic potential at full turgor, zero turgor and appoplastic water content for each clone are shown in Table 1. The osmotic potential at full turgor ranged from -0.75 MPa to -1.32 MPa (Table 1). On average TRI '4000' series clones recorded a higher osmotic potential at full turgor than TRI '3000' clones. The same pattern of variation was characterized by osmotic potential at turgor loss point.

Table 01. Osmotic potential at full turgor, zero turgor and appoplastic water content of tea clones.

Clone	op=full turgor (MPa)	op=zeroturgor (MPa)	Osmotic adjustment (MPa)	Appoplastic water content
TRI 2025	- 0.784	-0.971	0.184	0.48
TRI 3058	-1.010	- 1.114	0.104	0.34
TRI 3025	- 0.754	- 0.860	0.116	0.43
TRI 3041	- 0.985	- 1.098	0.113	0.42
TRI 3057	-0.757	- 0.879	0.122	0.36
TRI 3052	- 0.871	- 0.991	0.120	0.43
TRI 4042	- 1.034	- 1.240	0.206	0.23
TRI 4052	- 0. 828	- 1.039	0.211	0.27
TRI 4049	-1.012	- 1.275	0.263	0.28
TRI 4033	- 0.917	- 1.033	0.116	0.29
TRI 4014	- 1.319	- 1.562	0.243	0.30

Relatively higher values of appoplastic water content were recorded by TRI 2025 and TRI '3000' series clones. Wijeratne (1994) reported that the drought tolerant TRI 2025 had a higher appoplastic water content together with a wider osmotic adjustment than the drought susceptible TRI 2023.

Wijeratne (1994) documented that the drought tolerant clone (TRI 2025) had a higher leaf water potential under well watered conditions and was able to withstand soil drying by lowering its plant water potential to a more negative value than drought susceptible clones (TRI 2023). It was evident with the present results that TRI '3000' series and TRI '4000' series clones can withstand moisture stress to a greater extent through osmotic adjustment than TRI 2025.

Based on these results, it can be stated that higher osmotic potential at zero turgor alone can be used to evaluate drought resistant properties. Observations of field trials in most of low country estates have revealed that TRI '4000' series and TRI '3000' series clones can withstand dry weather conditions better than TRI '2025'. This can be attributed to the ability of

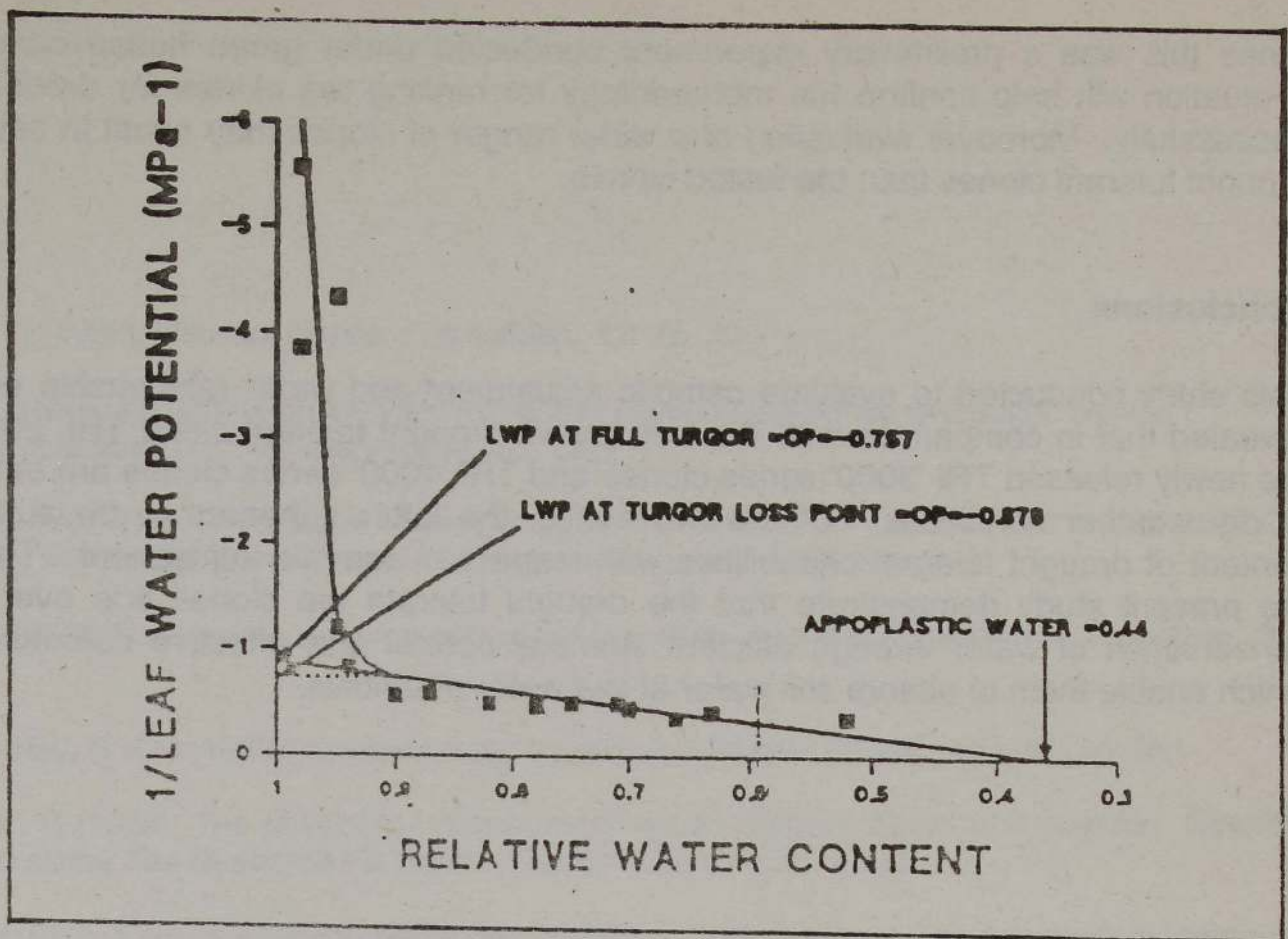


Figure 3. Pressure volume curve of TRI '3057'

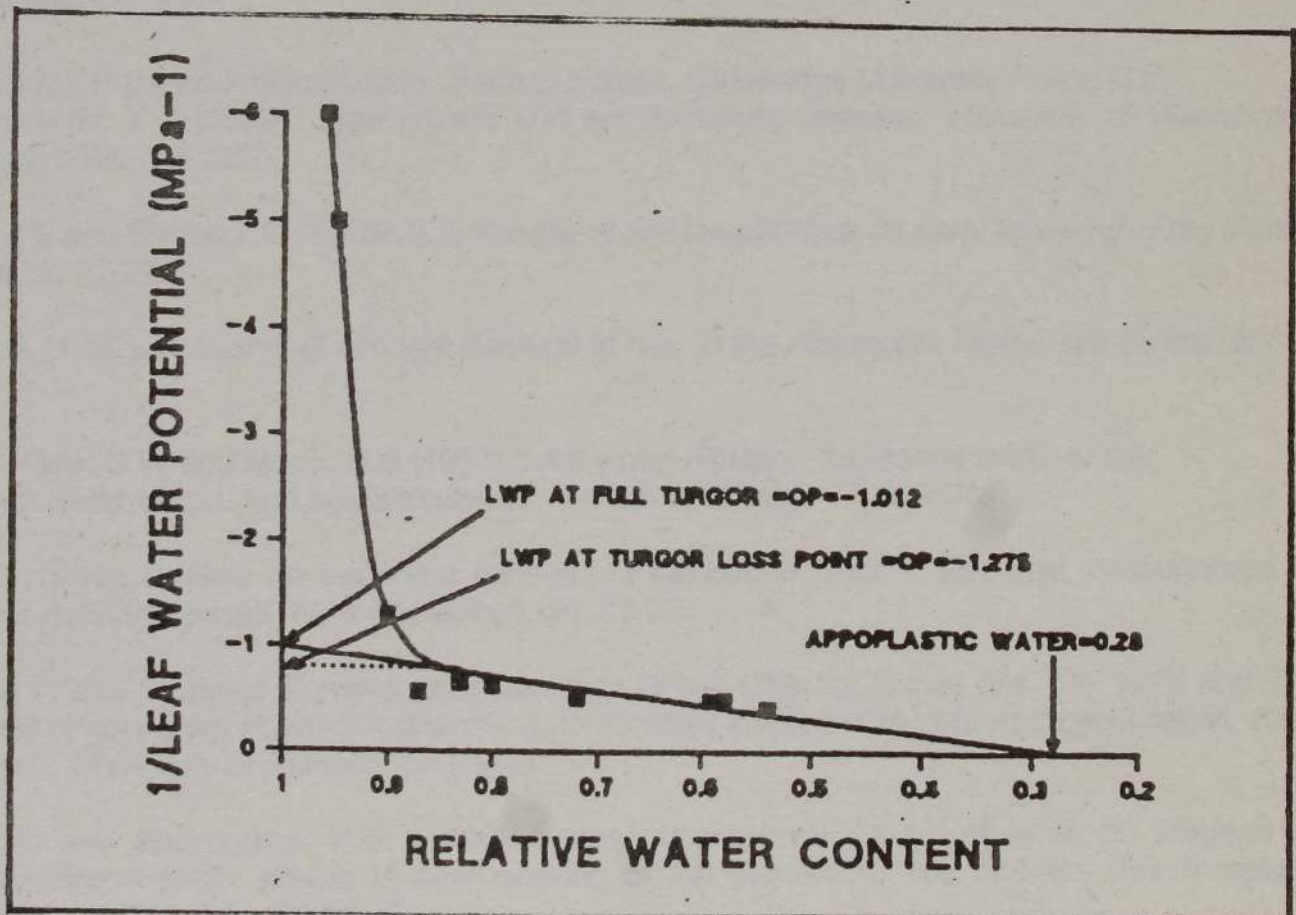


Figure 4. Pressure volume curve of TRI '4049'

TRI '4000' series clones to reduce the plant water potentials to more negative values and to have wider range of osmotic adjustments. These clones can absorb water from the drier soils than the other clones tested.

Since this was a preliminary experiment conducted under green house conditions, field evaluation will help confirm the methodology for ranking tea clones for drought tolerance successfully. Moreover evaluation of a wider ranger of clones may result in selecting more drought tolerant clones than the tested clones.

Conclusions

This study conducted to evaluate osmotic adjustment and water relationship of tea clones revealed that in comparison with the well known drought tolerant clone TRI '2025', most of the newly released TRI '3000' series clones and TRI '4000' series clones are better adapted to dry weather conditions. Of the two series, the latter appeared to be superior in the content of drought tolerant capabilities with respect to osmotic adjustment. The results of the present study demonstrate that the drought tolerate tea clones tide over periods by conservation of water through efficient stomatal control and effective osmotic adjustment which enable them to absorb soil water at low water potentials.

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A Comparison of Different Models of Estimating Actual Evapotranspiration from Potential Evapotranspiration in the Dry Zone of Sri Lanka

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Abstract

This paper compares widely used methods of estimating actual evapotranspiration from potential evapotranspiration and shows that actual evapotranspiration is approximately the same irrespective of the method used to estimate it in the dry zone of Sri Lanka. This finding is in line with the findings of a similar study in UK.

Abbreviations and Notation

The abbreviations and notations used in general in this paper are explained as follows.

AKP	= Angunakolapelessa (Study location)
AWC	= Available water capacity of soil in the root zone (mm/m)
EMB	= Embilipitiya (Study location)
ETa	= Actual evapotranspiration (mm/day or mm/y)
ETp	= Potential evapotranspiration (mm/day or mm/y)
F	= The ratio of ETa/ETp when soil moisture deficit is greater than root constant
FC	= Field capacity of soil (%)
Isc	= Interception (rainfall) storage capacity (mm/day)
KAL	= Kalpitiya (Study location)
MI	= Maha Illuppallama (Study location)
PFc	= Preferential flow co-efficient
PFt	= Threshold of daily rainfall above which preferential flow occurs (mm/day)
PWP	= Permanent wilting point of soil (%)
R	= Rainfall (mm/day or mm/y)
RC	= Root constant (% of AWC)
ROc	= Runoff coefficient
ROt	= Threshold of daily rainfall above which runoff occurs (mm/day)
SMD = smd	= Soil moisture deficit (mm)

Introduction

Evapotranspiration is a hybrid word, comprising of the two words 'evaporation' and 'transpiration'. The term evaporation usually means the transfer of water, in the form of vapour from water and soil surfaces and from other surfaces. Transpiration is the transfer of water from vegetation to the atmosphere. The term evapotranspiration therefore, can be defined (Basnayake, 1985) as the transfer of water in the form of vapour from the earth's surface including soil, vegetation and ocean surfaces, to the atmosphere.

A distinction needs to be made between the 'potential evapotranspiration' and the 'actual evapotranspiration'. The former is defined as the evaporative demand of the atmosphere. The latter is defined as the actual amount of water evaporated and transpired from soil, precipitation from plants to meet the evaporative demand of the atmosphere. When there is no shortage of water to the vegetation (or when there is enough water available for evaporation) the actual evapotranspiration will be equal to the potential evapotranspiration.

The study of actual evapotranspiration is important in studies of hydrological balance of a catchment, estimating deep percolation to aquifers, scheduling irrigation to crops and in a host of other applications.

This paper therefore compares 4 different models commonly used for estimating actual evapotranspiration from potential evapotranspiration by estimating actual evapotranspiration with these 4 different models at different locations in the dry zone of Sri Lanka and comparing them objectively.

Estimating actual evapotranspiration (ETa)

There are many ways of estimating actual evapotranspiration. The ones used more commonly are discussed below.

Lerner et al., (1990) suggest the Penman-Monteith model (equation 1) as the best to estimate actual evapotranspiration in humid climates.

$$ETa = \frac{[s.H + c.d.(e_a - e_d)/r_a]}{l.[s + g.(1 + r_s/r_a)]} \dots\dots\dots(1)$$

In equation 1, s is the slope of saturated vapour pressure curve, H is available energy, c is specific heat of air, d is density of air, e_a is saturated vapour pressure at air temperature, e_d the vapour pressure at screen height, r_a the aerodynamic resistance, r_s the stomatal resistance, l is latent heat of vaporisation and g is the psychrometric constant. However, this method is rarely used because of the difficulty of estimating the aerodynamic and stomatal resistance parameters.

A different approach is to estimate the potential evapotranspiration (ETp), and use this parameter to estimate actual evapotranspiration.

To estimate Potential evapotranspiration, an empirical method (such as the Blaney-Criddle method and the Radiation method) or a semi empirical method (Penman method) can be used. However, these methods need temperature, humidity, wind speed, sunshine and radiation data to estimate the potential evapotranspiration.

A different method to estimate potential evapotranspiration is to measure the evaporation from a pan (121 cm diameter and 25.5 cm deep) placed on a wooden platform with the bottom of the pan 15 cm from the ground. This measure called pan evaporation is converted to potential evapotranspiration by multiplying by a pan coefficient (Kp), depending on climatological, vegetative and wind factors (Doorenbos and Pruitt, 1977).

The Penman-Grindley model (equation 2) is a widely used method for estimating actual evapotranspiration from potential evapotranspiration [Lerner et al., (1990)].

$$\begin{aligned} &\text{If } SMD < RC \text{ or } ETp \leq R, ETa = ETp \\ &\text{If } AWC < SMD \leq RC \text{ and } ETp > R, ETa = R + F.(ETp - R) \dots\dots\dots(2) \\ &\text{If } SMD = AWC \text{ and } ETp > R, ETa = R \end{aligned}$$

Here SMD = the soil moisture deficit of the root zone, RC = root constant (defined later), R= rainfall, F = ratio of ETa/ETp, when the soil moisture deficit is greater than the root constant. In this method a root constant, [RC; defined as the soil moisture deficit at which actual evapotranspiration (ETa) falls below the potential evapotranspiration (ETp)] and a ratio of ETa/ETp (= F) are required to estimate actual evapotranspiration. For agricultural crops (cereals, potatoes, vegetables and grasses), other vegetation (grazing and woodlands), bare fallow lands and riparian zones the values of the root constant are different and the relevant values for each month in UK are available (Grindley, 1969).

The value of F is considered as 10% for UK climatic and soil conditions (Lerner et al., 1990). Fig. 1 shows the variation of the value of F with soil moisture deficit in graphical form for climatic, vegetative and soil conditions in UK.

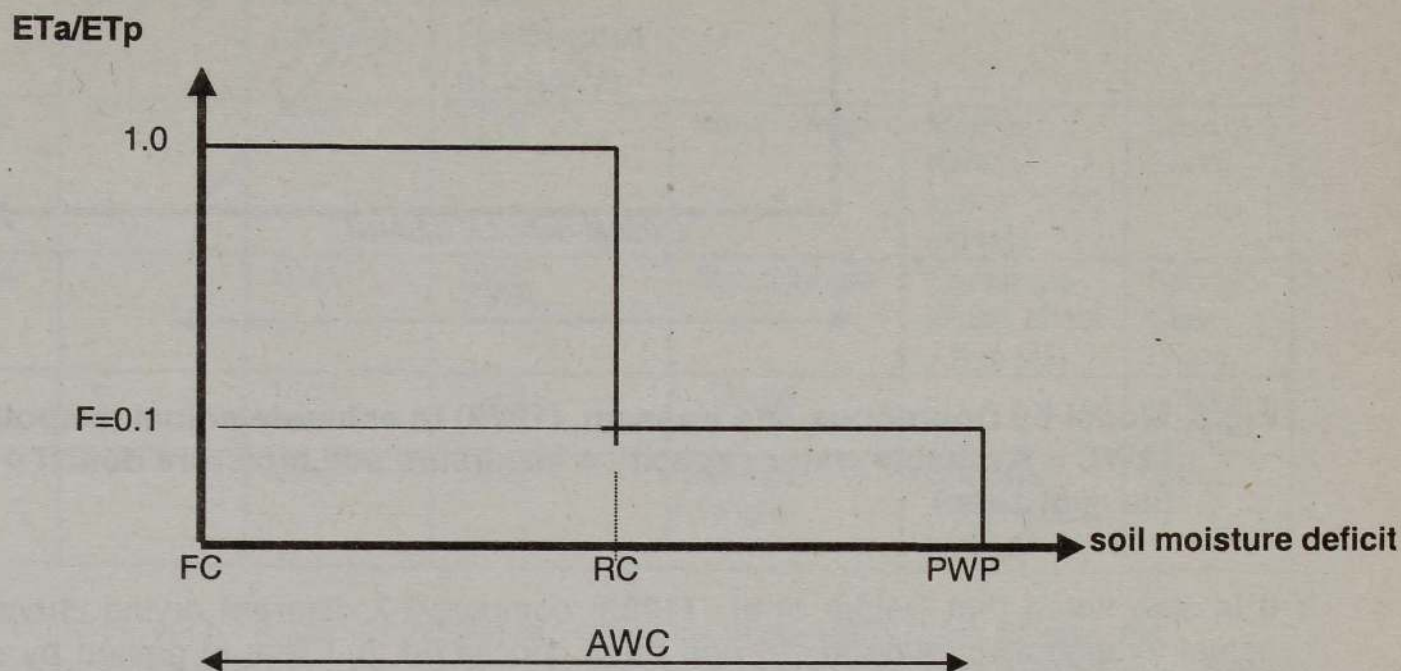


Fig. 1 Penman-Grindley model for estimating actual evapotranspiration

Calder et al., (1983), Baier et al., (1979) and Rushton and Ward (1979) describe some other relationships between actual evapotranspiration and potential evapotranspiration (when soil moisture deficit > root constant) as shown in Fig. 2.

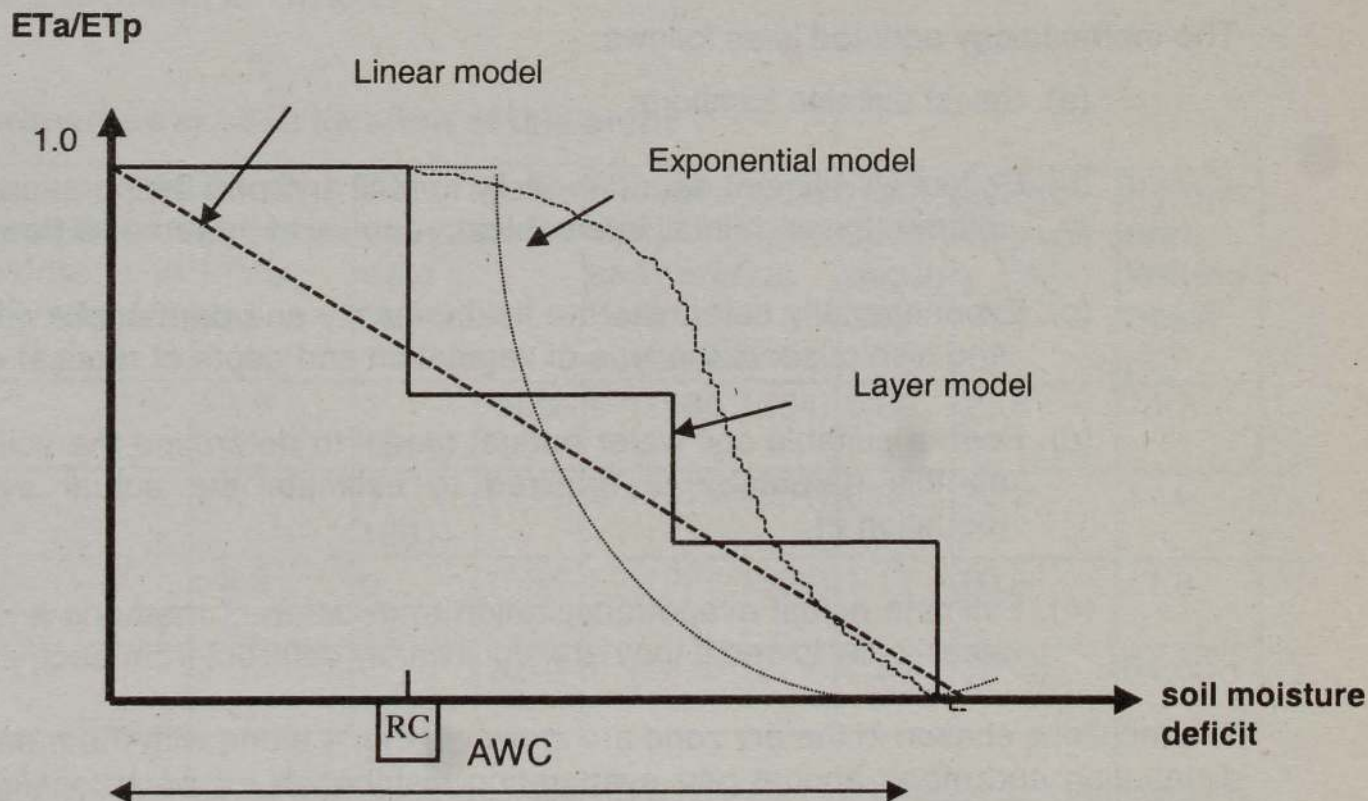


Fig. 2 Different models for estimating actual evapotranspiration

Doorenbos and Kassam, (1979) describe a model (as shown in Fig. 3), which assumes a linear reduction of F . By taking critical deficit = 0, this model becomes effectively the same linear model described by Calder et al., (1983) and Rushton and Ward (1979) in Fig. 2.

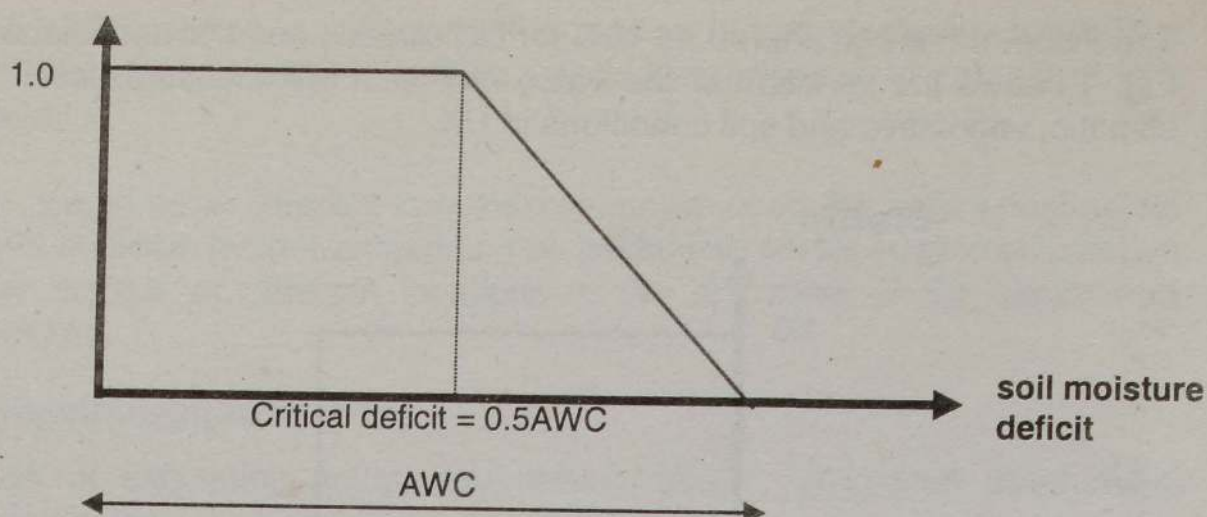


Fig.3 Model by Doorenbos and Kassam, (1979) to estimate actual evapotranspiration (AWC = Available water capacity = maximum soil moisture deficit possible in the root zone)

It is also noted that Calder et al., (1983) compared 7 different drying curves to estimate actual evapotranspiration in UK and have concluded that little is gained by using detailed models requiring a lot more information.

The objective of this paper is therefore, to compare 4 commonly used models (in Figs. 1,2 and 3) which are required to estimate ET_a from ET_p using the Penman-Grindley model (equation 2). The chosen models are shown in Fig. 6 (a), (b), (c) and (d) respectively.

Materials and Methods

The methodology adopted is as follows.

- (a). Select suitable locations.
- (b). Collect all relevant data (i.e., daily rainfall and pan evaporation for a few years, information on rainfall interception, runoff and preferential flow).
- (c). Experimentally determine the field capacity and permanent wilting point of soil and also observe the type of vegetation and depth of roots at each location.
- (d). Form a suitable soil water budget model to determine the soil moisture deficit as this parameter is required to estimate the actual evapotranspiration (equation 2).
- (e). Estimate actual evapotranspiration from different methods and compare them statistically to see if they are significantly different from each other.

The locations chosen in the dry zone are shown in Fig. 4 along with the mean annual rainfall distribution and mean annual pan evaporation distribution for each location. In choosing these locations, the factors considered were the availability of climatic data and the different types of soil types and vegetation. Climatic, soil and vegetation details at the study locations are shown in Table 1.

Table 1. Details of locations in the dry zone

Location	No in Map (Fig. 4)	Mean Annual Rain ¹ (mm/y)	Mean Annual Pan Evaporation ¹ (mm/y)	Vegetation	Major Plant type	Top soil
Embilipitiya	1	1397	1729 ²	Shrub jungle	Maana (Grass about 30 cm tall)	Loamy Sand
Angunakolapellessa	2	1041	1868	Shrub jungle	Eraminiya (Bush about 1.5 m tall)	Sandy Clay Loam
Maha Illuppallama	3	1305	1579	Jungle	-	Loamy Sand
Kalpitiya	4	955	1958 ³	Sparse Jungle	Bolpana (Tree about 3m tall)	Sand

¹ 6 year mean value except for Angunakolapellessa, where the mean value is the 17 year one.

² Pan evaporation values are from the climate station at Sevanagala (ie, the nearest agro-climatic station).

³ Pan evaporation value are from climate station at Vanathavillu (ie, the nearest station where evaporation data is available).

Details of climatic data are presented in de Silva (1996). The number of years these data collected are given in Table 2. The soil properties at each site (which were experimentally determined) are also shown in Table 2.

Table 2. Soil properties at each location of this study

Location	No of sampling points in the site	Depth to water table (m)	No of years daily rainfall data collected	No of years pan evaporation data collected	Root zone depth (m)	Field Capacity (%)	Permanent Wilting Point (%)
Embilipitiya	8	>2.9	6 (1989-1994)	6 (1989-1994)	0.69	21.4	15.7
Angunakolapell-essa	12	>4.1	6 (1976-1981)	6 (1976-1981)	0.95	20.2	12.0
Maha Illuppallama	12	>3.2	6 (1986-1991)	6 (1986-1991)	1.17	20.9	11.0
Kalpitiya	5	2.3	6 (1970-1975)	6 (1970-1975)	1.50	14.00	04.00

(Note : The number of years rainfall and pan evaporation data collected for different locations differ as the computerised data were available for these years only. Also in some cases the data were available for more years, but, overlapping years for both types of data could be obtained for these years only. The study could have been made for 10 years of daily data, had it been available, but the end result is unlikely to differ as will be seen later.)

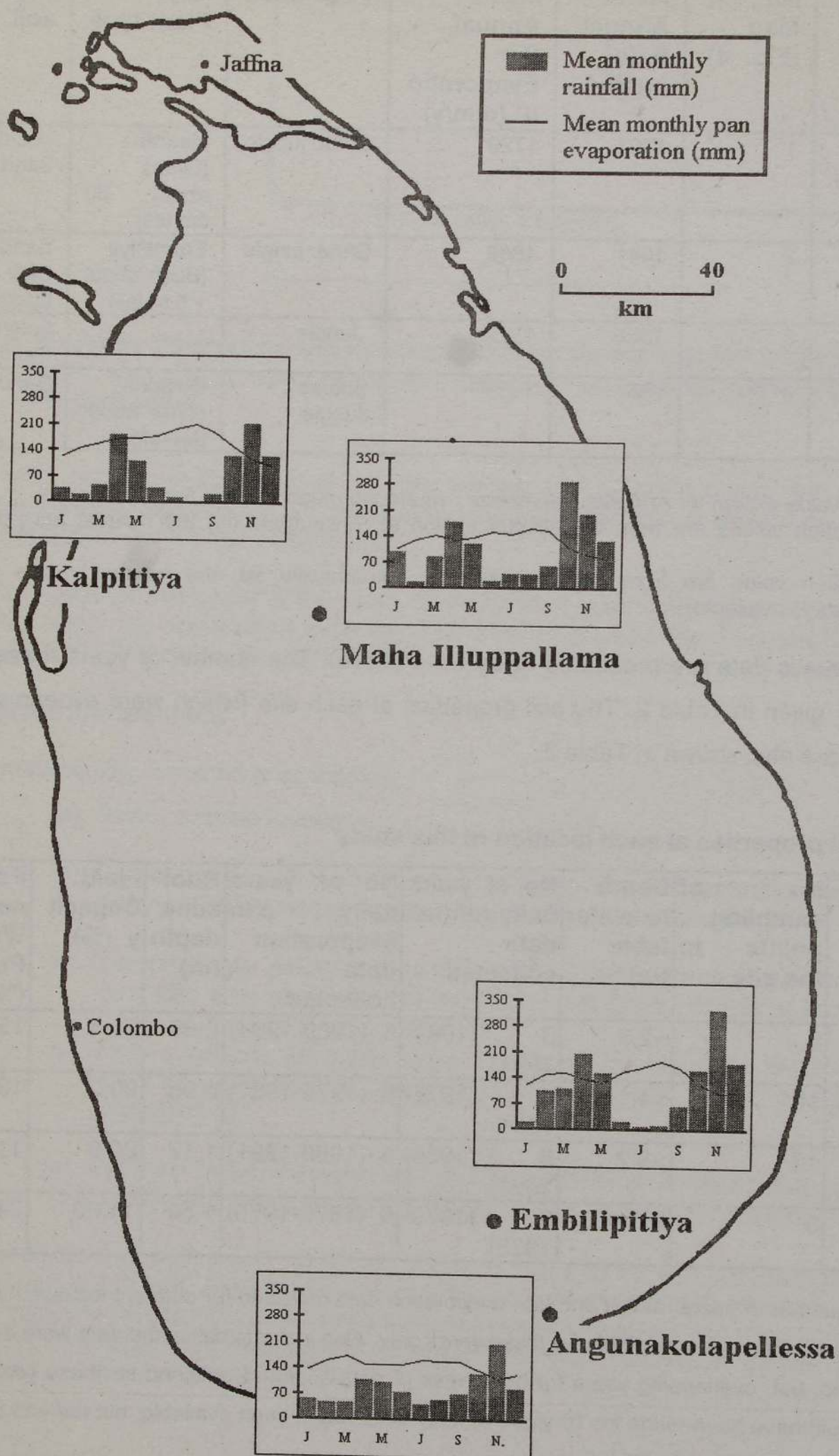


Fig. 4 - Study locations in the dry zone of Sri Lanka (Mean monthly rainfall and pan evaporation for each location is also shown).

A soil water budget model to calculate the soil moisture deficit, which is required to estimate the actual evapotranspiration (equation 2), was formed and the flow chart is shown in Fig. 5. A detailed explanation of the soil water budget model is given in de Silva (1996) with an explanation of the spreadsheet model used for the calculations.

As seen from Fig. 5, parameters of rainfall interception storage capacity (Isc), Runoff threshold (ROt), runoff coefficient (ROc), Preferential flow threshold (PFt), Preferential flow coefficient (PFc) and root constant (RC) for a particular location are required for the soil water budget model. Table 3 shows the values of these parameters obtained by considering the vegetation, rainfall distribution and soil types at each location. A detailed explanation of obtaining these parameters for each location are given in de Silva (1996).

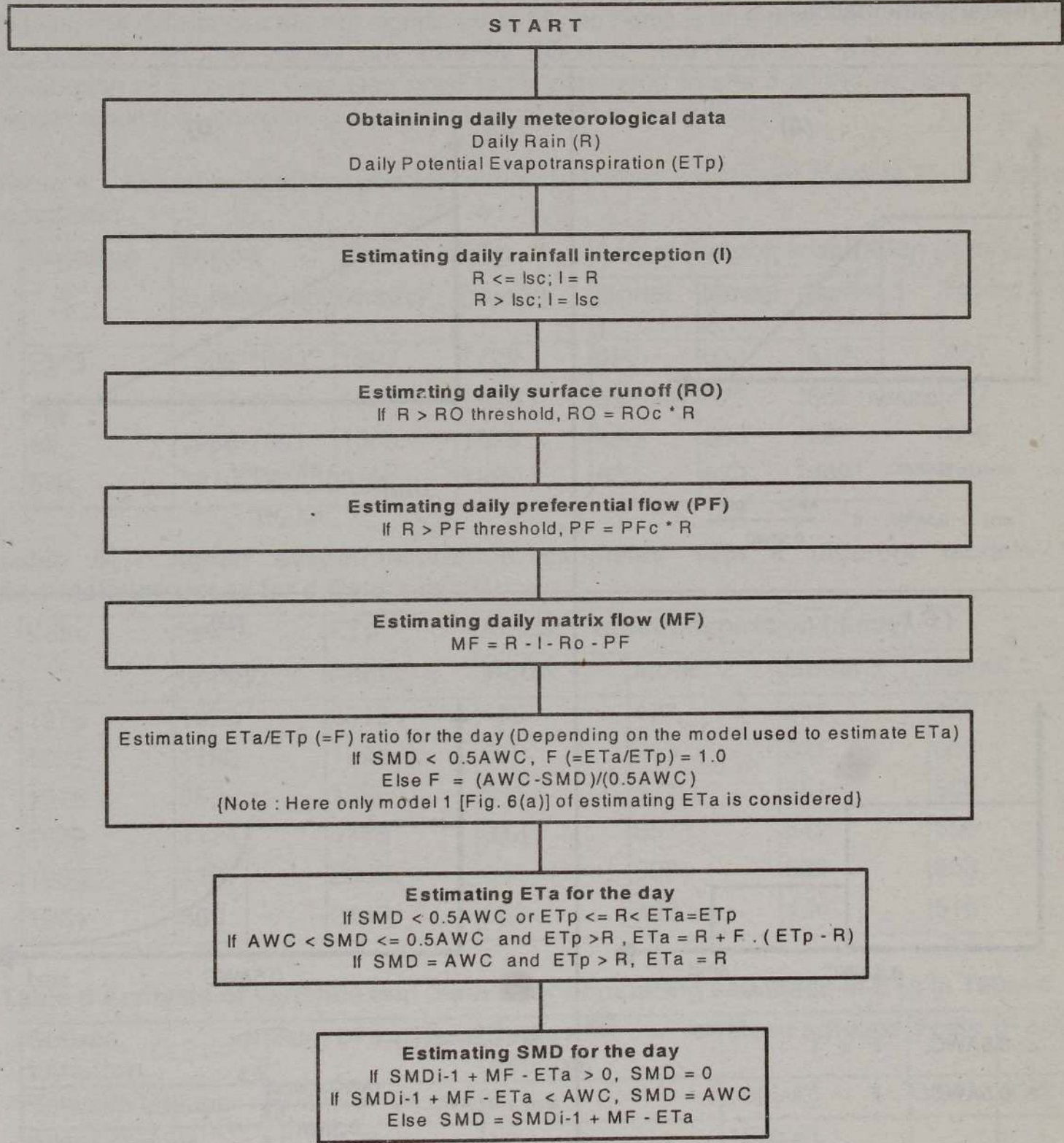


Fig. 5 Flow chart of the soil water budgeting model to estimate soil moisture deficit

Table 3 Rainfall interception storage capacity (Isc), Runoff threshold (ROt), runoff coefficient (ROc), Preferential flow threshold (PFt), Preferential flow coefficient (PFc) and root constant (RC) for the study locations.

Location	Isc	ROt	ROc	PFt	PFc	RC
Embilipitiya	1.8	12.5	0.25	10	0.075	50% of AWC
Angunakolapelessa	1.6	12.5	0.32	10	0.075	50% of AWC
Maha Illuppallama	2.0	12.5	0.27	10	0.075	50% of AWC
Kalpitiya	1.2	15.0	0.00	10	0.075	50% of AWC

The 4 models chosen to estimate F (i.e., the ratio of ETa/ETp when SMD>RC) are graphically shown in Fig. 6(a), (b), (c) and (d) with the corresponding equations describing each model mathematically.

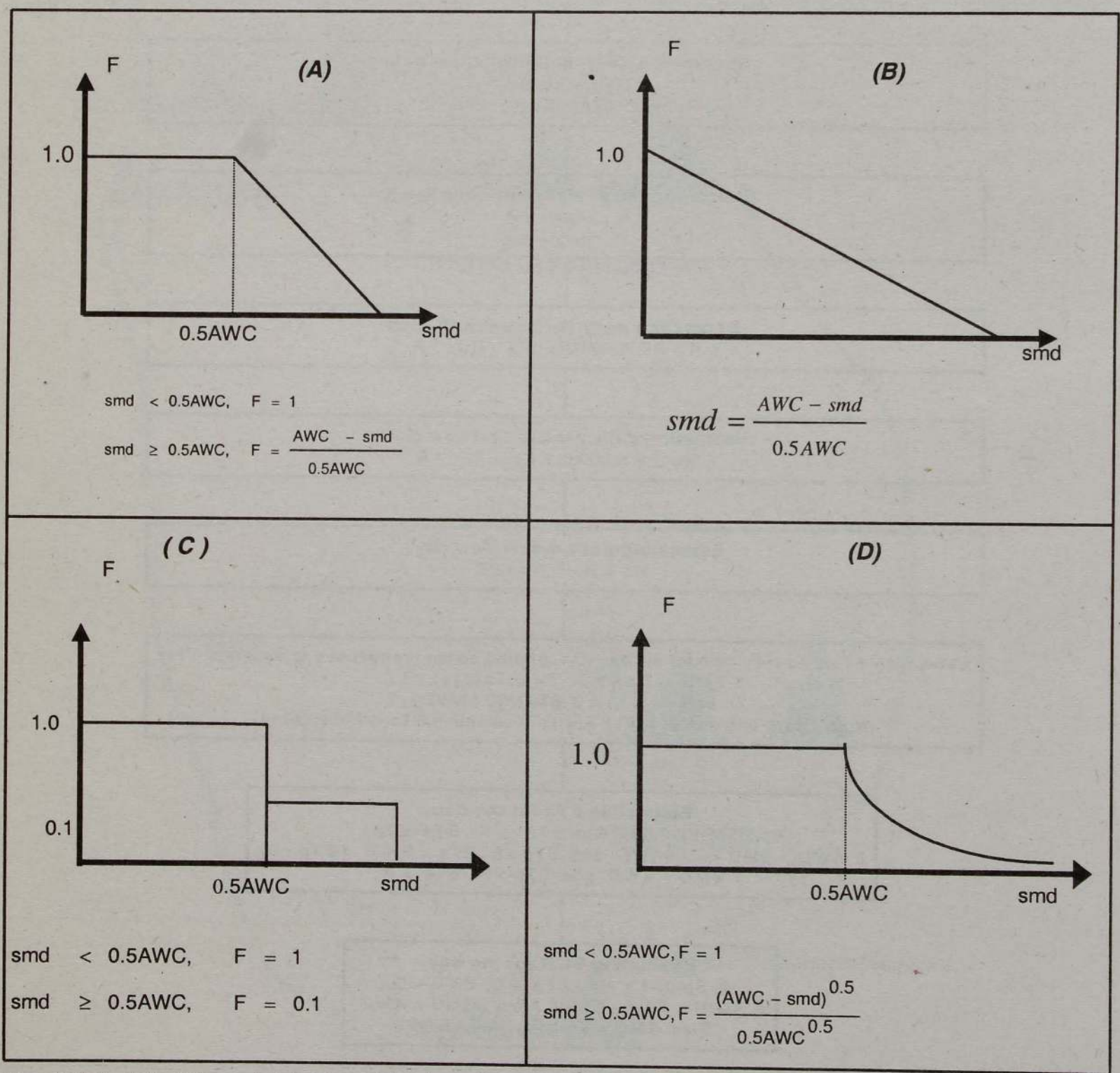


Fig. 6 (a), (b), (c) and (d) Graphical and mathematical representation of the 4 models of estimating ETa from ETp used in this study

Results

The climatic data were fed into the soil water budget model shown in Fig. 5 for all 4 models and some of the results obtained are given in Tables 4 and 5 and in Figs. 7 and 8. Table 4 shows the annual estimates of ETa for the 4 different location with 4 different models of estimating ETa in the dry zone considering 6 years of daily data (Periods considered are given in Table 2). Table 5 shows the estimates of ETa for Angunakolapelessa for different years from 1976 to 1981 with the 4 different models.

As seen from Tables 4 and 5, the estimates of ETa are similar with all the 4 models for different locations and also for one location in different years. To test if the very small differences are significant, an analysis of variance test can be carried out. Tables 6 and 7 show the results of analysis of variance test at 5% significant level. As seen from these two Tables, the differences are not significant at 5% as Fcalc is less than Fcrit; rejecting the null hypothesis that the values are different (Gomez and Gomez, 1976). However, the distribution of ETa with time also need to be compared to see if all the models produce a similar result (i.e., comparing annual values of ETa is not sufficient).

Table 4 - Actual evapotranspiration estimated from 4 different models for 4 different locations.

Location	Period considered	Rain (mm/y)	ETp (mm/y)	Actual Evapotranspiration (mm/y)			
				Model 1	Model 2	Model 3	Model 4
EMB	1989-1994	1397	1729	657	638	610	667
AKP	1976-1981	1048	1920	589	579	562	597
MI	1986-1991	1305	1579	680	668	639	686
KAL	1970-1975	955	1960	687	672	649	698

Table 5 - Actual evapotranspiration estimated with 4 different models for Angunakolapelessa for different years.

Year	Rain (mm/y)	ETp (mm/y)	Actual Evapotranspiration (mm/y)			
			Model 1	Model 2	Model 3	Model 4
1976	1020	2015	489	477	475	496
1977	1182	1695	650	643	621	660
1978	993	1866	581	571	551	589
1979	1124	1748	662	657	642	666
1980	1137	2056	641	628	600	653
1981	830	2140	508	496	484	516

Table 6 Analysis of variance test results for comparing estimates of ETa in Table 4

Source of Variation	Sum of squares	Degrees of freedom	Mean squares	Fcalc	F crit
Between Groups	5042.13	3	1680.71	0.91	3.49
Within Groups	22185.71	12	1848.81		
Total	27227.84	15			

Table 7 Analysis of variance test results for comparing estimates of ETa in Table 5

Source of Variation	Sum of squares	Degrees of freedom	Mean squares	Fcalc	F crit
Between Groups	4020.4	3	1340.14	0.24	3.10
Within Groups	112242.2	20	5612.11		
Total	116262.6	23			

Fig. 7 and 8 shows the distribution of ETa over a period of one year for Angunakolapelessa and Maha Illuppallama respectively with the 4 different models. An analysis of variance test can be carried out to see if these distributions are significantly different or not.

Tables 8, 9, 10 and 11 show the results of analysis of variance tests to see if distributions of ETa estimates are significantly different or not. In this test the daily estimates of ETa for 6 years were considered. Here again, the distributions at each location are significantly not different at 5% as Fcalc is less than Fcrit in Tables 8, 9, 10 and 11.

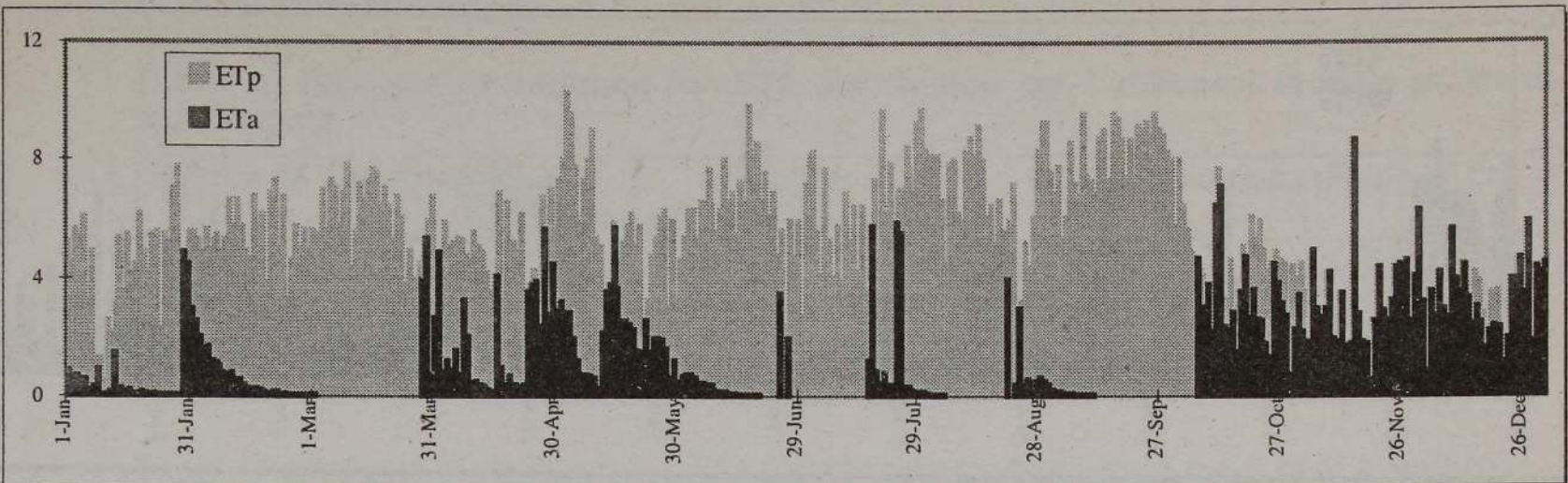
Therefore, it is concluded that from the evidence shown in this study, the 4 commonly used models of estimating ETa from ETp produce almost the similar result and in estimating ETa from ETp, any of these models may be used.

Table 8 Analysis of variance for ETa distribution by 4 different models at Embilipitiya

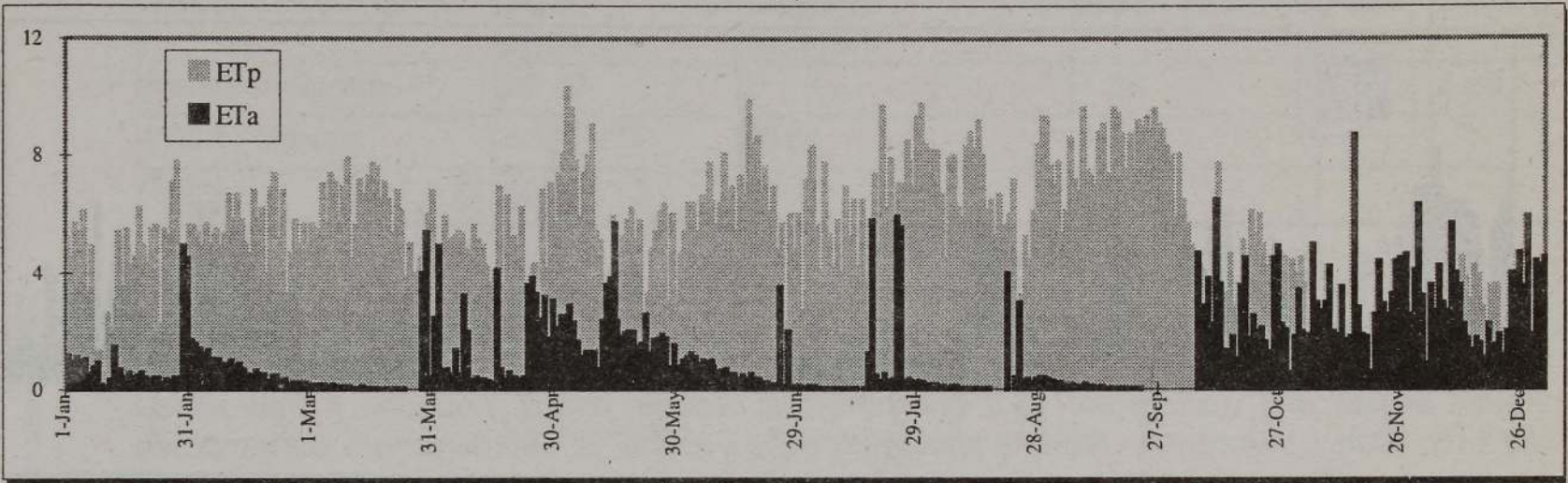
Source of Variation	Sum of squares	Degrees of freedom	Mean squares	Fcalc	F crit
Between Groups	31.17	3	10.39	2.44	2.60
Within Groups	37176.69	8764	4.24		
Total	37207.87	8767			

Table 9 Analysis of variance for ETa distribution by 4 different models at Angunakolapelessa

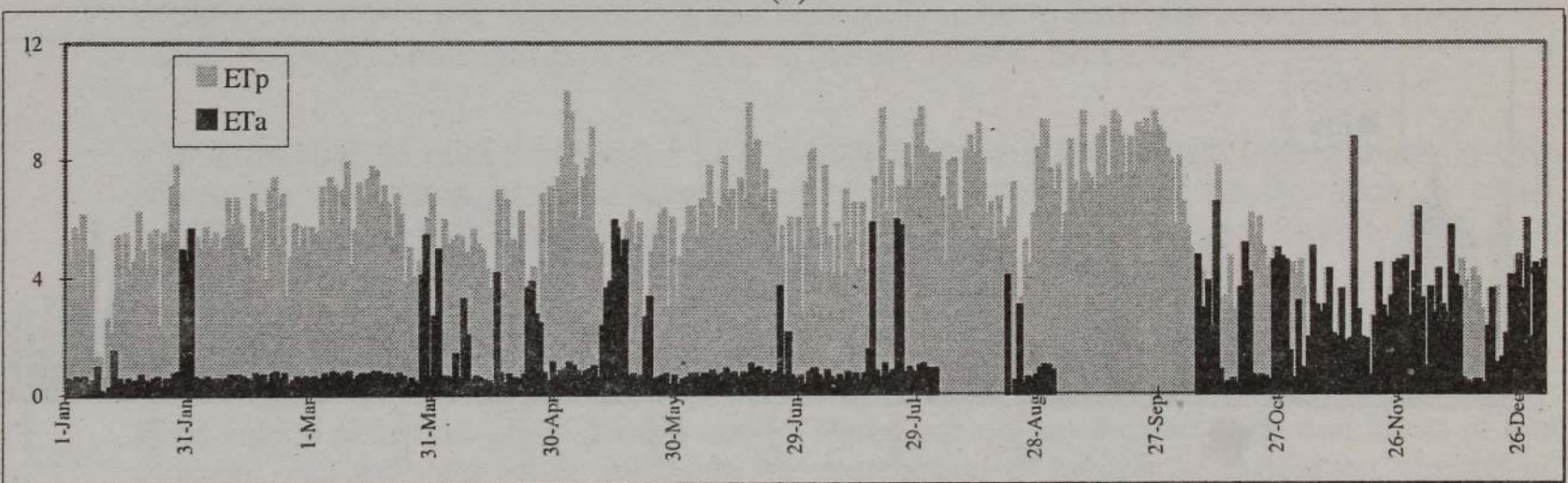
Source of Variation	Sum of squares	Degrees of freedom	Mean squares	Fcalc	F crit
Between Groups	11.06	3	3.68	1.09	2.60
Within Groups	29617.55	8764	3.37		
Total	29628.61	8767			



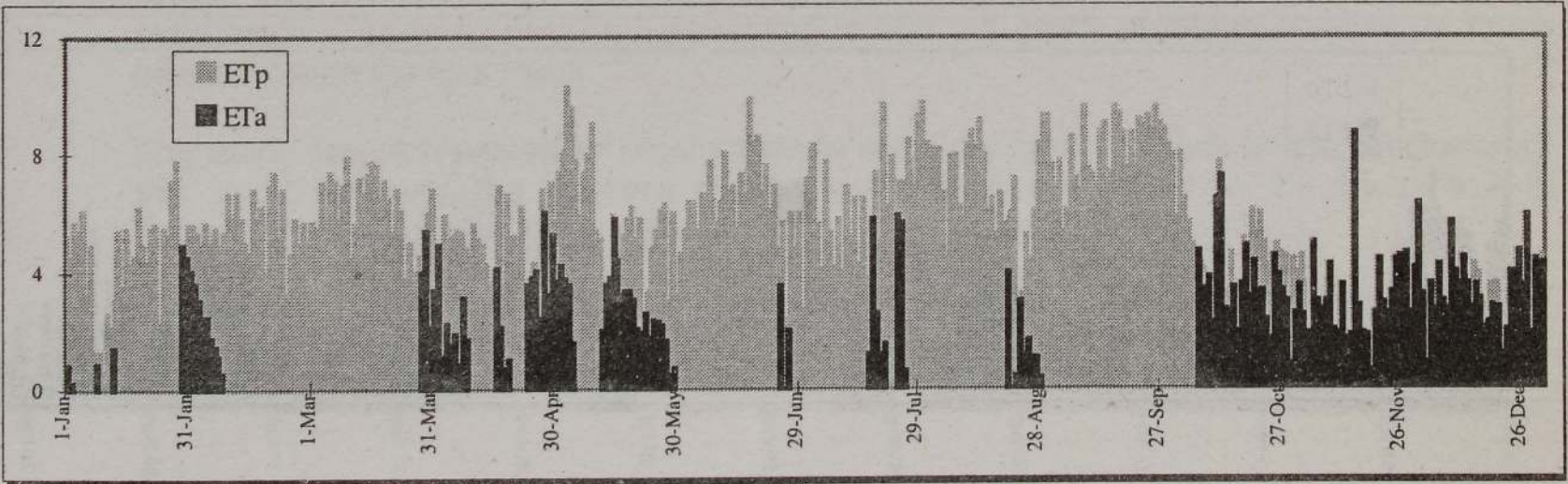
(a)



(b)

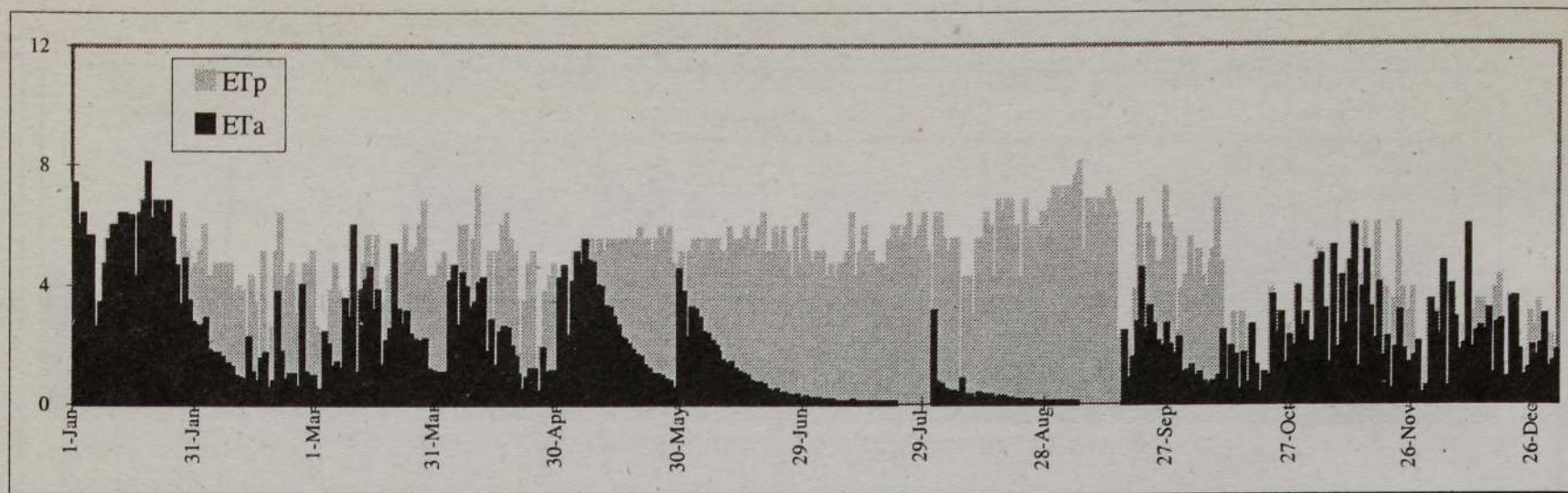


(c)

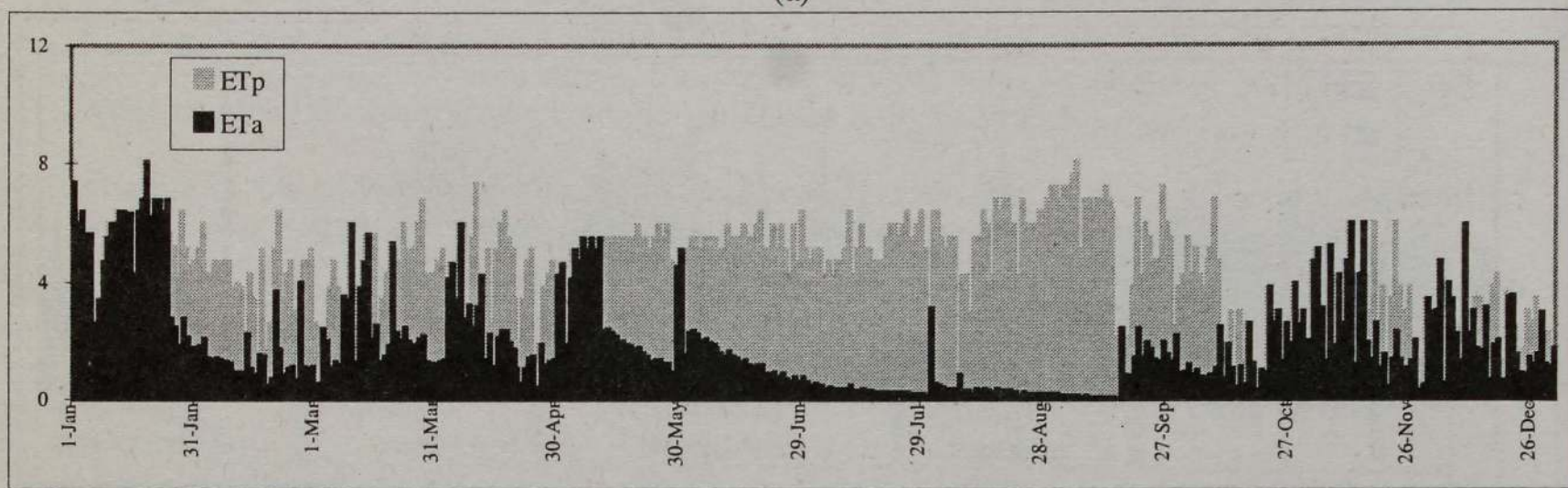


(d)

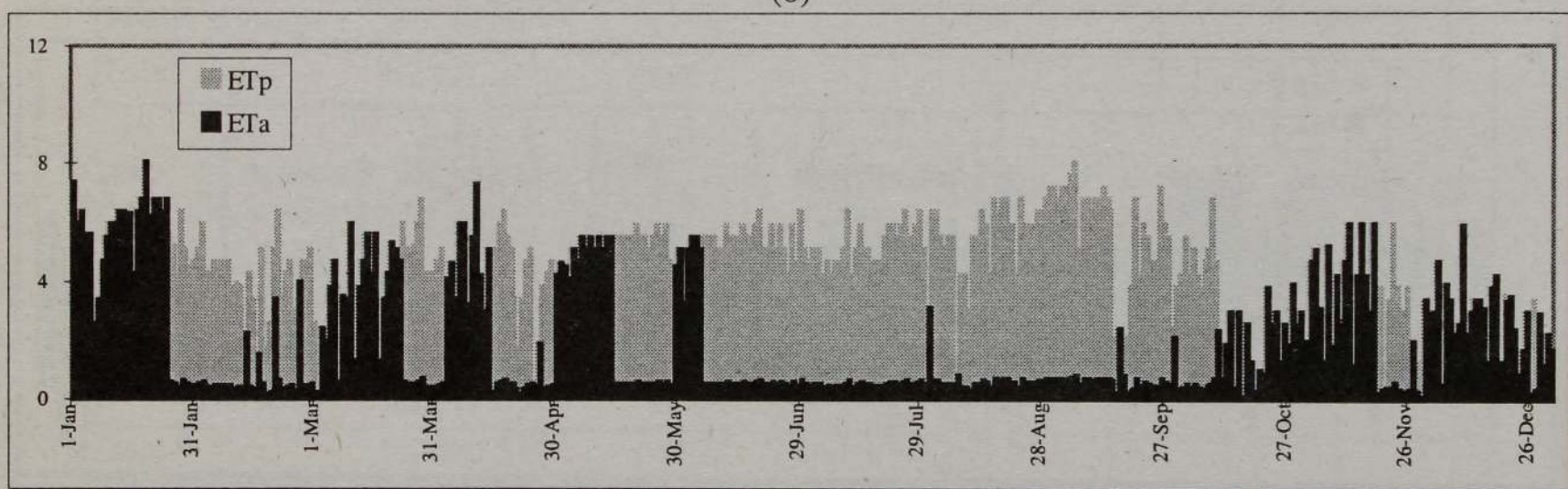
Fig. 7 (a), (b), (c) and (d) Potential Evapotranspiration (ETp) and Actual evapotranspiration (ETA) estimated with different models for Angunakolapellssa for the year 1976. (ETp and ETA values are in mm)



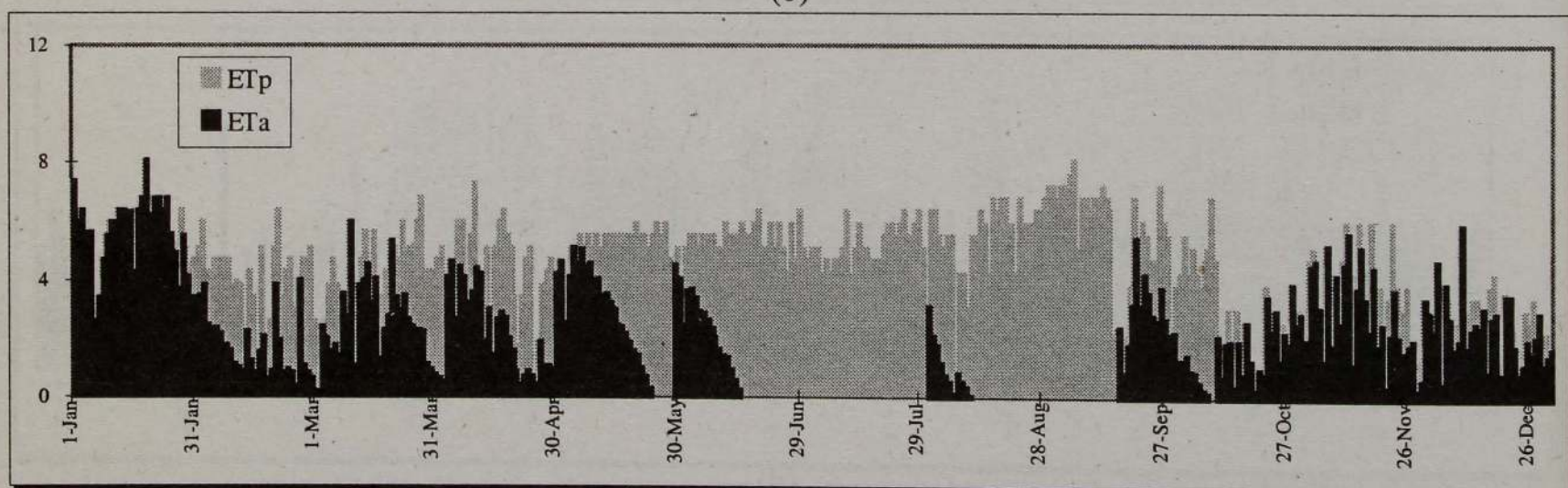
(a)



(b)



(c)



(d)

Fig. 8 (a), (b), (c) and (d) Potential Evapotranspiration (ETp) and Actual evapotranspiration (ETA) estimated with different models for Maha Illuppallama for the year 1986. (ETp and ETA values are in mm)

Table 10 Analysis of variance for ETa distribution by 4 different models at Maha Illuppallama

Source of Variation	Sum squares	of Degrees freedom	of Mean squares	Fcalc	F crit
Between Groups	21.54	3	7.18	2.58	2.60
Within Groups	24365.49	8764	2.78		
Total	24387.04	8767			

Table 11 Analysis of variance for ETa distribution by 4 different models at Kalpitiya

Source of Variation	Sum squares	of Degrees freedom	of Mean squares	Fcalc	F crit
Between Groups	22.03	3	7.34	1.59	2.60
Within Groups	40275.11	8764	4.59		
Total	40297.15	8767			

Concluding Discussion

This paper estimates the actual evapotranspiration at 4 locations in the dry zone of Sri Lanka with 4 commonly used models (of estimating ETa from ETp). The results clearly demonstrate the estimates of actual evapotranspiration (both the annual values and the distribution with time for 6 years) are independent of the method used. Therefore, it is evident that any of the methods that are commonly used to estimate ETa from ETp can be safely be used to estimate ETa from ETp in the dry zone of Sri Lanka.

It is interesting to note that Calder et al (1983) found a similar result from a study in UK, where he concludes that measuring rainfall and potential evapotranspiration is more important than placing the importance on the selection of models to use. From this study, it is evident that this statement is true for the dry zone of Sri Lanka as well.

A simplification was used in using the parameters (of estimating interception storage coefficient, runoff coefficient and threshold and preferential flow threshold and coefficient) as fixed values shown in Table 3 were used. (These values are the best one can arrive at the moment with the information available for interception of rainfall by vegetation, run off of rainfall and preferential flow). This simplification is not thought to affect the result significantly. However, it will be interesting to see the effect of different values of these parameters on the final result.

This study can be repeated for other locations in the dry zone to check on the conclusion of this study. However, the locations chosen in this study are typical for the dry zone, it is thought that the conclusions one can arrive at are as same as in this study.

This finding has important practical implications in many issues such as in the assessment of safe groundwater yield in aquifers, irrigation scheduling to crops and in the studies of hydrological and hydro-geological balance of catchments.

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Socio-Economic and Environmental Impact of Gem Mining Industry In Sri Lanka: A Case Study of Hunuwala Village In Ratnapura District

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Abstract

The gem mining industry (GMI) is one of Sri Lanka's major sources of income and employment. However, it also has considerable socio-economic and environmental (SEE) consequences affecting gem miners and the general public as well. This paper discusses the present SEE impact of the GMI, based on primary data gathered from a field survey undertaken at a gem mining village - Hunuwala in the Ratnapura district. The decline of agricultural production, rising income inequality, seasonal unemployment of gem mining laborers as well as a decline of education, health and living standards were identified. In addition, water pollution, soil erosion and the destruction of areconut trees are the major environmental problems. In order to develop the GMI, it is recommended that both labourers and mine owners are made aware of the adverse consequences of these activities and that the applicable rules and regulations are observed strictly.

Introduction

Sri Lanka produces all the varieties of gems found in the world except for diamond and turquoise. Varieties of corundum, and chrysoberyl found in Sri Lanka are precious gems while all others such as Spinel, Topaz, Beryl, Zircon, Garnet, Quartz, Tourmaline and feldspars are semi-precious. Eighty five percent (85%) of Sri Lanka's gems are found in the Ratnapura district where eighty percent (80%) of all mines in Sri Lanka are located. Gem mining in Sri Lanka are classified as Tunnel Mining, Open pit deep Mining, Open Pit Shallow Mining and Riverbed Mining. Tunnel mining, used to obtain gem bearing gravel (GBG) deposited more than 10 meters below the surface, while the other types of mines use to take GBG deposited less than 10 meters deep. All the mining use traditional techniques and methods.

According to historical sources our gemstones have mainly been purchased by India and the Middle East, since the first century A.D. and they were a significant export commodity during the colonial period (Economic Review, 1977: 3-8). However, the gem industry in Sri Lanka was rather informal and unsystematic until the establishment of the State Gem Corporation (SGC) in 1971. Since then, smuggling has been controlled, gem exports were increased, and skills improved, licenses for mining were issued and state owned land for mining has been allocated. After the introduction of open economic policy in 1977, the involvement of gem dealers from Thailand, the introduction of heat treatment of *Geuda* (a variety of precious gem) and improved opportunities for the private sector to export gems resulted in further development of the GMI. Consequently, foreign exchange earnings from gem exports have increased considerably. While the income from gem exports increased from Rs. 2933 million in 1990 to Rs. 4772 million in 1996, the percentage of total export decreased from 3.6 to 2.1 during the same period, due to a significant increase in industrial exports especially garments. Furthermore, GMI is significant in generating employment. In 1987, Karunathilaka estimated that 1,74000 people were directly employed in the gem industry (1989: 132). However, benefits generated by GMI were only enjoyed by a few mines owners and laborers. They create SEE consequences that are incurred by the wider society.

Main focus of this paper is to analyze the SEE impact of GMI in detail. Primary data for the analyzes were gathered from a field survey undertaken at a gem mining village, Hunuwala in the Ratnapura district and data were collected from a sample of 20 mines, observing pits,

interviewing owners, labourers, gem dealers, land owners, and also officers of the general public. In addition, secondary sources of GMI were studied.

Hunuwala village is located 128 km from Colombo between Pelmadulla and Balangoda on Badulla Road. It has an elevation of 500 to 700 feet above mean sea level. The land area comprises 649 acres, of which 65 percent are under rubber and owned by a private management company. Twenty four percent (24%) is privately owned land located near and around the main road and the river as well as the rest are comprised with river reservation, forest, and grasslands. Thirty two (32) acres are under paddy and 121 acres comprises home gardens. In 1996, the population of the study area was 1821 (906 male and 915 female). The estimated labour force is 956, of which 31 percent are employed in the rubber estate, 22 percent are farmers 23 percent are unemployed, 8 percent are employed in other jobs and 16 percent are employed in the GMI.

Hunuwala village has a long historical background of gem mining. Ancient gem mining tools and instruments have been found. The GMI in the village developed sharply during the recent decade due to the finding of a lot of *Geuda*. All types of gem mining in Ratnapura district occur in the study area. Today nearly 40 gem pits employing 204 peoples, is in operation. They comprise 3 tunnel pits, 6 open pit shallow and 10-river bed mining. There are 11 licensed pits and 39 unlicensed. Licensed gem mining are organized by a few entrepreneurs while unlicensed mines are informally organized by illegal gem miners. However, villagers enjoy some direct and indirect benefits due to GMI. After 1990, they have built 12 new houses, repaired 23 houses, purchased durable consumer goods and properties. Despite, these benefits, SEE costs were widely generated by the GMI. The decline of agricultural production was the major impact of GMI because most gem mines are located in agricultural lands (08 paddy fields, 06 home gardens and 16-rubber estates). Income inequality between owners and labourers, seasonal unemployment and the decline of health and living standards have been the significant problems. Environmental impact such as water pollution, soil erosion in agricultural lands and riverbanks and the destruction of arecanut trees can be observed. The following section discusses the SEE impact of GMI in detail.

a) Decline of Agricultural Production

Paddy harvest in selected paddy fields in the study area has decreased by 29 percent in the Yala season (from March to August in 1997). One major reason for the decrease of the paddy harvest was the GMI. Thirty percent (30%) of the total mines was scattered in paddy fields and 31 percent of the paddy fields have been destroyed due to GMI. Reservation of a large extent of paddy fields for gem mining in future, was the main reason. Though only 20 perches is required per mine to reserve legally, in most cases the mines cover a much wider area. In addition, reserved lands were used only for gem mining and not used for paddy production. Most mines in the paddy fields reserved more than 40 purchase for a mine. This reason is common to the other agricultural lands as well. Unclosed abandon gem pits and a large amount of pile of clay, sand and stones of abandoned gem mines in agricultural lands were the other reason for the decline in agricultural production. Fertility of the soil in agricultural land decrease due to composite sand and stones of gem pits along with soil erosion. This reason is also caused adversely for the decline of agricultural production.

Illegal gem mines led to the destruction of rubber estates as in the area of study, GBA have been found to be deposited all over such land. Estate officers mentioned that the illegal gem miners have destroyed many a rubber trees, consequently 150 to 200 of rubber trees have been destroyed annually. 2000 rubber trees were destroyed during the period between 1990 and 1996 due to illegal gem pits.

b) Income Inequality

GMI causes for the income inequality between the mine owners and the labourers and also among the villagers. Table 01 shows that more than 25 percent of total gem income goes to the owners while less than 3 percent goes for the labourers indicating a vast income disparity between them. Traditional share system used for the distribution of gem income is the major reason for this. Gem mines are organized using a traditional share system by the gem dealers, landowners or license holders. Gem income is distributed among the shareholders according to their value, because all the shares do not have a similar value. The most valuable share is the share of water pump machine while shares of land and license are the other valuable shares. The shares of expenses, labourers and managers are the less value shares. The traditional process of the gem income distribution is as follows. Firstly, 8 percent is allocated for the taxes secondly, 10 percent of the balance goes for the share of water pump machine, thirdly 20 percent of the balance is allocated for the share of land and 10 percent of the balance is paid for the share of the license. Finally after deducting the cost it is equally distributed among the shares of expenses, labourers and the manger. As a result, license holders and owners of water pumps and land earn a relatively high income while mine labourers possesses a relatively low income. In addition, illegal gem mines use no such share system and they equally divided gem income into two. One portion is equally shared by the shareholders of expenses while the mines' labourers similarly share the other portion. As a result, illegal gem miners earn more gem income than the labourers' of licensed gem mines. (See table 01).

Unfair dealing at the gem auctions is also a cause for the inequality in income. For instance, the gem dealers together with mine owners purchased gemstones at a very low pre-decided price in the gem auctions. They sell such gems at a very high price after the auction and they equally share the profit. Mine owners escape the tax payment, and other shares by selling gems confidentially and distributing a small proportion among the labourers. As a result, owners earn much more income than the labourers. Labourers do not tend to go against the unfairness, because they assist the labourers by providing financial and other assistance at emergencies. For instance; illegal gem miners sometimes are caught and arrested by the police. Mine owners intervene and get them released. If a released labourer find gems, he sells them at a low price to owners who help them. Owners sell these gems at a higher price and this is also another reason for the income inequality.

Owners invest their additional income in plantations or in some other business ventures and they make a profit. This is also one reason for income inequality. Income inequality increases due to the uncertainty of gem income. In most gem mines, gems could not be found regularly. Labourer are given Rs. 75/= per week as pocket money. This is the only income for some labourers. Though the owner do not earn income from gem pits they do not have to face any difficulties since they have other sources of income. On the other hand, if miners do not find gems they tend to take loans from dealers or owners. Ultimate result is the increase of the income inequality since labourers have to settle debts whenever they find gems.

Table 01: distribution of Gem Income between Owners and Labourers in selected mining

Mi nin g	Total gem income Rs	No.of labor	No.of expen ce share rs	Total cost for mining Rs	Gem income gained by owners										Gem income per labour	
					Share of water pump Mechine		Share of land		Share License		Share of Expences		Total Income per Owner	As a % of total Income	As a % of Total Income	
					No	Rs	No	Rs	No	Rs	No	Rs				
A	125200	10	12	23500	01	115184	-	-	01	82932	5	144579	342695	27.4	Rs. 34669	2.8
B	887000	08	12	19000	01	81604	1/4	36721.8	01	58754.8	4	84607	261688	29.5	25382	2.9
C	821000	10	12	25000	01	75532	1/8	16994.9	01	54383.4	4	74312. 5	221223	26.9	22294	2.7
D	460000	06	08	12500	-	-	-	-	01	30430	5	84937. 5	115368	25.0	22650	4.9
E	176000	04	05	4500	-	-	-	-	-	-	5	85750	85750	48.7	21438	12.2

c) Seasonal Unemployment

A considerable extent of seasonal unemployment could be identified among the labourers in the gem pits. Data in table 02 shows that the labourers in the gem mines did not have to work for a number of dates during the period from 1st January to 31st August in 1997. According to the data, most labourers of unlicensed or illegal gem pits are unemployed i.e. 33.5% of total working days. Unemployment among the labourers of gem pits could be at a very high rate compared with the other employees like a schoolteacher of a government school or a labourer in a private garment factory.

Table 02: Seasonal Unemployment among the Laborers of Gem Pits

Category of Employment	No: of unemployed days	as a % of Total working days
1. Labourer in licensed gem mining.	60	26.4
2. Labourer in unlicensed gem mining.	76	33.5
3. Teacher in government school	16	8.0
4. Worker in private garment factory	08	4.0

Source: Field Survey 1997.

(Total working days defined as 227 working days after deducting 16 of official holidays during the period between 1st January and 31st August in 1997.)

There are many reasons for the seasonal unemployment among the mine labourers. Managerial weaknesses of mine owners are a major reason. After finishing work at the gem mine, labourers wait so many days without work until the activities and functions of the mine starts again. Sometimes gem miners of paddy fields may have to wait till the harvest is completed in order to shift the mine to the another place. As a result of that labourers are unemployed for long periods.

Owners sometimes stop mining work during the festival season like New Year and Christmas. Labourers are unemployed for 1 or 2 months during such seasons. On the other hand, some owners fail to renew their license on or before the due date. In that case, labourers are unemployed until the license is renewed. One of the other reasons for seasonal unemployment is that the labourers themselves are unemployed until they find a new mine or shift from one mine to the another.

Natural reasons like rain and flood also contridutes adversely to the seasonal unemployment among the mine labourers. Labourers of illegal gem mines are mostly unemployed seasonally due to police investigations.

d) Decline of Education.

Most of the labourers of the GMI do not have sufficient education. Eighty five percent of the labourers have attended school up to or below grade 10 and the remaining 15 percent have attended classes beyond grade 10. On the other hand, 55 percent of the labourers are below 30 years of age. Gem mining has caused for the decline of the education level of younger generation in the study area. They are attracted by gem mining interrupting their education. If schoolchildren join gem mining during the school vacation, they are attracted by gem mining industry and continuously do it without attending school further. Some parents also encourage children into gem mining since they can easily earn an additional income.

The other reason for the decline of educational level is the consequences of attraction towards the luxury lives of gem dealers. If experienced mine labourers earn large income they become gem dealers. Most of these dealers invest their additional income only in GMI. They are not aware of the other sources of businesses and they spend more money to lead a luxury life. As a result, most of the gem dealers become bankrupt due to the irregularity of gem industry. Most of the dealers are not aware of the financial management since they do not have sufficient education.

e) Decline of Health

Gem mining directly causes the decline of health of both gem miners and the general public. Unclosed gem pits bring about a rapid expansion of mosquitoes. It is one of the major issues faced by the villagers. Sixty percent (60%) of the villagers uses mosquito nets or coils. Some villagers mentioned that the problem of mosquitoes had been sharply aggravated since 1980s. Furthermore, unclosed gem pits are a threat to both villages and animals. It was reported that a child and some buffaloes had fallen into an empty gem pit. In addition, muddy water in river causes a decline in the health of the villagers. Thirty (30%) percent of the population in the area uses water from the river. Water is always polluted due to the gem pits located in and around the river.

Working inside gem pits is a very dangerous and risky task. Mine labourers always face unexpected accidents due to the sudden collapse of walls in the pits. Use of poor techniques and poor quality materials increases accidents in the gem mining industry. Some miners use poor quality materials such as poor quality rubber wood, arecanut trees, etc, in order to reduce capital cost. Furthermore, some miners do not have the proper technical knowledge required in gem mining.

As a result, many accidents occur in the industry. Further, miners are not aware of first aid and none of the mines have first aid boxes. Most miners do not know how to react or face in the event of an emergency. Thus, many reasons are found regarding the decline of health of the people in this industry.

f) Decline of the Living Standards

Decline of the living standards of labourers is the most significant consequence of GMI. It is not a continuous income source and its income is very uncertain. Some labourers have not earned any income during the period from 1st January to 31st August in 1997. Some of them does not even have any other income source or properties and a knowledge or skill for doing self-employment or another job. Because, they have experience only in the working of gem mining. Living standards of such labourers is very low. They live on loans from gem dealers or any other sources. Though most labourers as well as dealers earn

gem income they spend most of the income within a very short period without managing their finances carefully. They fail to take maximum benefits from these income. Most labourers and dealers tend to consume durable and luxury consumer goods and they try to lead a luxury life. But after spending all the income that they have earned their living standard declines to the previous level. Furthermore, labourers or dealers invest their income only in gem pits or to buy gem stones. Most of them does not even know to invest their income in another business. Living standards of them decline due to the uncertainty of gem income. Some dealers continuously do gem mining selling their properties, and businesses. This reason is also a cause for the decline in their living standards since they fail to earn gem income.

g) Water Pollution

Water pollution is the main environmental consequence of GMI. Unlicensed river bed mining directly pollutes water in the river and streams in the study area. Unlicensed river bed mining goes on throughout the whole day. Consequently, water in the river and streams are completely polluted with mud. A constant release of muddy water from open pit and tunnel mining is another way of polluting the water in the river. In addition, washing the GBG of unlicensed open pit shallows into the river is the another method of water pollution.

Polluted water in the river and streams cause so many difficulties for the villagers. Some people use water for the fulfillment of their basic water needs like drinking, washing and bathing. The main problem that the villagers face is that they cannot find fresh water for drinking. Despite, a few wells in the study area, some wells do not have sufficient drinking water. According to the point of view of the villagers, water level in the wells has reduced because miners pump underground water out.

h) Soil Erosion

Most gem pits are located near and around the river. Erosion of riverbanks generally takes place during the rainy season, because some mining is done on the riverbanks. Riverbed mining directly causes the erosion of the riverbank destroying the larger of bushes and plants. In addition, GBG is washed in the river and this practice is a good example for soil erosion. Erosion of home gardens also takes place due to open pit shallow mining. Gem bearing gravel of open pit shallow is dug unsystematically and soil is easily eroded due to light rain.

i) Destruction of Arecanut trees

Destruction of arecanut trees is one of the other environmental impacts of GMI. Arecanut trees are mostly used for the tunnel mining, open pit deep and river bed mining. Around 4 to 8 of arecanut trees are used for a gem pit per one session and 2 to 4 for river bed mining. Seventy eight of arecanut trees have been used for gem mining in the study area during the period January to August 1997 and out of this 45 arecanut trees has been purchased from the study area itself. Today arecanut trees are very rare and also expensive. They are destroyed rapidly due to the GMI.

Conclusions

Though the GMI in Sri Lanka generate income and employment it has many SEE impact. Therefore, this paper studied such impact in a selected gem-mining village Hunuwala in the Ratnapura district. Decline of agricultural production, income inequality, seasonal unemployment, decline of health, education and living standards, water pollution, soil erosion, destruction of arecanut trees have been the significant adverse effects of GMI. The situation has been further aggravated due to the unawareness and the negligence of

mine owners and labourers and the inapplicability of current rules and regulations are the major reasons. In order to develop the GMI overcoming SEE impact, labourers and mine owners should be aware to control such impact as much as possible. The available rules and regulations need to be observed strictly at regional levels by responsible authorities. The authority should provide advisory services regularly for the miners to overcome the SEE impact, help to value gem stones accurately and sell them at a high price preventing unfairness in the gem auctions. It is also necessary to introduce modern techniques and protection methods to reduce accidents in the gem mines. In addition, it is needed to introduce a rather fair system to ensure a fair distribution of the gem income in providing a similar value to all the shares in order to reduce income inequality between mine owners and labourers. Since gem income is unascertained, mine owners and labourers required to be encouraged to invest gem income not only in GMI but also in other ventures. Furthermore, in order to increase agricultural production, adequate reservation of agricultural land has to be ensured for gem mining in future. Assistance to landowners to prepare the destroyed lands and bring them back to the previous level is essential. Controlling the work of illegal gem mines will reduce water pollution, land erosion and destruction of agricultural lands. Gem mine owners should award the work in the gem mines according to a well defined plan to reduce seasonal unemployment of the mine labourers.

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Critical Evaluation of Fashioning of Gemstones in Sri Lanka

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Abstract

Sri Lanka exports about six million carats of gemstones worth Rs 4000 million per year, of which, over four million carats are calibrated stones and the balance is free sized stones. The value of the free sized stones is about Rs 3600 million per year. The calibrated stones require accurate dimensions and proportions, whereas free sized stones are cut without paying much attention to the lustre and brilliance, which are essential properties of gemstones. Sri Lankan lapidarists always optimize the weight of the stone than the quality. Foreign gem traders almost always re-cut Sri Lankan cut and polished stones. Advertisements still appear in international magazines making available "Sri Lankan cut and polished stones suitable for re-cutting"

This paper discusses the importance of the quality of cutting, in order to enhance the value of gemstones and also the possibility of expanding the gem industry by introducing the use of ornamental stones.

Key words: Gemstones, Fashioning of Gemstones

Introduction

Sri Lanka is well known for its wide varieties of gemstones of various sizes. Many of the large precious stones discovered in Sri Lanka are displayed in many gemmological museums in the world (Gunarathne & Dissanayake, 1996). Gem and jewellery industry in Sri Lanka has a long history. Over the centuries, gems have been cut and polished without paying much attention to achieving optimum beauty, which is an essential property required in gemstones.

The earliest styles of fashioning were those, which produced a curved surface, a style now perpetuated by the cabochons, or a flat surface upon which the worker could engrave. The engraving of gems was carried out in times far earlier than the fashioning with symmetrically arranged flat surfaces as in the styles that are in common use today. Perhaps the cutting styles in Sri Lanka have evolved as a result of international trade. Up to the time the State Gem Corporation was established in 1971, the gem trade was confined to a handful of people and the jewellery industry, if it existed, was mainly geared to meet the local demand. The gem industry rapidly gained ground since 1971, and it has now become a major industry providing employment to over 30,000 personnel and much needed foreign exchange to the country (Ellawala, 1995:30).

But the Sri Lankan gem industry sadly lacks the advanced technical knowledge, which could make us one of the leading gem traders in the world. Although local traders have adopted the international gem cutting styles, Sri Lanka has paid little attention to the quality of cutting. Furthermore Sri Lanka has modified accepted cutting styles giving rise to new styles identified as Ceylon cut. In fact, Sri Lankan cut for some time was synonymous with heavy or flat bottomed ill cut gems whose main claim was caratage (Hughes, 1990:273-283)

Classification of cutting styles

There are two basic styles of cutting gems depending on the type of material (Webster, 1983:471-501)

Curved

surfaces:

Translucent, opaque or heavily included gemstones with or without special optical effects are cut in this style. Most common are the cabochons, carving (cameos and intaglios), beads, spheres, egg shapes etc.

Cabochons:

These cut stones consist of a polished domed top and a bottom which may be polished or unpolished. The shape is usually round or oval. The "Simple cabochon" has a flat rough base, and is used for gems, which display special optical effects, such as asterism or chatoyancy. Silvery rays are well defined when the base is left unpolished. The "Double cabochon" has both top and bottom, dome shaped but the bottom is less steep. The stones such as moonstone and opal with special optical effects are cut with "Double cabochon". The "Hollow cabochon" has its underside hollowed and polished. Deep coloured stones are cut in this style to lighten the colour. In some cases the hollowed back is foiled to make the stone look brilliant. When the rough material is flat, the top dome is made low and it is called "tallow topped cabochon"

Carving, Cameos (raised carvings), Intaglios (incised carvings):

Translucent to opaque materials such as jade, agate, onyx, coral and shell are used for this type of fashioning.

Beads:

Translucent to opaque material such as amber, hematite, rhodochrosite, rhodonite, jade, agate, chrysoprase, onyx and heavily included emerald, ruby, sapphire and tourmaline etc. are used for bead making.

Spheres, egg
shapes:

Spheres and egg shapes of different sizes are made out of any translucent to opaque materials.

Special optical effects

Certain gemstones possess special effects, attributed to the reflection of light from internal structures or inclusions.

Asterism:

This is the "star" effect produced by several rays caused by the reflection of light from sets of parallel fibers or crystals. Each set of inclusions cause a ray and there are 4, 6, 12 ray stars. Corundum usually has three sets of inclusions intersecting at 60° and therefore it produces a 6 ray star. Some stones belonging to the cubic system, such as spinels and garnets have only two sets of inclusions intersecting at 90° and therefore produce 4 ray stars.

Chatoyancy:

This is the cat's eye effect or the appearance of a streak of light caused by the reflection of light from parallel groups of fibers, crystals or empty channels within the stones. The finer and more highly reflecting the fibers or channels are, the brighter is the ray. Chrysoberyl, kenerupine, tourmaline, apatite, enstatite and quartz are some of the stones possessing chatoyancy.

- Iridescence:** This is the play of rainbow coloured light caused by extremely small regular structures beneath the surface of the gemstone, Precious opal, fire agate etc. show the effect of iridescence.
- Labradorescence:** A particular form of iridescence, which can be seen in the labradorite variety of feldspar, is caused by the reflection of light from thin layers beneath the stone's surface.
- Adularescence:** Also known as " Schiller", this is the bluish or orange sheen seen in moonstones. It is caused by thin laminated plates or layers within the stones.
- Colour changing effect:** Certain gemstones show one colour in daylight and another in incandescent light. Alexandrites show green in day light and red in incandescent light. Similarly there are some garnets, spinels and sapphires which show this effect.

Faceted stones

Faceting of gemstones was developed through diamond cutting. The present day brilliant cut evolved from the point cut where only the natural crystal faces of octahedrons were polished and table cut, where additionally one end of point cut was ground away to produce a square flat surface. These two styles were further improved by octagonal or rounded single cuts. The modern brilliant cut was thus evolved and subsequently it was introduced with different shapes such as oval, marquise, heart shape etc. A totally different cut was next developed to suit particular gem varieties, and it is called trap cut or step cut.

Over the years many modifications of the modern brilliant cut have taken place. The trap cut was modified as the octagonal cut with corners cut off and adopted particularly for emerald. The faceting basically has two conditions viz : style and form. There are several basic styles such as brilliant cut, step cut, star cut, cross cut etc. The style can be any one of them or any combination. The form is the shape of the cut gem and any form can be applied to any cut. The style of cut is based on the following properties;

- Colour:** Selective absorption of white light causes the colour in gems. It is important to select the correct direction to get the desired tone or the intensity of colour. For example, stones faceted out of dark tourmaline crystals will have their table facet parallel to the C axis where the crystal shows a lighter shade of colour. If the crystal is already light, to obtain optimum colour, the table facet will be cut perpendicular to the C axis.
- Lustre:** Lustre is the optical effect created by the reflection of light from the stones' surface. It is directly related to the quality of the stone's surface polish and is therefore partly dependant upon the hardness of the gem, as well as its internal structure. Because of the differences in hardness and other properties, the degree of lustre varies for different stones and are termed, adamantine, vitreous, resinous, waxy, pearly and silky etc. depending on the quality of their lustre.
- Brilliance:** Brilliance is the amount of white light rays, reflected upwards from the pavilion of the gemstone. This is the property of total internal reflection of light, which depends on the angle of the pavilion facets.

Fire: In colourless gemstones, spectral colours shown from the facets is called fire. Total internal reflection and the colour dispersion of white light produce it. The fire is masked by the body colour in the coloured stones.

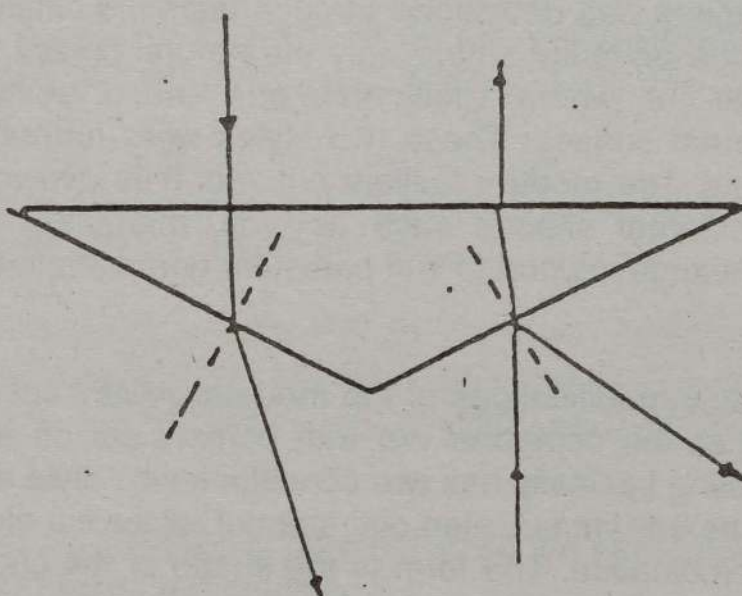
The lapiderist or gem cutter in an attempt to gain the maximum yield while maintaining optimum optical properties of a given gem will decide on the type of cut he will use, largely on the rough material he has at hand, as different material will require different approaches in cutting.

Common Defects in Locally Cut Gemstones

Cabochons

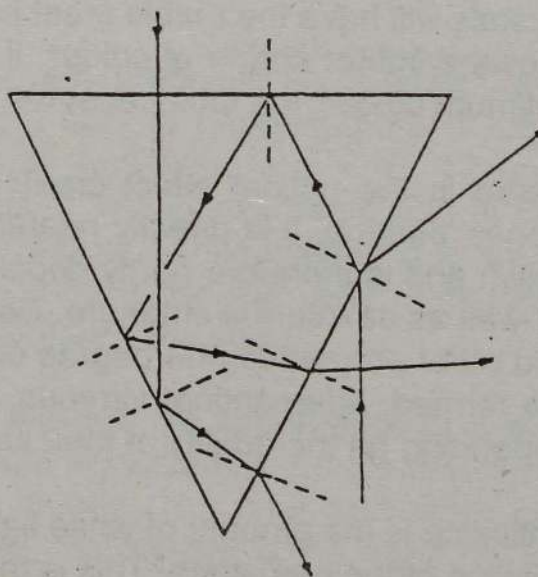
The gemstones with star effect and cat's eye effect are cut without paying much attention to the position of the effect. This gives rise to off centered star or cat's eye effect, thus reducing their beauty and value.

Fig. 1



(a) Open Star

- One ray parallel to the width and hence rays are evenly spaced



(b) Closed Star

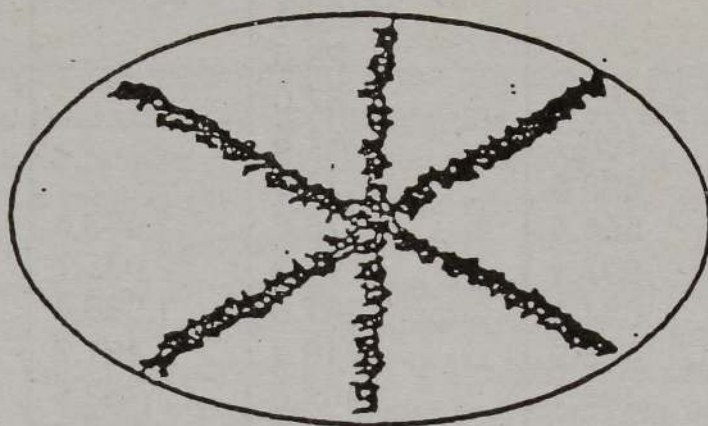
- One ray is parallel to the length of the oval and hence rays appear to be pinched together

Oval cut star stones, should be oriented in such a way, so that one ray is parallel to the width of the stone. This produces an 'open star' where the rays are well spread and attractive. However, most often stones are oriented so that one ray is parallel to the length of the oval and it produces a 'closed star' with rays pinched together (Figure 1b). In order to obtain a proper star, the curvature of the dome must be uniform throughout , but the Sri Lankan cut stones have a large flat area at the center and it causes the star to appear diffused.

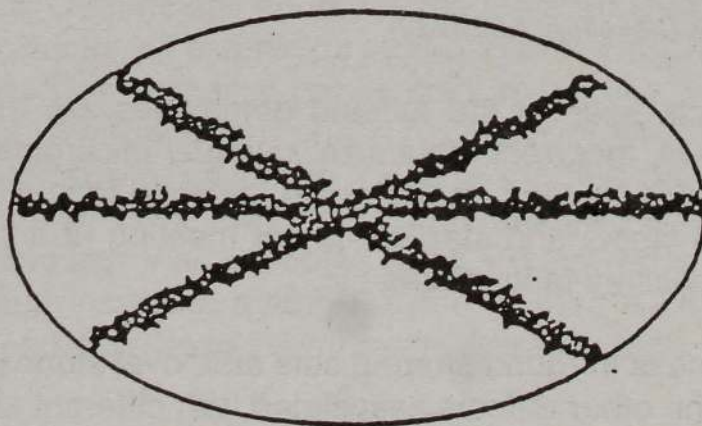
Faceted stones

The transparent gemstones need to be cut to obtain maximum brilliance, however, in most cases, more attention is paid to the weight, and hence stones are either too flat which produces a dull and low intensity colour zone called "window" (Fig. 2a) or too deep which produces a dark zone called "extinction" (Fig 2b)

Fig. 2



- (a) Pavillion facets cut too shallow produces a low intensity dull colour zone called window



- (b) Pavillion facets cut too steep produces a dark zone called Extinction

Table 1 Export of Gems and Jewellery (Value Rs Mn.)

YEAR	GEMS	GEUDA	JEWELLERY	DIAMOND	D.JEWELLERY
1972	15.5				
1973	153.0				
1974	132.9				
1975	188.9				
1976	287.1				
1977	253.9				
1978	525.0		3.6		
1979	494.7		6.4		
1980	663.7		9.3		
1981	632.5		15.3		
1982	393.4		19.9		
1983	520.5		33.3		
1984	523.3		23.1		
1985	447.1		23.0		
1986	653.0		37.0		
1987	1,156.2	188.7	51.8		
1988	1,425.2	528.6	74.3		
1989	1,351.4	554.4	76.6	1,903.6	
1990	1,840.0	597.1	94.3	2,035.7	
1991	1,568.8	634.1	251.8	1,986.4	
1992	1,620.9	455.9	310.4	4,491.2	
1993	1,989.8	494.1	401.6	7,752.5	240.1
1994	2,253.6	450.6	463.6	7,568.7	643.2
1995	1,990.9	435.6	526.3	8,976.3	844.8
1996	1,498.8	462.8	438.7	9,384.7	884.6
1997	*3,594.1	304.0	559.4	8,350.0	412.0

*with consignments

(Source- The National Gem & Jewellery Authority)

The other common defects seen in the faceted gemstones are the asymmetrical table facet, asymmetrical pavilion, incorrect table size, unequal thick girdle, wavy girdle, upper (contd.) and lower facets not meeting on the girdle, unequal facets, additional facets, star facets not meeting, girdle facets and star facets not meeting at a point, overlapping star facets and creating unnecessary facet edges etc.

The lack of perfect roundness in round shaped cuts and, oval stones having improper proportions are some of the other defects associated with different shapes.

Discussion

The annual exports of gems and jewellery in Sri Lanka are over Rs. 4000 million and Rs. 550 million respectively (Table1). For over two decades, exports have grown up by nearly 200 times. The re-export of diamonds after cutting and polishing started in 1989 and over a period of 9 years it has grown by nearly eight times. The export of diamond studded jewellery too is slowly picking up. With the liberalization of imports to develop the gem and

Jewellery industry, imports of rough gemstones have reached Rs 248 million in 1997 and Rs 134 million upto May 1998.

As a support to develop this industry, the government allows the imports of rough gemstones and machinery required for the lapidary industry free of both the duty and national defence levy. Perhaps this is the only industry which received such concession from the National budget of 1998.

However Sri Lanka has not reached perfection in cutting and polishing of gems. It has been discussed in many national fora that local gem traders place much emphasis on the quantity or the size than the quality (Rahuman, 1995:63-69). The author has had on many occasions to go through hundreds of blue sapphires to find a single, properly cut and polished stone. Most often stones are cut with asymmetrical, deep or shallow pavilion. It is extremely difficult to find a good one carat or larger blue sapphire with a perfect cut. Even when properties are correct facets may not be symmetrical. There are many other cutting defects in our gemstones which can be easily avoided without losing weight. The increasing value due to proper proportions and increasing lustre and brilliance do not seem to be understood properly.

It is important to consider the pleochroism when deciding a direction of cutting. For both ruby and sapphire, the best colour is seen along the c-axis. Failure to position the c-axis perpendicular to the table results in a lower colour intensity and hence a lower value. An exception to this is, the cutting of "ottu" stones where only patches of blue are in the colourless stones. Then it is important to orient the stone, so that the colour patches lie around the culet or fully across the crown. This will make the whole stone appear blue in colour. Most often ruby and sapphire have rutile needles as inclusions perpendicular to the c-axis. If the table is cut perpendicular to the c-axis in such cases, needles become obvious and give rise to bright reflections. However, orienting the table parallel to the c-axis makes them much less visible. Therefore the cutter must strive to balance desirable and undesirable features to obtain maximum value.

Most often ruby and sapphires are not cut as round brilliants, because the pavilion facets in this case, extend all the way from the girdle to culet and it is not possible to increase the yield by rounding the pavilion. Instead, a mixed cut is used for these stones, where the crown is brilliant cut with a step cut pavilion. Thus the weight retention can be increased while maintaining some brilliance.

During the commercial Gemmology course in the German Gemmological Association, the author had the opportunity of examining a 6.2 carat Sri Lankan alexandrite, with a German gem dealer. The beautiful green coloured stone with almost perfect colour change had been cut with the colour changing effect parallel to the girdle. Although the cutter would have been able to save 1 to 1.5 carats in this cut, the present dealer wanted to re-cut it into two smaller stones with the colour changing effect on the crown as it really should be. The resulting loss was expected to be around two carats. Whereas had it been cut properly at the first instance, a single stone of over 4 carats would have been the result and it would certainly have been more valuable than the wrongly cut 6.2 carat stone.

The author has come across many occasions, when gem dealers have got their locally purchased stones re-cut before taking them away. The resulting loss of weights was around 10-15%. For many years, advertisements have been appearing in international gemmological magazines on the availability of "Sri Lankan cut and polished stones suitable for re-cutting" (The Australian Gemmologists, 1994:38, Lapidary Journal, 1991:58)

Sri Lanka at present exports over six million carats of gemstones, of which, about four million are calibrated stones. While this four million brings in Rs 400 million, the balance two million carats of free size stones fetch Rs 3600 million. The calibrated stones require accurate dimensions and proportions. Therefore it is obvious that Sri Lanka has mastered the cutting. However, their application to free sizes, is still not satisfactory.

There are many varieties of less valuable gemstones in Sri Lanka, and they are not suitable for faceting. Topaz, rock crystal (vein quartz), smoky quartz, rose quartz, serpentinite, agate, dolomite, feldspar, garnet rock corundum rock, black tourmaline crystals are the most commonly available of the valuable gemstones. The gem industry can be expanded by harnessing the full potential of our lapidarists not only to facet gems but also to produce carved statues, cameos and intaglios, spheres, egg shapes, beads for ornamental jewellery, figurings and many other artifacts. Such objects consist of a major fraction of the international gem trade.

Conclusions

It is well known that most of the free sized stones are not properly cut. Either the proportions are not correct or facets are improperly cut and these stones make up a large percentage of "Sri Lanka cut" free size stones. Nearly all the Sri Lankan faceted stones are, re-cut by foreigners within Sri Lanka or elsewhere, thus wasting this valuable rare wealth, by cutting many times.

The experience with calibrated stones needs to be applied to free sized stones, since free sized stones fetch about five times the value of calibrated stones. Thus we can safely increase the value of total exports without additional resources. Perhaps in this regard, the Gem Traders Association, Lapidary Association and National Gem and Jewellery Authority should take an initiative to make the lapidarists aware of the importance of proper cutting of gemstones.

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Cost Effective Buildings with Local Bricks

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Abstract

Load bearing brickwork can be used in two to three storey buildings eliminating the reinforced concrete framework thus leading to a considerable economy. However, this method of construction is not often used since the locally available bricks are of low quality and hence structural engineers are rather reluctant to promote it. It is shown here that it is possible to achieve a characteristic strength of 1.5 N/mm^2 when bricks satisfy certain physical testing criteria. The quality control measures required for such construction are also highlighted. It is also shown that although the use of 1.5 N/mm^2 design compressive strength offers satisfactory behaviour with respect to primary effects, further precautions will be required in load bearing brickwork structures to prevent cracking due to stresses of secondary nature.

Introduction

Brickwork can be used in building construction for two different applications. They are as infill panels in reinforced concrete framed buildings and as load bearing brickwork. Brickwork can be used in any type of concrete framed buildings, especially in residential type, as a partition material due to its good sound insulation, fire resistance and thermal insulation properties. The only drawback is the material, which leads to a rather heavy concrete frame. In modern office buildings, lightweight partitions are preferred to brick panels.

Load bearing brickwork can be in houses, flats, hostels and hotels, preferably of two or three storeys, where the floor area is subdivided into a relatively large number of small to medium size units. In these buildings, the loadbearing brick walls can serve the dual purpose of carrying structural loads while serving as partition walls, thus leading to a considerable economy. However, many structural engineers in Sri Lanka are somewhat reluctant to use load bearing brickwork in two and three storey buildings. The following reasons can be attributed to this:

1. The strength of locally available bricks is generally low and the quality varies from one manufacturing site to another.
2. The strength data pertaining to brickwork out of local bricks can not be obtained from standard codes of practice such as BS 5628: Part 1: 1978.

In this paper, it is shown that these drawbacks can be overcome to a considerable extent so that the locally available bricks can be used with confidence by employing some quality controlling measures at the brick selection and brickwork construction stages. It is also shown that certain additional measures will be required in load bearing brick wall structures to ensure crack free structures, thus fully realising cost effectiveness.

Economics of Load Bearing Brickwork

In order to highlight the cost effectiveness of load bearing brickwork, a simple example can be considered. In this example, the cost of a load bearing brick wall is compared with the cost of an alternative consisting of a reinforced concrete frame with a brick panel partition.

The length of the wall is 3.0 m and the height is 2.7 m with one brick thickness. It supports a 125 mm thick concrete slab. The alternative for this load bearing brick wall consists of a

reinforced concrete column, a beam and one brick thick partition wall. In this example, only one column has been considered for the cost calculations since columns are shared in more than one direction. The size of the column is $0.2m \times 0.2m$ square and the size of the beam is $0.2m$ in width \times $0.3m$ in depth. The size of the column base is $1.0m \times 1.0m \times 0.2m$. The amount of reinforcement has been determined to ensure that the reinforced concrete frame can carry the upper floor wall and slab loads. The cost of rubble foundation construction has been assumed to be the same for both alternatives.

The Cost Comparison was carried out on the basis of the following information.

a. Cost of $1m^2$ of one brick thick brickwork	= Rs. 550/=
b. Cost of $1m^3$ of concrete	= Rs. 4,300/=
c. Cost $1m^2$ of shuttering	= Rs. 300/=
d. Cost of 1 Tonne of reinforcement	= Rs. 48,000/=

These rates include the cost of labour and materials.

Alternative 1:

Cost of masonry wall of size $3.0m \times 2.7m$	= Rs. 4,455/=
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Alternative 2:

Cost of $0.50 m^3$ of concrete	= Rs. 2,150/=
Cost of 0.055 Tonne of reinforcement	= Rs. 2,640/=
Cost of $5.36 m^2$ of shuttering	= Rs. 1,608/=
Cost of $2.8m \times 2.4m$ of brickwork	= Rs. 3,696/=
Total cost of alternative 2	= Rs. 10,094/=
Cost saving of alternative 1	= Rs. 5,639/=

It can be seen that the use of load bearing brickwork can save more than 50% of the structural cost at the ground floor level. If there are 16 columns in a two storey house, the saving can be about Rs. $16 \times 5,639/=$, which is equal to Rs. 90,224/=. It should be noted that the cost of reinforced concrete frame can increase further if higher spans are used. Hence a saving of the order of Rs. 100,000/= could be easily achieved for a two storey house where the reinforced concrete frame is replaced by load bearing brick walls at the ground floor level. It is assumed that the upper floor will be constructed with brickwork in both cases.

A saving of Rs. 100,000/= would mean a saving of about Rs. 1,800/= per month on mortgage payments with about 17% interest rate prevailing in Sri Lanka over a period of about 10 years or about Rs. 1,600/= over a period of 20 years when the money is raised for construction as a loan. In addition to the above cost savings, load bearing brickwork also allows rapid construction of the structure thus reducing the overall project duration.

Use of Local Bricks as Loadbearing Material

In load bearing brick wall buildings, the dead and imposed loads from the roof and the brick walls, in addition to the weight of brick walls should carry floors. Therefore, in normal practice, a proper structural design should be carried out prior to the construction to select the appropriate strength of bricks and the mortar designation. However, this approach is not quite possible with locally available bricks since the brick manufacturers do not practise the grading of bricks according to the strength. In Sri Lanka, the bricks manufactured should comply with the requirements given in SLS 39. However there can be considerable difficulty in assessing the strength of bricks.

It was reported by Chandrakeerthy and Mohottige (1985) that it is extremely difficult to test the locally available bricks after saturating them as specified in SLS 39, since the particles

are well lubricated by the large amount of water absorbed. During testing, bricks begin to compress under gradually increasing load with substantial increases in the bed area and the failure occurs at an unrealistic strain, generally in excess of 50%. It is also difficult to observe a momentary decrease in the rate of advance of the indicator of the testing machine while observing the fracture of the brick. This shows that there are considerable difficulties associated with testing of low strength bricks.

In order to overcome this difficulty, an alternative approach has been presented by Jayasinghe (1996). In this approach, physical testing of bricks is used to identify the bricks that are suitable for construction. The strength of the brick walls has been determined experimentally for bricks that satisfy physical testing criteria and for those that fail to satisfy. The physical testing criteria used is as follows:

1. When a randomly selected brick is dropped from a height of $1.2m$ on another brick laid on level ground, the brick on the ground should not break due to the impact. This test gives an indication of the strength of the bricks.
2. When two bricks are tapped together, they should give a ringing sound. This is an indication of the amount of water used at the moulding stage and the degree of burning. The use of an excessive amount of water during moulding is profitable for the manufacturer since the volume of clay will increase thus giving a higher number of bricks. However, excessive amount of water will give a lower compaction thus leading to weaker bricks due to high voids ratio. It can also increase the water absorption of the bricks. Poorly burnt bricks are not acceptable since they tend to loose strength and disintegrate when exposed to water. The dimensional stability is also poor in partially burnt bricks. It is possible to identify partially burnt bricks by inspecting the cross section of a broken brick. If the brick is partially burnt, the core would have a colour different to the outer crust.
3. The surface texture of bricks should be smooth without lumps and cracks. The presence of lumps and cracks is an indirect indication of lack of quality controlling at the brick manufacturing stage. It may also be an indication of lack of will to produce quality bricks since bricks of any quality can be sold.

Jayasinghe (1998) has showed that the most important physical testing criteria is the dropping of one brick on another placed on the ground. For bricks that do not break, it is possible to obtain a characteristic strength having a minimum value of $1.5 N/mm^2$. It is also shown by Jayasinghe (1998) that the stress at 1st crack for the bricks that satisfy physical testing criteria is sufficiently high so that a factor of safety for material strength, $Y_m = 3.5$ given in BS 5628: 1979: Part 1, is satisfactory. These findings can be extremely useful since they can simplify the structural design process considerably. With a unique design strength, the designer will be left with finding a suitable value for only one variable, that is the width of the brick wall.

In order to assist during the selection of initial layout for load bearing brick wall structure with local bricks, a set of rules of thumb has been develop by Dassanayake and Mohottige (1993) by considering a large number of possible structural arrangements. Since the size of the bricks available is also non-standard, a size of $200 mm$ in length, $100 mm$ in width and $50 mm$ in thickness is used for the design study. Bricks of this size can give a wall width of $210 mm$.

These rules of thumb have been developed on the following basis:

1. There are external and internal walls in a house. The external walls are likely to carry fewer loads than the internal walls since the floor slab is only on one side.

2. The wall length considered for the analysis is $4.0m$ and the maximum length of the opening allowed is $2.0m$ in length. This opening can be either a door or a window.
3. The height to the soffit of the slab is less than $3.0m$ to limit the effects of slenderness.
4. The upper floor roof can be either calicut tiles or asbestos.
5. The slabs are considered as one way spanning. However, better load distribution can be obtained from two-way spanning slabs. They are also more economical than one way slabs due to better utilisation of reinforcing steel. They will improve the robustness of the structure as well. Hence two-way slabs should be used wherever possible.
6. Slabs rest directly on masonry walls except at an opening where a lintel or a beam is provided with sufficient bearing lengths on either side.

The proposed rules are the following:

1. The maximum length of an opening at a ground floor external wall is $2.0m$ over a length of $4.0m$ which means that the ratio of the length of opening to the total length of the wall is $0.5m$. This ratio should be maintained for shorter wall lengths.
2. For external walls, it is possible to use one brick thick walls ($210mm$) in the upper floor. There is no need to have the ground and upper floor openings coinciding as far as the above opening length to wall length ratio is maintained. A sufficiently stiff lintel with a suitable bearing length should be provided over the openings.
3. Since the internal walls are heavily loaded, the following precautions should be taken:
 - a. If the slab spans on either side of the wall, at first floor level, are not more than $3.0m$, one brick thick walls may be used in the upper floor internal walls with or without openings. Ground floor opening to wall length ratio should be maintained at around 0.25 . The height of the upper floor wall should not exceed $4.0m$.
 - b. If the spans on either side of the wall at first floor level are between $3.0m$ and $4.0m$, either half brick thick walls $100mm$ or $150mm$ thick hollow block work should be used for the upper floor internal walls. The selection of material should be based on the maximum value for slenderness ratio, which is set as 27.
4. When it is necessary to use one brick thick walls as the upper floor internal walls due to slenderness effects, it is advisable to increase the ground floor wall thickness to one and a half brick.

Generally, it would be possible to satisfy these conditions in a two storey house because there would be a considerable number of walls acting as partition walls. It is a good practice to have approximately the same arrangement of walls in the ground floor and in the upper floor as well. This will minimise the effects of concentrated loads.

If the ground and upper floor arrangements are different, it would be a good practice to provide sufficient number of beams at the first floor level to transfer loads to the ground floor as approximately distributed loads.

When these arrangements fail to keep the stresses sufficiently low, it is possible to consider a number of other alternative solutions. One such alternative is to increase the thickness of the wall in the locality without affecting aesthetics. This will, however, reduce the space inside the building by a small margin, which would need an adjustment of the external dimensions suitably.

Another alternative is to use concrete columns and beams only at the location where the loads are excessive. This may be preferable if the site is restricted and it is important to keep the internal space lost due to walls to a minimum. When reinforced concrete columns are used in isolation, it is important to provide beams. These should connect the concrete columns to brick walls, with adequate bearing at the brick wall to ensure smooth transfer of loads without causing bearing failures.

These rules of the thumb are expected to guide the architect at the preliminary layout design stages. A structural engineer can use the same rules at the preliminary structural design stage when selecting the wall thickness. A proper structural design of the structure should be carried out subsequently to ensure that the allowable stresses are not violated.

Quality Control(ling) for Construction

If a characteristic strength of 1.5 N/mm^2 is used for structural design calculations, it is necessary to ensure that the brickwork is capable of developing this strength. Therefore, the following quality controlling measures should be taken:

1. The bricks, which satisfy all the following physical tests given in Section 3, should be selected for the construction
2. At the construction stage, the following factors should be paid considerable attention:
 - a. The brickwork should be constructed with 1:6 cement to sand volume based mortar with a sufficient quantity of water to give adequate workability. Mortar batching should be done with containers of fixed volume such as gauge boxes or buckets since batching with "thachchis" as commonly used can give a certain variability in mortar mix proportions. Such a variability is not desirable especially with bricks of low strength. Dassanayake & Mohottige (1993) have shown that the characteristic strength of local brickwork can be reduced to about 1.1 N/mm^2 when the mortar mix is changed from 1:6 to 1:8 cement to sand. The cement used should comply with BS 12, the British Standard for testing cement.
 - b. Bricks must be immersed in water for at least 10 minutes. This will ensure that bricks will not absorb the water available in mortar, thus allowing a satisfactory level of hydration of cement in mortar. Immersing bricks in water also helps to eliminate poor quality since low strength partially burnt bricks will disintegrate when soaked in water until saturation. This will also remove dust from the brick surface thus enhancing the bond between mortar and the brick.
 - c. The mortar bed thickness must be maintained between 10 – 12 mm; a gauge rod as shown in figure 1 can be used to maintain the thickness of the mortar joint. Thicker mortar beds deform considerably increasing the shortening of the masonry wall when subject to vertical loads (Jayasinghe et al., 1987).
 - d. Walls must be built perfectly plumb so that any deviation from verticality is within the construction tolerances. Out of plumb walls will have lower strength due to increased eccentricity.

- e. It is shown that special curing of walls constructed using saturated bricks is not essential (Chandrakeerthy, 1987). However, curing may help in the enhancement of strength and also reduce the shrinkage of mortar. Therefore, it is recommended to keep brick walls wet as long as possible by spraying water.

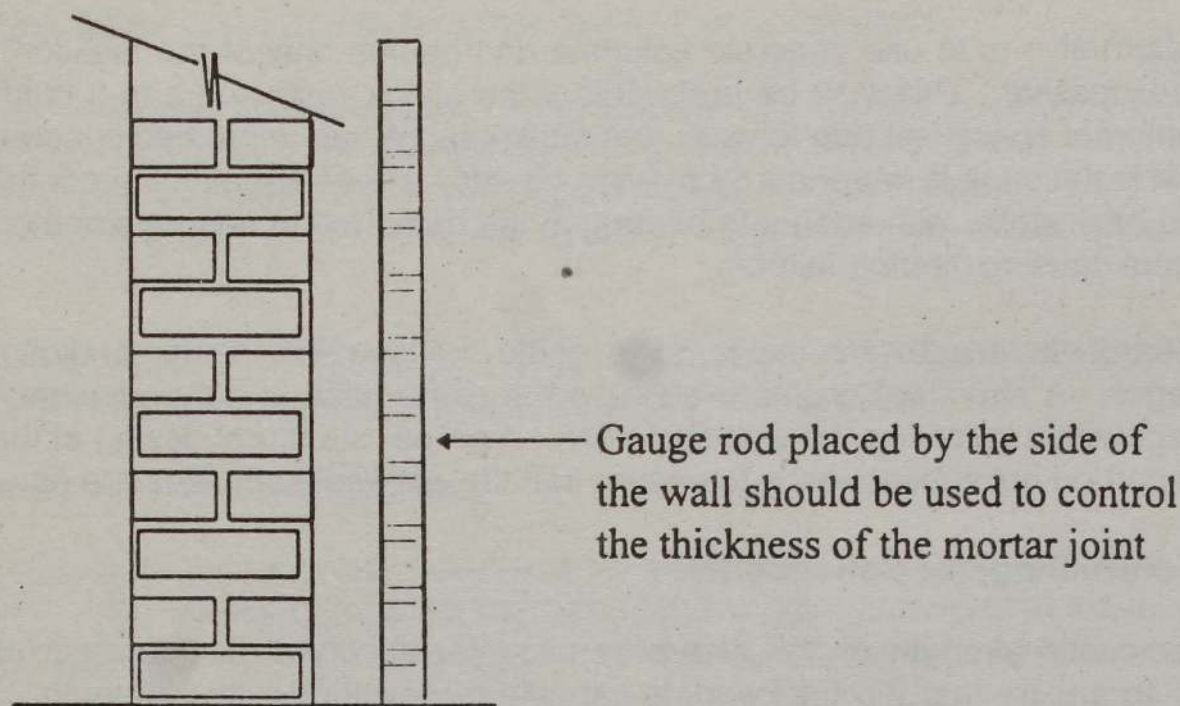


Figure. 1: Use of gauge rod to control the thickness of the mortar bed thickness

Secondary Stresses In Load Bearing Brickwork

The use of a design strength of 1.5 N/mm^2 will provide adequate safety against primary stresses, which would be the compressive stresses due to vertical loads such as dead, imposed and in plane loads induced by wind acting on the structure. However, even a properly designed load bearing structure can still develop vertical, horizontal and inclined cracks due to secondary effects such as:

1. thermal stresses caused by diurnal fluctuation of temperature of walls,
2. thermal stresses caused by exposed structural members such as concrete roofs and balconies without roofs, and
3. foundation movements.

The common locations for these cracks can be summarised as follows:

Cracks at windows

In many brick wall structures vertical and inclined cracks can be observed at external windows as shown in Figure 2. It has been shown that vertical cracks are caused by tensile stresses induced in brickwork due to shortening of the brickwork (Jayasinghe and Maharacchi, 1998). Such shortening occurs due to restraint offered by the floor slabs and foundations, which would be at a lower temperature. When subjected to compressive stresses of long durations, brickwork can relieve the stresses by shortening, which is called the creep of brickwork. The creep of brickwork can relieve the stresses by about 50% in brick walls (Henry, 1981). When the temperature of brickwork drops during the night, tensile stresses can develop in already shortened brickwork. These tensile stresses will build up gradually in the brick wall with the highest stresses below the windows. When the tensile stresses exceed the tensile strength, cracks will develop below the windows.

The inclined cracks occur due to uneven stress distribution that give rise to some tensile stresses in brickwork. It is possible to draw a Mohr's circle and show that the principle tensile stresses will occur in the direction shown in Figure 3 for the element shown in Figure 2, which is subjected to vertical stresses and shear stresses.

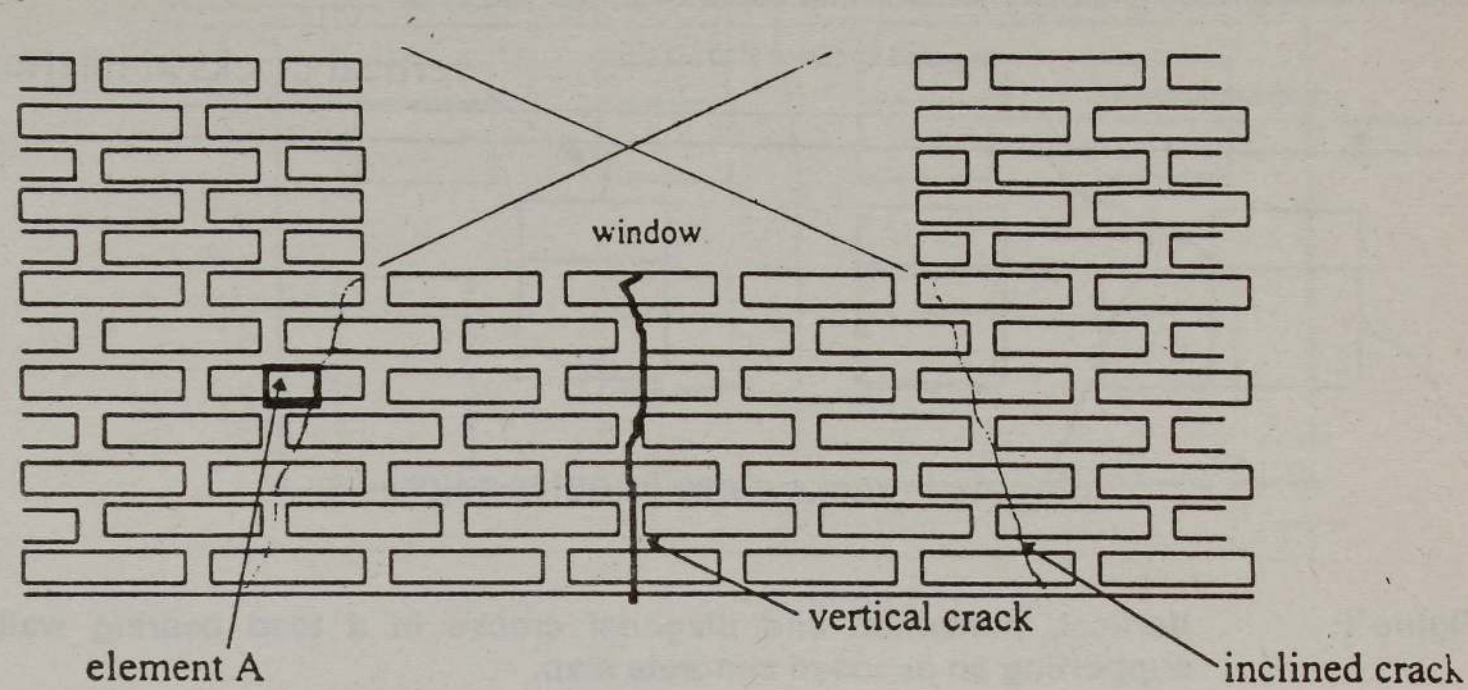
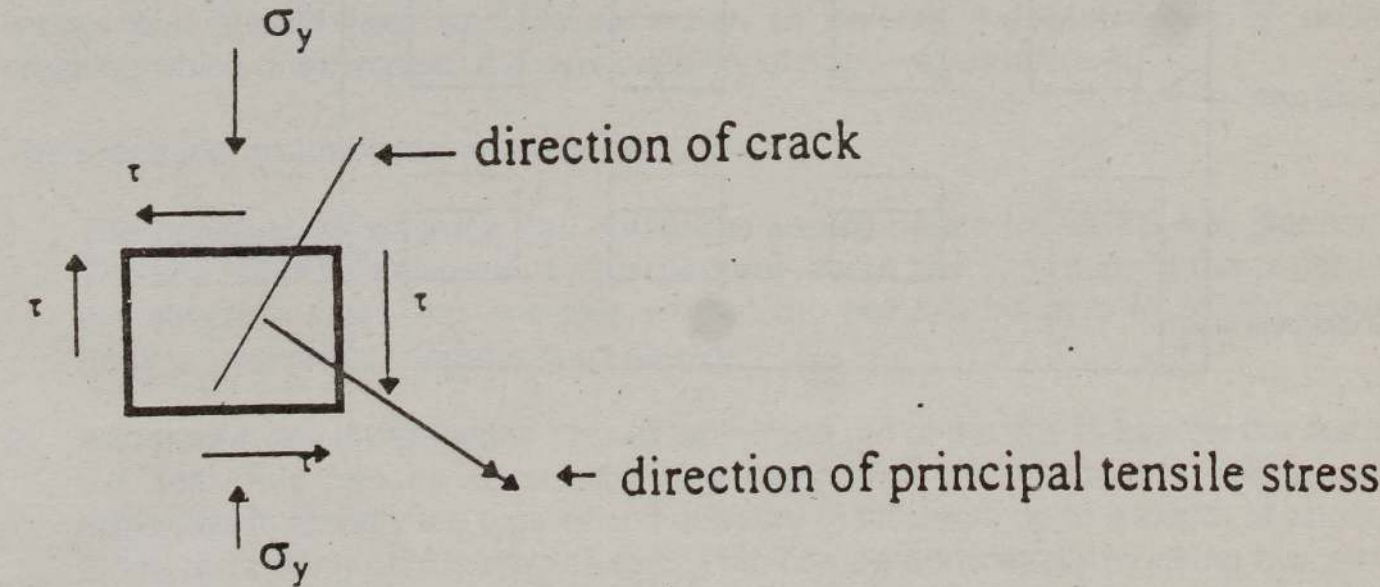


Figure 2: Thermal cracks below the window in the brick wall

Only reducing the shear stress can reduce the tensile stress. This shear stress occurs due to uneven stresses that occur under the window and away from the window.

Under the window, the stress in brickwork is very much lesser than that away from the window. The shear stress can be minimised by ensuring that a load of considerable magnitude is transferred to the area below the window which can be achieved by providing a tie beam at the window sill level.



**Figure 3: Stresses acting on element A and the direction of principle tensile stress
Cracks under Exposed Roof Structures and Balconies**

When concrete roofs are used for load bearing masonry buildings, the horizontal roof will absorb a lot of heat during the day time, where the intensity of solar radiation can be in the range of 1 kW/hour (Silva & Vas, 1984). The expansion of roof slabs can cause a lot of cracking as shown in Figure 4. The inclined and vertical cracks are associated with thermal expansion. Horizontal cracks occur due to creep shortening of brick walls in the vertical direction. The stress distribution below the slab is not uniform and this can give rise to differential shortening in the brick wall that expands below the slab.

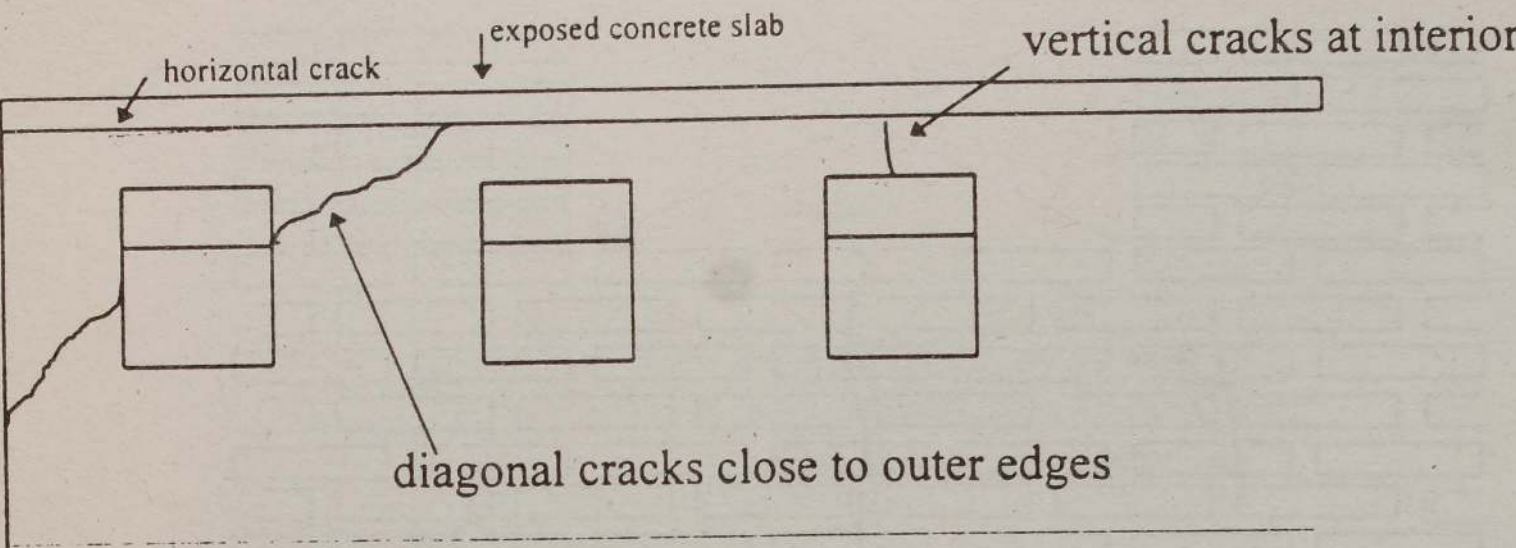


Figure 4: Vertical, horizontal and diagonal cracks in a load bearing wall supporting an exposed concrete slab.

Cracks due to Foundation Movement

The foundation movement that occurs in a brick wall structure can be either due to differential settlement or heaving of the foundation. Differential settlements often occur in weak clayey soils and this can lead to diagonal cracks as shown in Figure 5.

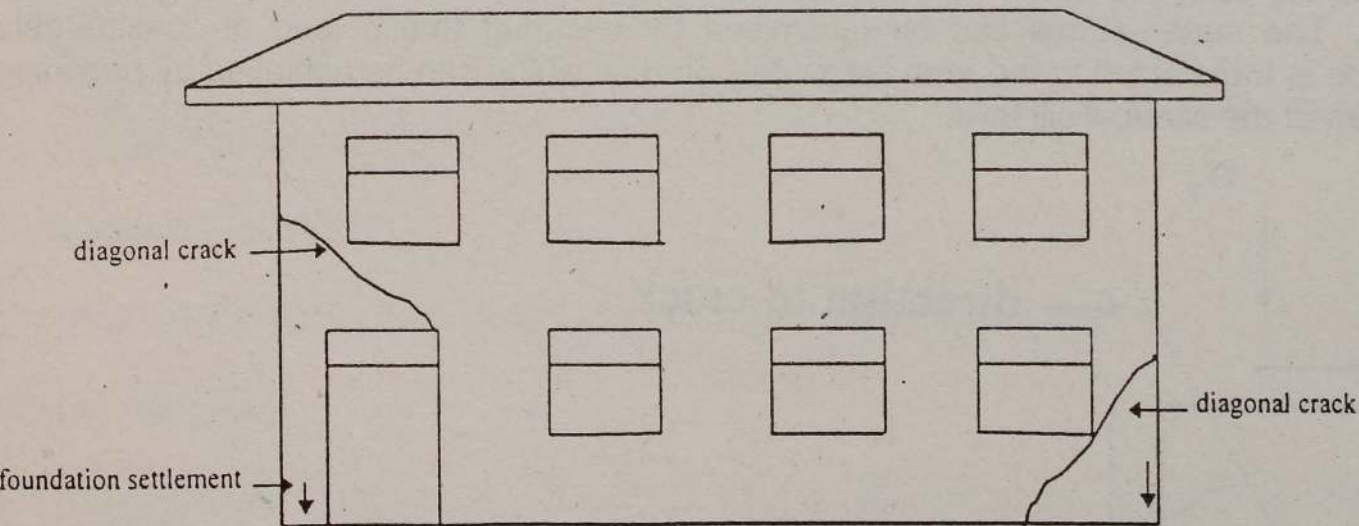


Figure 5: Diagonal cracks due to foundation settlements

Heaving of soil can occur when the sites are cleared of trees immediately prior to construction of a building. Heaving of soils can caused both diagonal cracks and vertical cracks as shown in Figure 6.

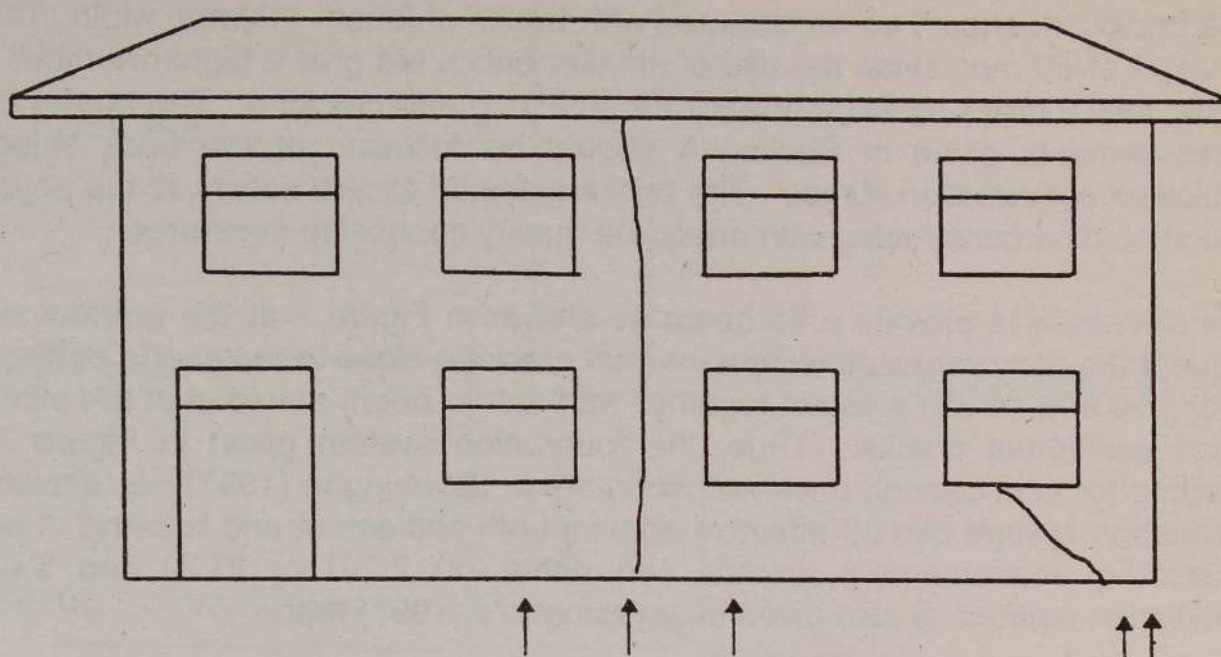


Figure 6: Swelling of clay under the centre and the edge of a building and the cracking due to it

Methods of Constructing Crack Free Load bearing Brick Walls

By taking adequate precautions, it is practically possible to construct load bearing brickwork structures, which would not show any signs of defects in the form of cracking. These precautions should be considered prior to starting the construction of the structure since some of them are applicable to site preparation, construction of foundations, walls, floor slabs, balcony slabs, roofs and finishes. Therefore, the builder has to be aware of these cracks and should take appropriate action to prevent the occurrence of undesirable cracking which often impairs the serviceability of brick wall structures.

The precautions can be summarised as follows:

1. The construction of crack free structures should be started at the site clearing stage. The site should be cleared of all large trees about one year prior to the construction of the structure whenever possible so that the soil will be able to regain naturally its moisture content during the rainy season.
2. A thorough soil investigation should be carried out at the site to identify the suitability of the soil. This can be done easily by using trial pits where the soil samples are inspected to identify the type of soil at every 0.3m depth up to a depth of about 1.5m - 2.0m, depending on the type of soil. This can be done easily by using trial pits where the soil samples are inspected to identify the type of soil at every 0.3m depth up to a depth of about 1.5m - 2.0m, depending on the type of soil. If undesirable soil types like peaty soil or clayey materials, which can shrink during dry spells are encountered, special precautions should be taken.

3. The foundation should be adequately tied so that it will be able to resist earthquake loads without disintegrating. Thus, the provision of a continuous tie shown in Figure 7 at DPC (damp proof course) level, which will connect all the internal and external walls, is highly recommended.
4. The brickwork should be constructed with bricks of length 200mm, width 100mm, and a height of 50 mm, since the use of smaller bricks will give a higher number of mortar joints, thus increasing the tendency for shrinking and cracking. The quality controlling measurements given in Section 4 should be followed at the brick selection and brickwork construction stages. The bricks selected should satisfy all the physical tests and should be constructed with adequate quality controlling measures.
5. It is advisable to provide a tie beam as shown in Figure 7 at the window sill level to prevent the occurrence of vertical thermal cracking close to the centre of the windows. These tie beams can also act together with the tie beam provided at the plinth level to resist settlement cracks. Thus, the foundation system given in Figure 7 can be adopted for load bearing brick wall structures. Jayasinghe (1997) has shown that this foundation system can be effective against both settlement and heaving of soils. The amount of reinforcement provide can either be 2T10 or 3T10 and the detailed calculation method is also given in Jayasinghe's (1997) report.
6. It is not advisable to have exposed reinforced concrete roofs supported on brickwork in tropical countries like Sri Lanka, since the thermal expansion of the roof can cause diagonal cracks in the brickwork close to the external walls and vertical cracks in the interior of the building.
7. It is appropriate to provide a roof for all the balconies so that the amount of heat absorbed by the exposed concrete can be minimised. The heat absorbed can cause various types of thermally induced cracks.
8. A concrete beam similar to the one provided at the ground floor window sill level should be provided below the upper floor windows as well. However, this beam need not be continuous. It may be possible to precast these beams to reduce the cost. Alternatively, these can be cast by using bricks as formwork as show in Figure 8. It is shown by Annamalai et al. (1984) that the thin beams formed resist flexure. The main advantages are that the formwork cost can be eliminated, concrete volume can be reduced and delays due to forming the tie beam can be minimised. Thus, it would be possible to prevent cracking due to thermal stresses and uneven stress distribution by using thin tie beams at the window sill level. Since the thin tie beams can alter the load transfer mechanism for the vertical compressive loads, these can preferably be used in the upper floor brick walls where the compressive stresses due to vertical loads are lesser in magnitude.
9. The lintel provided over the upper floor windows may be made continuous to enhance the resistance of the structure to withstand accidental loads like trees falling on the roof during high winds. It would also resist the spreading of the roof due to weakening of the roof structure with time. These could be in the form of a thin lintel as shown in Figure 8

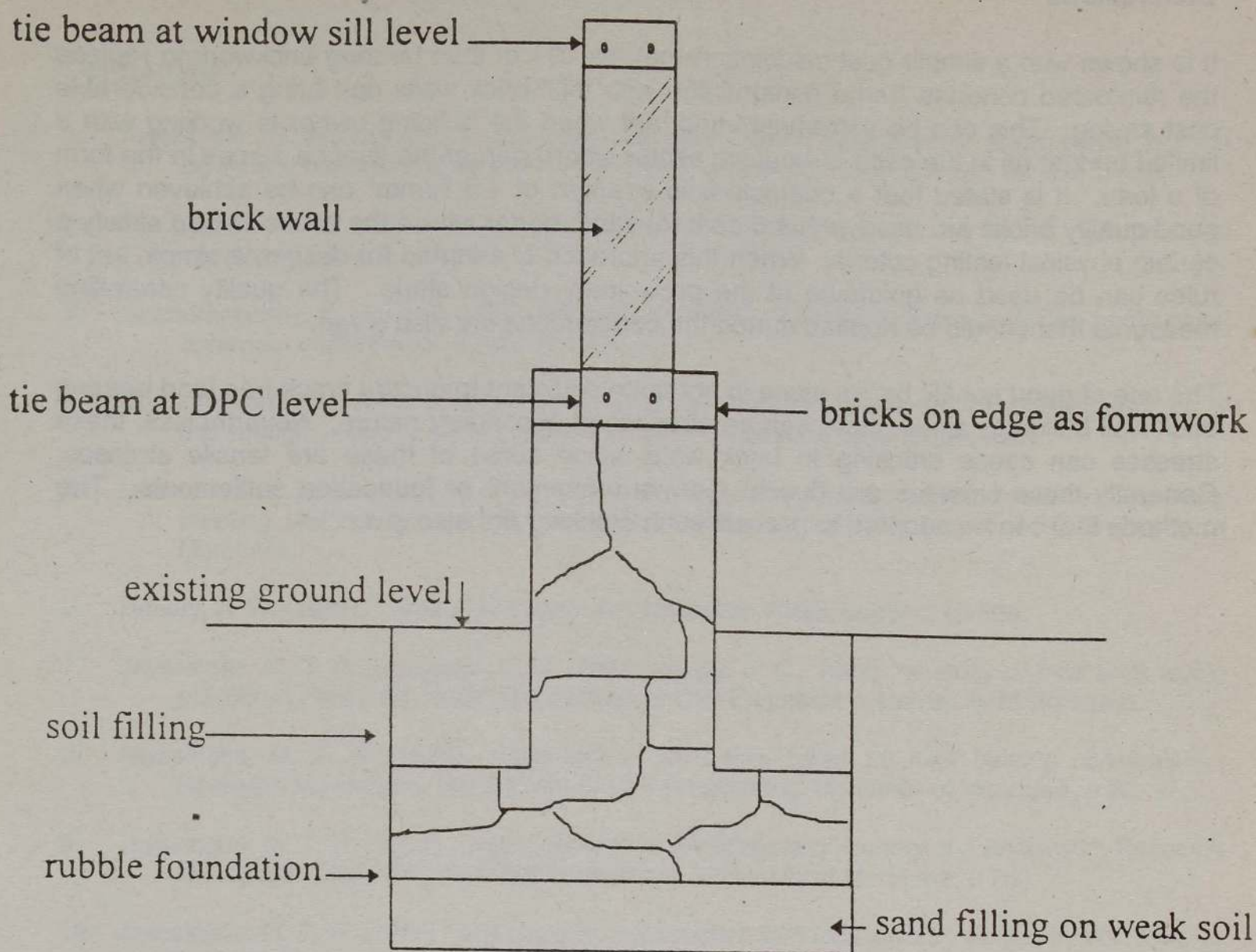


Figure 7: Rubble foundation with tie beams at DPC and window sill levels

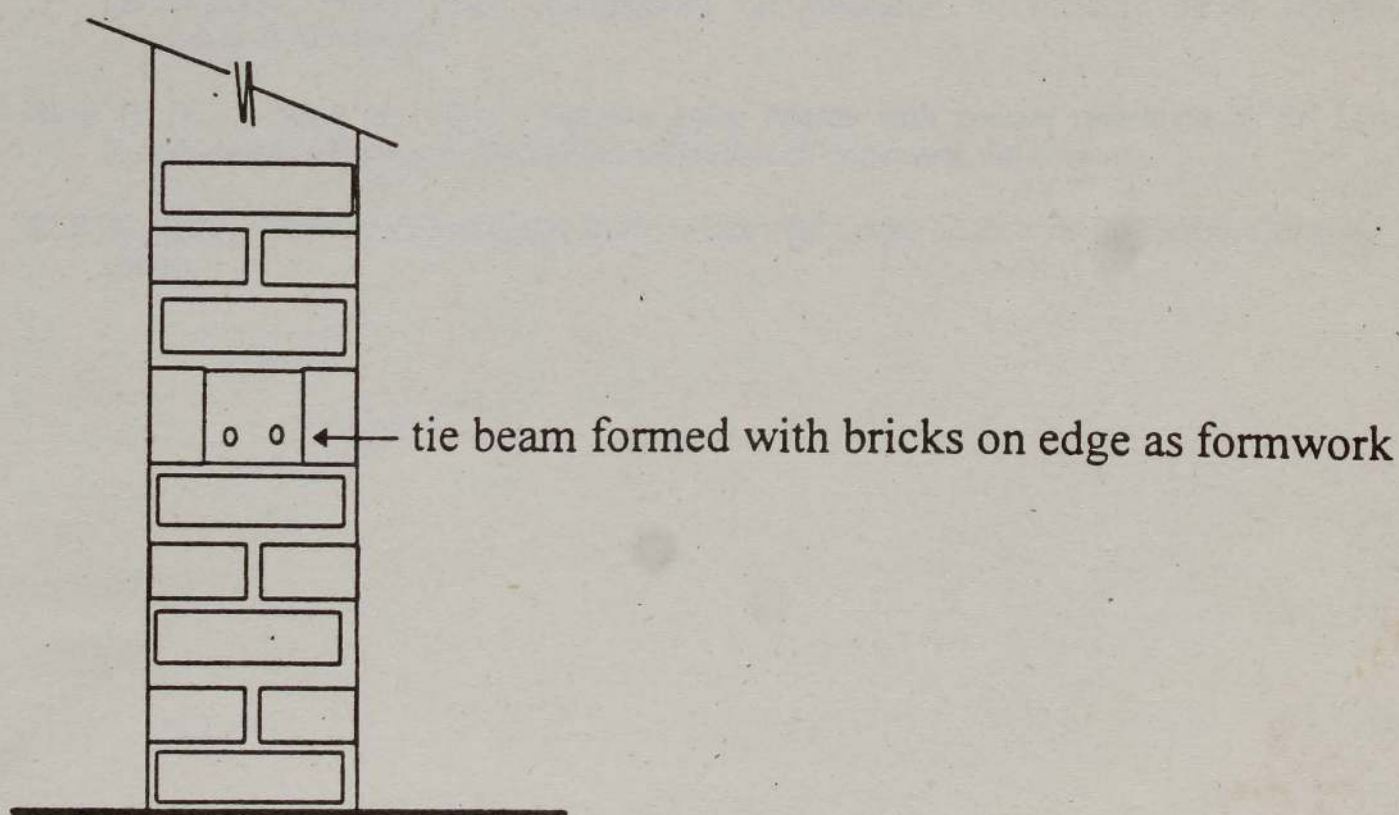


Figure 8: Construction of thin tie beams where bricks on edge have been used as formwork.

Conclusions

It is shown with a simple cost calculation that the use of load bearing brickwork to replace the reinforced concrete frame construction with infill brick walls can bring a considerable cost saving. This can be extremely important when the building owner is working with a limited budget as in the case of housing sector where part of the finance comes in the form of a loan. It is stated that a characteristic strength of 1.5 N/mm^2 can be achieved when good quality bricks are used with 1:6 cement sand mortar where the bricks should satisfy a certain physical testing criteria. When this approach is adopted for design, a simple set of rules can be used as guidance at the preliminary design stage. The quality controlling measures that should be applied during the construction are also given.

The use of good quality bricks alone is not quite sufficient to ensure crack free load bearing brick wall buildings since, there can be stresses of secondary nature. Nevertheless, these stresses can cause cracking in brick walls since some of these are tensile stresses. Generally these stresses are due to thermal movement or foundation settlements. The methods that can be adopted to prevent such cracking are also given.

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Editorial Note	1
Dayananda Somasundara	
Thin Traded Capital Markets: An Empirical Investigation of Colombo Stock Exchange	3
W.M. Gunaratne Bandara, G. Abeyratna	
An Empirical Study of Membership Participation in Trade Union Activities: Evidence from Selected Service Organizations in Sri Lanka	17
P.C.V. Jinadasa, H.H.D.N.P. Opatha	
Redefining Parameters: The Case of Lankan Urban Bilingual Discourse	35
Chandana Dissanayake	
Computer Applications in Medical Education and Training: A brief review	47
I.P. Goonewardene	
Pulmonary Functions in Pregnant Sri Lankan Women	57
Deepal S. Weerasekera, D. Kusuma Ruberu, S. Sivayogan	
A Note on the Chemistry and Mineralogy of Apatite Crystals of Eppawala and Ridigama Phosphate Deposits	61
A.L.T. Hewawasam, K. Dahanayake	
Drying Characteristics of Potato Slices and Quality Parameters	69
V.P.A. Weerasinghe, A.R. Ariyaratne	
Osmotic Adjustments and Associated Water Relations of Clonal Tea	77
P.M.A.S. Karunaratne, M.A. Wijeratne, U.R. Sangakkara	
A Comparison of Different Models of Estimating Actual Evapotranspiration from Potential Evapotranspiration in the Dry Zone of Sri Lanka	87
R.P. de Silva	
Socio-economics and Environmental Impact of Gem Mining Industry in Sri Lanka: A Case Study of Hunuwala Village in the Ratnapura District	101
H.M.S. Priyanath	
Critical Evaluation of Fashioning of Gemstones in Sri Lanka	111
P.G.R. Dharmaratne	
Cost Effective Building with Local Bricks	121
M.R.T. Jayasinghe	