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The Application of Rainfall Confidence Limits to Crop Water Requirements in Dry Zone Agriculture in Sri Lanka

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(*Paper accepted : 5 September 1974*)

Abstract : One of the more important problems in the stabilization of rainfed agriculture in the dry zone of Sri Lanka is the development of systems that would ensure an optimum use of the incident rainfall. This would principally involve : (1) a proper choice of sowing time and (2) a proper selection of sowing-to-harvest duration of crops so that there is a maximum likelihood of the rainfall satisfying the crop water demand at every stage of growth and development.

In this paper, the probability of rainfall for the growing seasons in the different regions of the dry zone have been specified by the use of 3-weekly moving totals of 1 : 1 rainfall confidence limits calculated according to Manning's method. It is observed that within the dry zone itself there is a significant regional differentiation in both the break of season as well as the close of season, especially for the major 'Maha' season. The manner of selecting proper sowing dates for the respective regions is indicated. By matching the crop water requirement against the 1 : 1 confidence limits of expected rainfall, it is demonstrated that one could select an age class for a particular crop so that its water demand fits as closely as possible with the probable seasonal supply of moisture. Predicting the adaptability and performance of individual crops to the different regions of the dry zone as well as some other practical applications are also discussed.

1. Introduction

Countries with a long established agricultural tradition are fortunate to have at their disposal the heritage of an accumulated weather lore of centuries. Indeed, through centuries of empirical observation and experience in rainfed farming in the dry zone of Sri Lanka, there has evolved a cropping calendar which, within the constraints of a subsistence economy, is observed to be quite logical as it is sound. Despite this level of development, factors such as risk at time of planting and even more at time of grain filling and maturing, especially for rainfed rice and other shallow rooted crops are often in doubt. Such risk factors may perhaps more than any other, account for the fatalistic attitudes that tend to cloud an objective assessment of occurrences in the recent run of years, which could be explained in terms of a statistically normal run of events, that may, not infrequently, tend to bunch together.

Any kind of year to year prediction of a season's rainfall is yet not possible according to our present state of scientific knowledge. However, subjecting the past rainfall data to stringent tests of statistical probability, at least such central tendencies of rainfall expectancy that are known to have a significant bearing on an inter-related range of agricultural practices could be objectively assessed.

*The late Mr A. Walgama

An important characteristic of the annual rainfall of the dry zone is its division into two well defined rainy seasons : (1) *Maha*—the major rainy season from early October to late January and (2) *Yala*—tne minor rainy season from late March to late May. The mean monthly rainfall records for any dry zone station shows this bi-modal rainfall pattern with two marked dry seasons, one during February to March which is short and moderate, and the other during May to September which is long and protracted. The intensity and duration of the component wet and dry seasons themselves show minor but significant regional variations within what is broadly termed the dry zone of Sri Lanka ; and the nature of these variations do have an important bearing on the regional specialization of crops within the dry zone.

The main climatic features of the dry zone have been adequately described in several publications and therefore needs no further elaboration. For the special needs of this paper, however, the meteorological data of the dry zone research station at Maha-Iluppallama, which could be considered as representing the modal situation in the dry zone is given in Table 1.

TABLE 1. Meteorological data for Maha-Iluppallama.

Month	Mean Rainfall in	Mean Evaporation Open Pan in	Mean Temperature Max °F	Mean Temperature Min. °F	Mean relative humidity	Mean daily wind mileage	Mean percentage sunshine
Jan.	5.3	5.2	83.3	69.1	81	106	65
Feb.	1.9	5.6	87.0	69.4	74	91	75
Mar.	3.9	7.1	91.2	71.6	73	85	85
Apr.	7.4	6.8	91.6	74.4	76	93	82
May	3.9	7.0	90.8	76.4	76	190	77
June	1.1	7.2	90.0	76.4	71	264	75
July	1.5	7.5	90.8	75.9	70	243	73
Aug.	1.7	8.0	91.4	75.5	68	258	78
Sept.	3.0	8.2	91.8	75.0	68	246	74
Oct.	9.9	5.9	89.0	73.5	77	147	64
Nov.	10.5	4.6	85.8	71.4	81	79	56
Dec.	8.0	4.5	83.2	70.1	83	98	58
Total :	58.1	77.6					

One of the characteristic features of rainfed arable crops in the dry zone environment is the enormous variability in yield between years. Over a 25-year period at Maha-Iluppallama, rainfed rice yields have ranged between 74 to 8 bu/acre, while over a 12-year unbroken period, rainfed cotton yields have ranged between 1,120 to 220 lb/acre. Almost the whole of this variation in crop yields could be ascribed to the chance of obtaining a satisfactory trend of soil moisture during the growing season. Clearly, the pattern of incident rainfall and its interaction with the water consumption patterns of rainfed crops deserves a close study by such investigational techniques that are presently within our reach and capacity.

From the information that was available by 1962 on crop-water consumption patterns, rainfall expectation patterns and trends of the soil moisture profile, Abeyratne[2] made the following broad conclusions :

1. There is a good chance in most years for the successful cultivation of 4-month or shorter duration crops under rainfed conditions in the Maha season.

2. The cultivation of rainfed Yala crops at least in the northern dry zone may be possible if proper water conservation methods are used and if the fields are kept free of weeds.

3. The only long aged crops that will survive the dry season are the very deep rooted ones such as pigeon pea (*Cajanus cajan*) when planted in the Maha season.

Considerable advances have been made during the recent decade in the study of soil-plant-water relationships and soil-water energy characteristics in our dry zone environment. This paper presents our contemporary store of inter-related information in this field in order that agricultural scientists and policy makers could formulate a reliable and objective approach to the development of rainfed agriculture in the dry zone.

The initial sections of this paper deal with the main parameters of the subject : (1) the confidence limits of rainfall, (2) water consumption patterns of crops and (3) soil-water energy relationships. The latter sections discuss the matching of crop-water requirements with rainfall expectancy and the practical applications that arise from this study.

2. Confidence limits of expected rainfall

In tropical regions in particular, it has been clearly demonstrated that the mean monthly rainfall, even when derived from a large number of years, is at best an unreliable guide to the variation in rainfall with which the agriculturist must contend. In an analysis of the dry zone rainfall made in 1953, Farmer[5] drew attention to this, and he has shown that the median and other percentile values afforded a more reliable measure of rainfall expectancy.

The arithmetic mean that is usually calculated directly from rainfall figures does not take into account the inherent skewness of the raw data that results from a disproportionately large amount of the rain falling in heavy tropical downpours thereby raising the level of the mean much above the normal amount of rain received or expected. Thus, unless account is taken of the skewness of the frequency distribution of the rainfall where the mode is lower than the mean, estimates of rainfall expectancy made directly from raw data could be quite misleading.

Frequency distributions were constructed from weekly records of the past 50 years rainfall for selected dry zone stations using the class interval of one fourth the approximate standard deviation. It was observed that except for the weeks that fell within the month of November, the distributions in respect of all other periods were positively skew. Even monthly rainfall values as subsequently reported by Alles[3] show a non-normal positively skewed distribution. Clearly, any statistic derived from such distributions will give a distorted measure of the real values.

Several methods are available for transforming skew data to give approximately normal distributions. The method proposed by Manning[7] has been directly used in this study. Briefly this involves summing up the daily total rainfall for each year into 52 standard weeks so as to give an even run of data which may be subject to analysis. 3-weekly moving totals are used for several reasons indicated in subsequent sections of this paper. The data is then transformed by the function $y = log(x + c)$ where the size of the constant c varies inversely with the degree of skewness. The rainfall patterns are thus presented in a form free from the distortion imposed by the skewness of the actual data. Manning[8] observes that "from this transformed data the concept of rainfall expectation at selected levels of probability could provide a completely objective and reliable estimate of rainfall to be expected so as to assess long-term crop risk which is not apparent when means alone are used."

The real need in agriculture is for a precise estimate not merely of the average expected rainfall, but the limits within which this expected rainfall will occur. These limits can be calculated for any level of probability from the transformed data and are known as *fiducial* or *confidence* limits. A confidence limit may therefore be defined as an estimate of the chance of obtaining a value for a given statistic that falls within prescribed limits. For agricultural purposes, the limits within which rainfall may be expected to lie in 3 years out of 4, namely 75% fiducial probability or 1:1 confidence limits are considered adequate.

The 1:1 rainfall confidence limits calculated on a monthly basis for Maha-Iluppallama from a 20-year run of unbroken rainfall records are given in Table 2. In statistical terms, the rainfall for a particular month will be greater than the lower confidence limit value in 3 years out of 4 ; and similarly it will be less than the upper confidence limit value in 3 years out of 4. Expressed in this manner, it is of more direct relevance to agricultural problems than the mean monthly values quoted in Table 1.

TABLE 2. Confidence limits (1:1) for monthly rainfall at Maha-Iluppalama (20 years).

Month	Lower confidence limit (in)	Upper confidence limit (in)
Jan.	2.3	8.0
Feb.	0.3	2.9
Mar.	0.6	4.2
Apr.	3.0	8.7
May	1.5	5.6
June	0.3	2.1
July	0.1	1.8
Aug.	0.3	2.5
Sept.	0.2	3.1
Oct.	3.5	9.1
Nov.	5.5	13.4
Dec.	5.1	14.3

The trends of rainfall expectation during the progress of the season are as important to the agriculturist as the break of season and the close of season. A graphical method of presenting these processed rainfall confidence limits that would capture in a single diagram the main elements of the seasonal cycles would be the most pertinent. To this end, a diagram of the 1:1 rainfall confidence limits could be drawn to a convenient scale with the rainfall on the vertical axis and with weeks along the horizontal axis. Figure 1 shows the 1:1 confidence limits of 3-weekly moving totals that have been worked out from a 50-year run of data for the rainfall station Anuradhapura which is located very close to Maha-Illuppalama. According to the data presented in Figure 1, for a particular week one quarter of the values should fall above the upper limit as shown in the upper curve, and one quarter below the lower limit as shown in the lower curve.

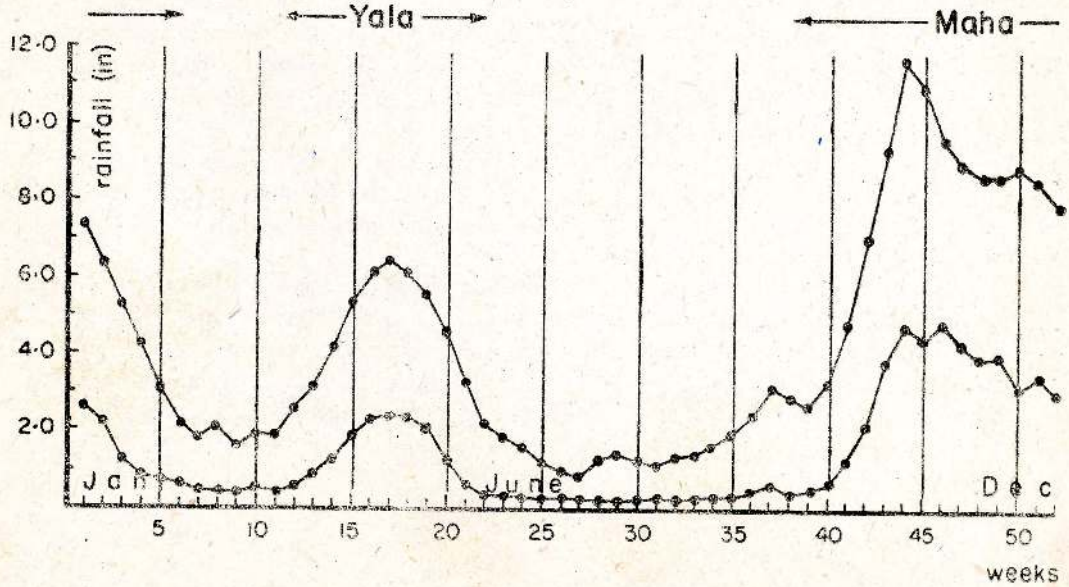


FIGURE 1. 1:1 Confidence limits of 3-weekly moving totals of Anuradhapura rainfall. (Minimum expectation for 3 years in 4 given by lower limit)

Therefore, for any one 3-weekly period, the total rainfall is likely to exceed the lower limit in 3 years out of 4, or in other words the minimum expectation for 3 years in 4 is given by the lower limit. Similarly, the total rainfall for the same 3-weekly period will not exceed the upper limit in 3 years out of 4. For example, in the 3-weekly period represented by the 15th week in Figure 1, the rainfall (3-weekly total) will exceed 1.8 inches in 3 years out of 4, and it will also not exceed 5.3 inches in 3 years out 4.

3-weekly moving totals of 1:1 confidence limits of rainfall have been worked out from the past run of unbroken data for 19 rainfall stations in the dry zone, 7 in the intermediate zone and 6 in the wet zone. The locations of these rainfall stations and the number of years of unbroken rainfall records from which the rainfall confidence limits have been calculated are shown in Figure 2. For the scope of discussion within this paper it would be sufficient to consider 15 rainfall stations from the dry zone proper, as well as 3 rainfall stations from the intermediate zone. The 1:1 rainfall confidence limits diagrams that have been constructed for the foregoing 18 rainfall stations are shown in Figures 3, 4 and 5 respectively.

3. Water consumption patterns of crops

Every crop requires during its growing season, a certain quantity of water which varies with the different stages of growth and development. The water consumption pattern of a crop within a growing season is therefore a more meaningful parameter of crop water requirement than the overall total consumptive use value, especially when estimating the probability of obtaining the desired distribution of rain through the duration of the cropping season.

The seasonal trends of moisture consumption in respect of the more important crops as measured during the Maha season at the dry zone research station Maha-Iluppallama have been reported earlier.[11] It was observed that the consumptive use of water by crops varied at different stages of growth, the evapotranspiration increasing with increasing leaf cover over the duration of the crop. The monthly evapotranspiration values (Et) for maize and cotton were compared with values of free water surface evaporation (Eo). It was observed that starting with a value of 0.63, the ratio Et/Eo steadily rises with increasing leaf cover of the crop until it reaches a peak value of 0.95 for maize. In the case of cotton, this ratio of Et/Eo could exceed 1.0 and attain a peak value of 1.4 at the 5th month of growth.

More recent studies that were conducted under irrigation on the Reddish Brown Earths during the long dry season by Sivanayagam[12] indicate very similar trends of increasing evapotranspiration with increasing leaf cover, and he has further observed that the duration of peak water use was short for maize, whereas for groundnut and other leguminous crops the peak water use period was less pronounced but extended

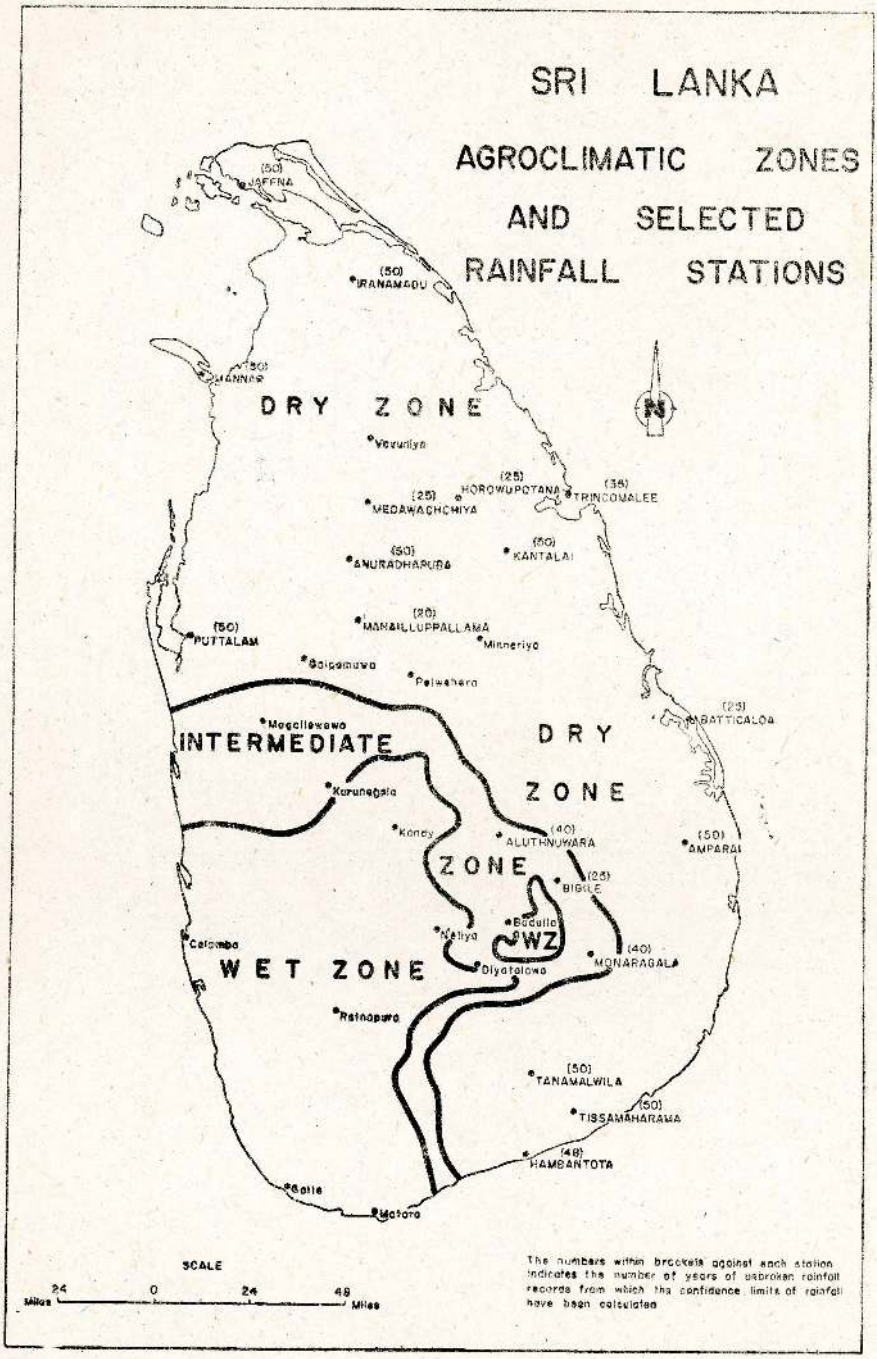


FIGURE 2.

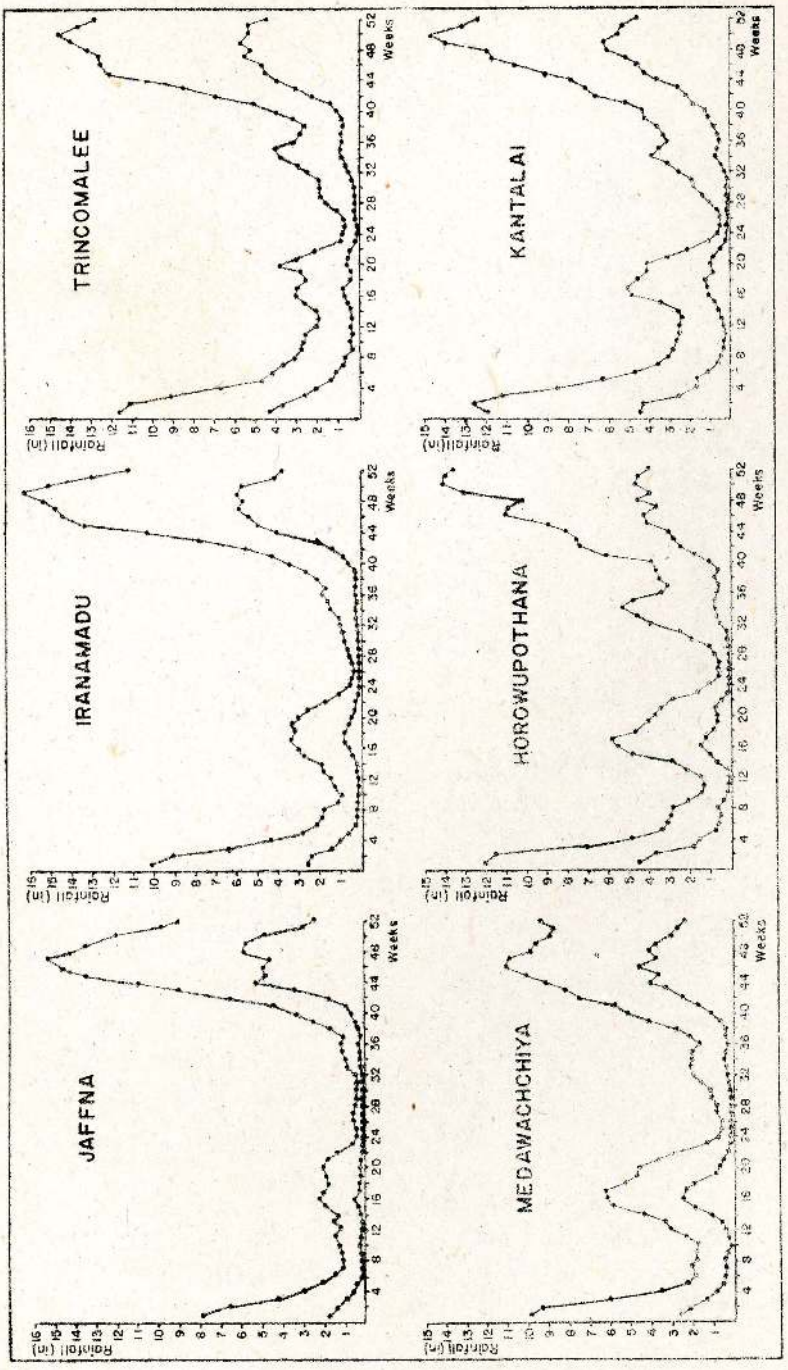


FIGURE 3.

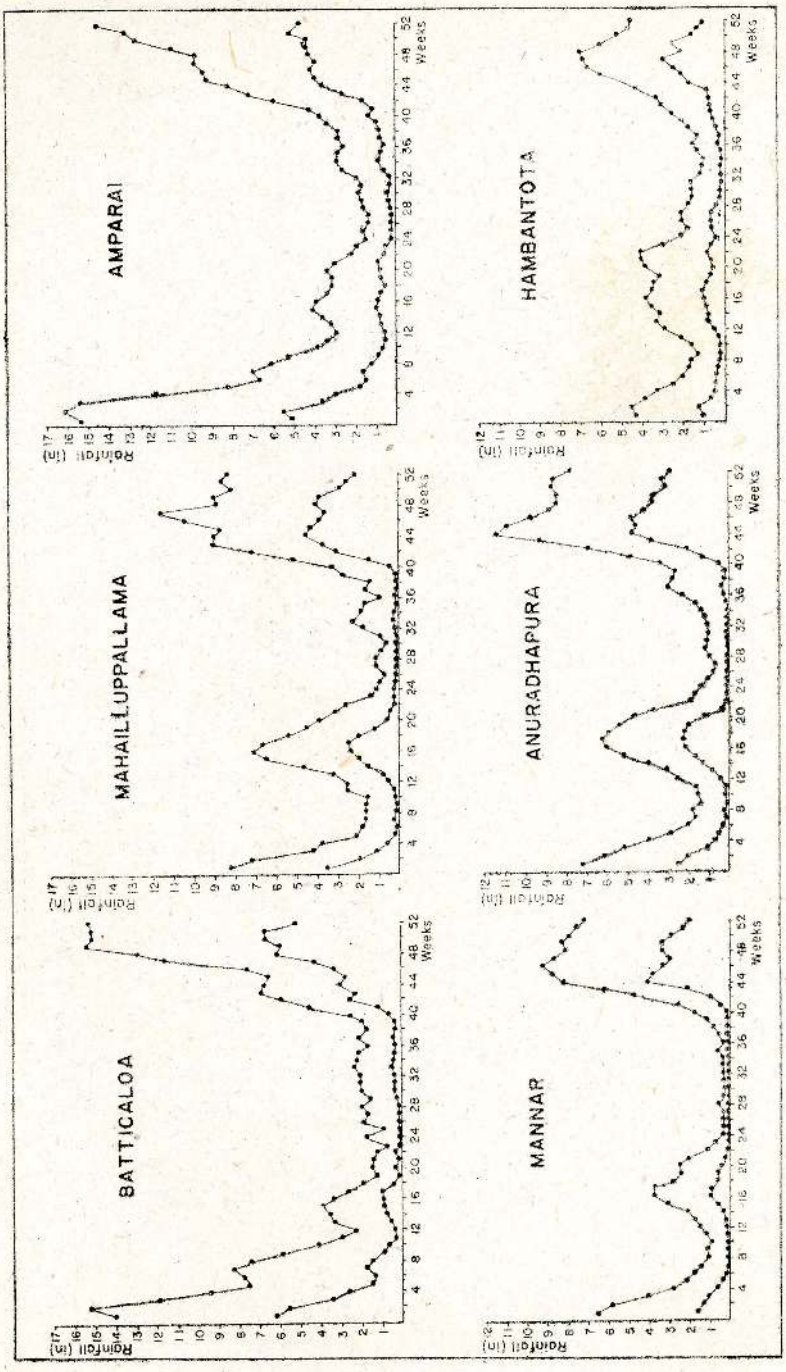


FIGURE 4.

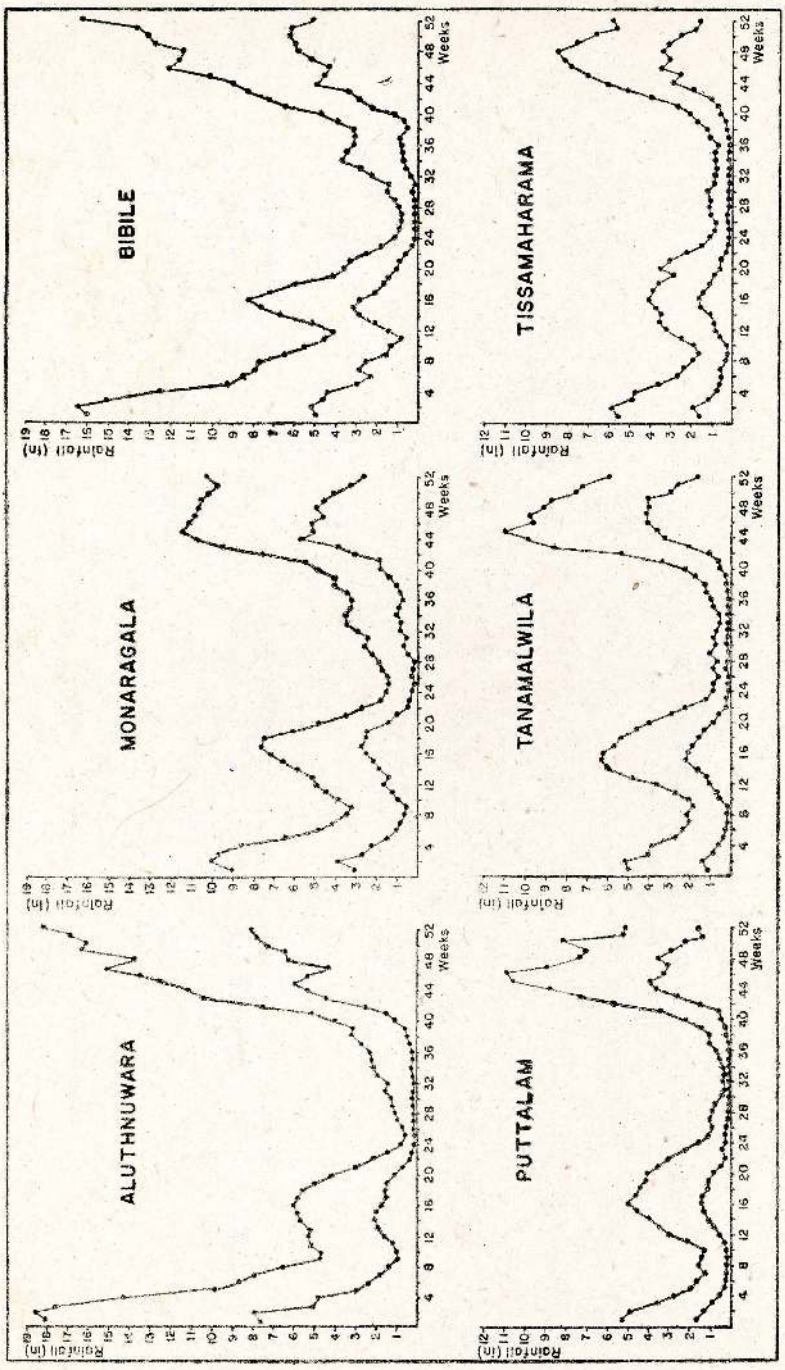
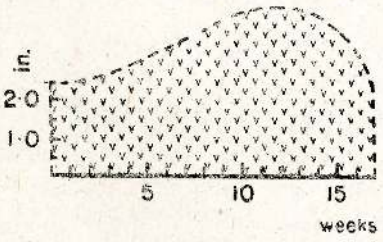


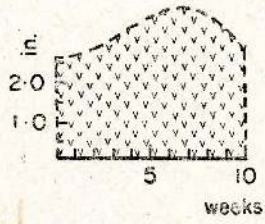
FIGURE 5.

over a longer period. It was also observed that the ratio Et/Eo in respect of maize reaches a peak value of 1.1 when irrigated at 50% depletion while when irrigated at 75% depletion this ratio reaches a peak value of 0.9. In the case of groundnut and other leguminous crops it was observed that this ratio reaches a peak value of 0.85 when irrigated at 50% depletion, while when irrigated at 75% depletion it reaches a peak value of 0.68. Evapotranspiration values in respect of rice grown under irrigated conditions have also been reported by Murakami and Vignarajah.[9]

From the data that is presently available at Maha-Iluppallama on the water consumption patterns of crops, it is possible to construct a modal water consumption pattern curve for a 120-day Maha cereal crop as well as a 70-day Yala legume crop. Since cereal crops such as rice and maize give maximum yields at soil moisture tensions corresponding to 50% depletion, the modal curve for a Maha cereal crop was constructed for evapotranspiration values obtaining for a low value of soil moisture tension. Since legume crops give maximum yields at soil moisture tensions corresponding to 75% depletion, the modal curve for a Yala legume crop was constructed for a high value of soil moisture tension. Such a modal curve for the water consumption pattern of a crop constructed on a 3-weekly moving total basis is referred to as a *crop water template* in this paper. Figure 6 shows this template for a Maha cereal crop as well as for a Yala legume crop. This template could be superposed on the 1:1 rainfall confidence limits curve drawn on the same scale with a view to matching the crop to the rainfall sequence so that there is a maximum likelihood of adequate water supplies during crop growth and development.



Crop water template for a 'Maha' cereal crop.



Crop water template for a 'Yala' legume crop.

FIGURE 6.

4. Soil-water energy relationships, infiltration and run-off characteristics

Attention has been drawn in a previous paper[10] to certain special features of the soil-water energy relationships of some soils of the dry zone. This section considers the soil-water energy relationships pertaining to three of the more important soil regions of the dry zone as represented by the Reddhish Brown Earths (RBE), the

Non Calcic Brown soils (NCB) and the Red Latosols (RL). The morphological and laboratory analytical characteristics of the different great soil groups of the dry zone are dealt with in a recent publication.[4]

Moisture retention characteristics have been determined for the diagnostic horizons of the soil profiles on samples collected from a very large number of profile description sites during a 12-year programme of soil survey investigations. Using the pressure membrane and pressure plate apparatus, measurement of water retention from 15 bar to 0.1 bar have been carried out on core samples as well as on disturbed samples. This data has been processed into a set of modal values of moisture properties by Joshua[6] and these are given in Table 3. From the modal depths and other characteristics of the individual soil series that have been mapped out in the respective areas of the dry zone, the moisture storage capacity of the different soil regions could now be properly defined.

TABLE 3. Moisture properties of dry zone soils.

Soil	Field capacity moisture %	Wilting point moisture %	Available moisture % by wt	Available moisture in/ft.
Reddish Brown Earths (RBE)	22 (18—24)	13 (9—15)	9 (8—12)	1.71
Noncalcic Brown Soils (NCB)	8 (6—10)	2 (1.5—3)	6 (4—7)	1.16
Red Latosols (RL)	14 (16—12)	7 (5—8)	7 (6—9)	1.21

Note : The figures within brackets denote the range of values measured.

The RBE can store approximately 1.7 in of available moisture in a 12 in depth of soil or approximately 1.1 inches in an 8 in depth of soil. On this basis, 1.0 in of cumulative rainfall over a 11-day period would be sufficient for the germination requirements of crops during the first half of October. Similarly, for the NCB and RL 1.0 in of cumulative rainfall over a 8-day period would be sufficient for the germination requirements during the first half of October.

An estimate of the total amount of available moisture that can be stored in a soil could be obtained by multiplying the modal depth of the soil profile by the available moisture content/ft of the respective soil. A 4 ft depth of a RBE could therefore store 6.8 in of available moisture when the whole profile is wet to field capacity.

Apart from the quantity of moisture than can be stored in the soil, it is desirable to have some measure of the frequency with which rainfall would be lost as surface run-off during the season. The quantity of rain that will be lost as surface run-off

will depend on (a) the infiltration capacity of the soil ; (b) its state of moisture at a certain time ; and (c) the intensity of rain at this particular time. Infiltration rates of dry zone soils have been determined by the ring infiltrometer for a very large number of sites. The modal values of the minimum infiltration rates work out to 1 in/h for RBE, 7in/h for NCB and 15 in/h for RL. These values represent the steady infiltration rate after a lapsed time of approximately 4 h. Initial infiltration rates could be 5 to 10 times higher.

For the RBE, when the profile is moist, any quantity of rain in excess of 1 in/h will therefore be lost as surface run-off, while when the profile is dry it could accept up to 3 to 4 in of rainfall/h during the initial stages. There could be appreciable run-off during the early Maha season only if very high rainfall intensities are experienced such as 2 inches in 30 or 40 min. The RL can easily accept rainfalls of this intensity without any run-off being experienced.

Comparing the moisture storage characteristics of the RBE with the 1:1 rainfall confidence limits for Anuradhapura, it could be inferred that the central tendency would be for a significant proportion of the rain to be lost as surface run-off during November and December. This also coincides with the period when the tanks or reservoirs in this region fill up rapidly. On the other hand, in the Latosol region represented by Puttalam, Mannar and Iranamadu even the peak rains of November and December can be completely accepted by the soil without any run-off occuring. In this region a greater part of the excess rain will be discharged as deep percolation into stream flow and underground aquifer re-charge.

5. Fitting sowing dates and crop water requirements to rainfall expectancy

The problem of choosing the correct sowing date for rainfed crops is, in fact, of fundamental importance if one wants to ensure high yields. From experimental evidence at the dry zone research station Maha-Iluppallama, Abeyratne[1] concludes as follows : "Time of sowing trials have clearly brought out the fact that the dry zone is no exception to the general rule that in any system of rainfed arable agriculture time of sowing has a great influence on yields of annual crops." Based on the results of field experiments and also using traditional experience as a guide, optimum sowing times were defined for different groups of crops, and these have proved valid for the rainfall patterns around Anuradhapura and Maha-Iluppallama. It would indeed be desirable to establish the optimum sowing times for the rest of the dry zone regions using the rainfall confidence limits as a guide.

The dilemma of the agriculturist in rainfed farming is quite often as to whether he should sow with the first arrival of rain for the season with some expectancy of the minimum rainfall that would be needed to raise the soil moisture to an adequate level for germination, or whether he should wait for the approximate date that is

usually accepted by traditional experience. In other words, he is interested in the risk to crop establishment that would be associated with a particular date of sowing. Since the week before as well as the week after sowing are as crucial as the actual sowing period, it is appropriate to express the suitability for sowing of each week as a 3-weekly total of the week before, that week and the week following.

A reliable index of the true break of the Maha season would be the point at which the lower confidence limit curve shows a sharp upward trend. For Anuradhapura this occurs between the 39th and the 40th week, namely between 29 September and 6 October (Figure 1). By the 41st week there is a 75% chance of a 3-weekly total of 1.3 in of rain, while by the 42nd week there is a 75% chance of a 3-weekly total of 2.2 in of rain. As observed earlier in the soil-water energy characteristics for RBE (Section 4), adequate levels of soil moisture for germination will be fulfilled at the values of rainfall expectancy reported above. The 1st week of October could herefore be considered a very reliable choice of sowing date for this region, and in fact the past 25 years experience at Maha-Illuppallama has confirmed that this sowing date has been the most successful for rainfed rice, cotton and maize. Similarly, the optimum sowing dates for the other dry zone regions could be quite objectively determined from the rainfall confidence limits diagrams of the respective rainfall stations in conjunction with the moisture characteristics of the soil.

Apart from taking advantage of the optimum sowing date, it should also be ensured that the water demand of the crop during its growth and development should fit as closely as possible with the probable water supply in a definite proportion of years such as 3 out of 4. By matching the crop water template against the rainfall confidence limits curve, it would be possible to estimate the maximum likelihood of the rainfall satisfying the crop water demands especially at those periods of its development when insufficient moisture would have its most serious effect on crop yield.

The crop water template of a 120-day cereal crop is superposed on the 1:1 rainfall confidence limits diagram for the duration of the Maha season for the rainfall stations of Anuradhapura and Amparai respectively in Figures 7(a) and 7(b).

It is observed that for the Anuradhapura rainfall there is a 75% probability that the rainfall alone could satisfy the crop water requirements up to a period corresponding to approximately the 50th week or the 51st week ; and beyond the 51st week there is only a 50% probability that the rainfall alone could satisfy the crop water requirements. While a deeper-rooting cereal crop such as maize could make good any deficiency in rainfall after the 51st week by drawing upon the soil moisture reserves beyond the 1 ft depth of soil, a shallow rooting cereal crop like rice will have to rely mainly on the supply of moisture by rainfall. There is a 50% chance that a rainfed rice crop would experience conditions of moisture stress during its last few weeks of growth (Figure 7(a)) and the experience at Maha-Iluppallama over

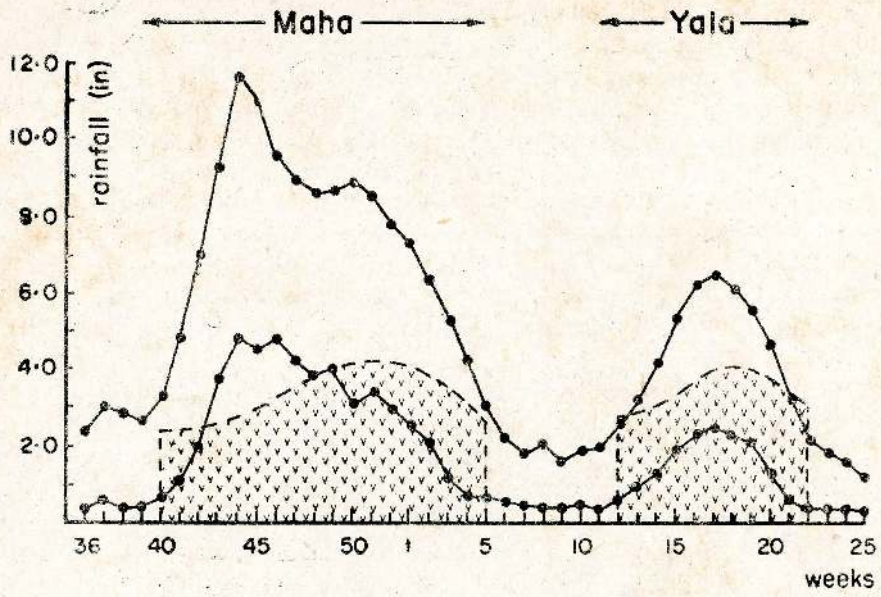


FIGURE 7 (a). Matching the crop water template of a Maha cereal crop and Yala legume crop with rainfall confidence limits of Anuradhapura.

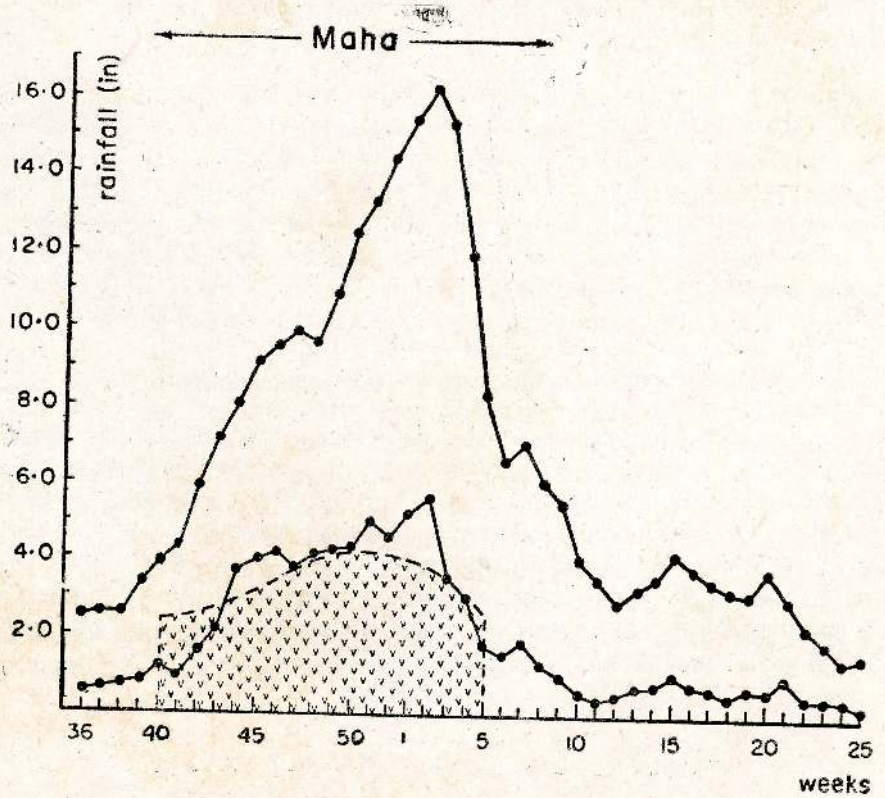


FIGURE 7 (b). Matching the crop water template of a Maha cereal crop with rainfall confidence limits of Amparai.

the past years confirms this observation in that the failure of the rainfed rice crop has always resulted from a deficiency of rainfall after around the 3rd week of December; and this has occurred with a frequency of approximately 4 years out of 10. On the other hand, for the Amparai rainfall (Figure 7(b)) there is a 75% probability that the rainfall alone could satisfy the crop water requirement for the whole duration of the period from sowing to harvest for a 120-day rainfed rice crop. It is therefore evident that a rainfed rice crop of sowing-to-harvest duration of approximately 4 months has a better chance of success in the Amparai and Batticaloa regions of the dry zone than in the Anuradhapura region. It is also clear that a shorter duration rice variety of approximately 95 to 100 days duration from sowing to harvest would be more appropriate for the Anuradhapura and adjacent regions.

As commonly experienced in several years, good crops of maize and cotton from early sowings can get adversely affected by heavy rains midway during the season. Abeyratne[1] has observed that depressions in certain crop yields, and even outright crop failures have occurred mainly on account of excessive rain during certain stages of the Maha season rather than on account of drought. This hazard of excess rain is reflected in the rainfall values represented by the upper confidence limits curve. Figures 4 to 5 show that this hazard of excess rain during the Maha season is least marked for Hambantota, Tissamaharama, Puttalam and Mannar. For all other stations, there is a significant chance of experiencing catastrophic rains during the months of November and December, and sometimes even during early January in the eastern region.

Superposing the crop water template for a 70-day Yala legume crop on the rainfall confidence limits for the Yala season of Anuradhapura (Figure 7 (a)) it becomes evident that there is only a 50% probability that the rainfall alone could satisfy the crop water requirements during this period. Furthermore, even this chance of 50% obtains only for those stations in the north central region, the intermediate zone and the area around Tanamalwila. It could also be demonstrated that a sowing-to-harvest duration not exceeding 70 days gives the best fit of crop duration with the rainfall expectancy for Anuradhapura for the Yala rainfed season.

6. Discussion and some practical applications

One of the more important problems in the intensification of agricultural production in the dry zone is the development of methods for ensuring that the best use is made of the incident rainfall, or "of every drop of rain that falls on the land" according to an ancient edict of Sri Lanka, historically associated with irrigation construction and irrigated rice culture. In rainfed agriculture, however, this involves the choice of crop and its management so that its yield is as high as possible from the water that is made available by rain as well as by soil moisture reserves. Having specified the probability of rainfall during the growing season, and with a knowledge of the

water requirements of crops during their growth, the main strategy would therefore be to tailor the crops to rainfall and adjust their management to the available sequences of soil moisture. Choosing or breeding crops whose water demands fit as closely as possible with the probable moisture supply and selection of proper sowing dates would therefore constitute the central strategy in the optimum exploitation of the rainfall resource.

The manner of choosing the proper sowing date for Anuradhapura has been outlined in Section **5**. Applying the same approach to the other stations it can be established that the proper sowing dates for the stations representing the north central, north western, northern and eastern regions of the dry zone would be around the 40th week, with the exception of the area around Medawachchiya—Horowpatana-Kantalai which would be approximately 7 to 10 days earlier. For the southern region of the dry zone it would be around the 41st week, while for the area around Hambantota-Tissamaharama it would be approximately 7 to 10 days later. For stations in the intermediate zone, the proper sowing date would be around the 39th week or even slightly earlier as in some areas around Moneragala. It can thus be observed that within the dry zone itself there is a significant regional differentiation in the break of season which ranges from the 38th to the 42nd week. While traditional experience bears out this pattern of regional differentiation in broad terms, it has not been hitherto specified in a form that could be of strategic meaning to the agronomist and the plant breeder.

Similarly, the close of season could be reliably specified by the rainfall confidence limits diagrams ; and the sowing-to-harvest duration for the different regions of the dry zone could be defined with a greater degree of precision than hitherto defined by using arithmetic means of rainfall. In some rudimentary form there has taken place, over the years, some kind of selective adaptation of the age class of both old and new crops to the different regions of the dry zone. This has, however, not been matched by a conscious breeding programme that has taken into account the variability of rainfall characteristics in the different regions, except at the research stations in the north central and southern region of the dry zone which have been mainly specific to their own environments. This paper demonstrates that the age class of a shallow rooting cereal crop like rainfed rice will have to be tailored to the particular region in such a manner whereby its water requirements are met solely by the incident rainfall and with little or no contribution by soil moisture reserves. On the other hand, in choosing the age class of a deeper rooting cereal crop like maize one could take into account both rainfall as well as contributions from soil moisture reserves. It could be demonstrated that the sowing-to-harvest duration for maize would be approximately 135 days for the intermediate zone and the eastern dry zone, while for the north central dry zone the present 115 day varieties would be quite appropriate.

The likelihood is that good crops resulting from the optimum time of sowing may in some years be lost by torrential rains during the middle or latter part of the season. This is a hazard that is particularly marked on the RBE where both the surface discharge and the downward drainage of surplus water is quite sluggish. It is less serious a hazard on the NCB while on the RL it presents little or no problem to management because of the high infiltration rate of the soil. The periods that correspond to the maximum likelihood of the occurrence of these catastrophic rains in the different regions of the dry zone are clearly revealed in the rainfall confidence limits diagrams. Advantage could, at the same time, be taken of the spell immediately following this period of maximum hazard to establish short duration deep rooting crops that may be harvested into late Maha.

A better feature of the Yala rainfall, despite its inadequacy to match the evapotranspiration demand of crops by rainfall alone, is the absence of this hazard of crop damage by excess rainfall. Residual soil moisture reserves from the Maha season can make a useful contribution to augment this inadequacy of rainfall in the RBE soil regions. Assuming a rooting depth of 3 ft, a RBE could contribute up to a total 5 in of available soil moisture which would help to satisfy this deficiency to some extent. Furthermore, some short age legume crops and sorghum are capable of giving good yields at high values of soil moisture tension or less ideal soil moisture conditions. The cultivation of Yala rainfed crops in the intermediate zone, the north central region and around the Tanamalvila area on the RBE soils is therefore quite feasible if the supporting management measures such as weed control, moisture conservation and optimum spacing are adopted. The appropriate sowing-to-harvest duration of crops for each of these regions could be reliably estimated from the rainfall confidence limits diagrams and the soil moisture characteristics of the particular region.

This paper has demonstrated that the patterns of rainfall expectancy have a very important bearing on the regional specialization of crops within the dry zone. Taking this factor in conjunction with our presently available knowledge of the soil moisture characteristics of the different soil regions of the dry zone, it would be possible to predict the adaptability and performance of individual crops to the different regions of the dry zone. For example, cotton which has hitherto been grown as a rainfed crop almost exclusively in the Hambantota-Tissamaharama area could be equally well extended to the red latosol areas in Mannar and Puttalam as a rainfed crop. Further, the sequences of rainfall and soil moisture that are considered desirable for the cultural operations and maturing of a rainfed sugarcane crop obtain in a satisfactory measure within the intermediate zone.

Selective allocations of areas for particular crops on the basis of a maximum chance of success is also rendered possible by the approaches outlined in this paper. Even the periods of minimum hazards to dry season irrigated crops by chances of

unseasonal rains can be reliably assessed by a study of the rainfall confidence limits. Similarly, the least number of irrigations that would be needed for irrigated crops during the Maha season could also be objectively determined by examining the rainfall confidence limits diagrams.

Some further applications that are not considered in this paper but could profitably engage the attention of other workers in related areas of study would be those concerned with (*a*) crop insurance planning ; (b) water resources planning ; and (*c*) the selective allocation of our total water resources to rainfed, semi-irrigated and irrigated farming in the dry zone. Although the full extent of all problems concerning the interaction between rainfall and crop water requirements is still not perfectly understood, these latest research findings are set out here in the hope that this new knowledge will become assimilated into agricultural practice.

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Toxoplasmosis and Heart Disease

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Abstract : This study is that of 12 patients with heart disease believed to be due to toxoplasmosis. A familial incidence of cardiomegaly, electrocardiographic and serological evidence was seen in several members of the families. Reliance has been placed on the serological findings. The usual picture was one of chronic heart disease. Some had only minimal symptoms, others were completely asymptomatic. Vascular manifestations without obvious involvement of the heart such as a sudden 'stroke' or arteritis were seen in some. It complicated other forms of heart disease. Toxoplasmosis as an aetiological factor should be looked for not only in patients with obscure heart disease of chronic nature but also in the acute forms with myocardial and or pericardial involvement. Toxoplasmosis might be commoner in Sri Lanka as an aetiological agent in obscure cardiac conditions than is realised.

1. Introduction

Toxoplasmosis is caused by a protozoon, *Toxoplasma gondii*. The world wide distribution and endemecity of toxoplasmosis was appreciated only after the introduction of the dye test by Sabin and Feldman in 1948. It is most common in warm and moist climates. Castellani[2] was probably the first to demonstrate the causative organism in man in Sri Lanka. Two forms of the disease have been suggested by Mohr:[13] (1) conatal and (2) postnatal. The conatal forms may manifest as malformations, neonatal deaths or may be latent. In the postnatal or acquired forms the protozoon may be disseminated throughout the body with clinical findings of multiple organ or system involvement. It may be localised from the very beginning and manifest itself as disease of a single organ ; or the disease may start as a generalised infection and then become localised.

Toxoplasma gondii can affect the myocardium as the primary target organ as the sole manifestation of the illness or as part of a generalised infection. Toxoplasmic myocarditis varies in its clinical manifestations and severity. It is potentially a curable illness and for this reason early recognition is of paramount importance.[24]

2. Patients and Methods

This study includes 12 patients with heart disease possibly due to toxoplasmosis and their family members; 4 of them were the subject of earlier reports.[14-16] All patients and their families underwent a complete diagnostic evaluation which included a history, physical examination and electrocardiographic, radiological and serological studies. They did not belong to any compact group such as farmers.

The specific serological tests used in the diagnosis were the Indirect Haemogglutination test (IHA) and the Indirect Fluorescent Antibody test (IFA). The IHA was originally devised by Jacobs and Lunde.[8] The test is sensitive and specific and has been employed for diagnosis and sero-epidemiological studies in man and animals.

2.1. Case Reports

2.1.1. *Family A*

*Case A*1 : A 29-year old single male (D.A.) was admitted on 21.2.72 with a history of pain on both sides of the chest and neck of one day duration. The pain radiated down his left arm and was accompanied by sweating.

Examination revealed an average built, anxious individual. The blood pressure was 130/80 mm Hg, pulse 64/min and temperature 98.4° F. Examination of the chest revealed no abnormality in the heart or lungs. An electrocardiogram revealed the following changes : Sinus rhythm, rate 112/min, low voltage complexes, Q waves in L2, L3, AVF, V1–V6 with ST elevation and inversion of T waves (Figure 1), the changes simulating an extensive postero-lateral myocardial infarction. SGOT 90 (23 – 110) units, serum cholesterol 168 mg/100 ml. IHA for toxoplasmosis 1 : 128 and 1 : 128 (2.3.72). He was treated with bed rest and sedation. He made an uneventful recovery. Teleradiogram revealed a slight enlargement of the cardiac shadow with hilar shadowing, and the electrocardiogram a slower heart rate and changes similar to the earlier record before discharge from hospital on 4.3.72.

*Case A*2 : A 32-year old sister of Case *A*1 gave a history of repeated still-births and abortions (6 in all). She was in the 8th month of pregnancy at the time of examination. She had no complaints. Examination revealed no abnormality in her heart or lungs. IHA was 1 : 32 and electrocardiogram showed small Q waves in L1, AVL widened and slurred, QRS complexes with inverted T waves in L1, AVL,V4-V6 and QS waves in V2-V4 (Figure 1B). Pregnancy was terminated by Caesarean Section and a live, normal baby delivered. Histological examination of the placenta revealed no abnormality.

*Case A*3 : A 39-year old sister of Case *A*1 had no symptoms. Her electrocardiogram was within normal limits. IHA was 1 : 1024.

2.1.2. *Family B*

*Case B*1 : A 29-year old man (AWAJ) was admitted on 24.4.70, with a history of severe retrosternal pain radiating down the left arm.

Examination revealed a young man of average build. The pulse was 92/min, blood pressure 170/80 mm Hg and temperature 98.4° F. The heart and lungs were normal clinically. Electrocardiogram showed Q waves in L3, AVF with ST elevation in L3, AVF. SGOT 180 (23 – 110) units, LDH 500 (100 – 400) units. He was treated as a case of acute myocardial infarction.

He was seen again in March 1971 with pain in chest. Electrocardiogram revealed a recent anterior myocardial infarction pattern. He made an uneventful recovery. IHA 1 : 512, IFA 1 : 256 (27.3.71) and IHA 1 : 1024, IFA 1 : 1024 (29.4.71).

He was re-admitted on 23.2.72, with a history of difficulty in breathing of 3 weeks duration. He had been treated by his doctor with Tetracycline and Hetrazan. Radiological examination on admission revealed no abnormality. He was breathless. His jugular pressure was not elevated, the blood pressure was 150/110 mm Hg and pulse 96/min. He was afebrile. The heart sounds were masked by the breath sounds. There were bilateral rhonchi with prolonged expiration in the lungs. The liver was not palpable. He was treated as a case of left ventricular failure with bed rest, diuretices, digitalis, aminophyllin and antibiotics. On the following day, there was no change in his condition with much cough and profuse expectoration. Electrocardiogram revealed sinus rhythm, rate 84/min, and changes consistent with old anterior and posterior infarction. The blood pressure was 130/80 mm Hg. As he showed no improvement Ampicillin and Cloxacillin were substituted for Tetracycline. An X'ray done on 1.3.72 showed no cardiac enlargement but a homogenous shadowing of both lung fields. White blood cell count was 9,600/mm,^{3} N 40% and E 9%. His condition remained the same and he continued to cough up whitish expectoration. On 4.3.72 he was given Prednisolone (30 mg daily) when he showed improvement with reduction in the cough, sputum and breathlessness. An X'ray done on 6.3.73 was normal. He was sent home on 7.3.72 and since then there has been no recurrence of symptoms. SGOT units, IHA 1 : 512.

*Case B*2 : A 24-year old wife of Case *B*1 had no complaints. Electrocardiogram showed low voltage complexes, broad and slurred QRS, low and flattened T waves. IHA 1 : 256 and IFA 1 : 256.

*Case B*3 : A 1-year old male child of Case *B*1 had a meningomyelocele at birth and was operated on. He had no other abnormality. No serological test was done.

2.1.3. *Family C*

*Case C*1 : A 26-year old male (SHPT-25669) was admitted with pain in chest and breathlessness. He was afebrile and no abnormality was detected. On the following day his pulse was 124/min, regular and blood pressure 130/80 mm Hg. There were no murmurs. That evening a pericardial rub was heard. He complained of pain in the back and had swelling over both buttocks. His temperature was 100° F and continued to remain so for the next 4 days. On the 10th day of his illness, a gallop rhythm was heard. Electrocardiogram showed sinus rhythm, QS waves in L1, AVL, V1-V4 with widened QRS complexes, ST elevation in L1, AVL, V1-V4. Serum cholesterol 284 mg%, ESR 8 mm, SGOT 240 (23-110) units. X'ray of chest revealed no abnormality. HAI for Arbo viruses was negative. IHA 1 : 64, IFA not done (12.9.72) ; IHA 1 : 64, IFA 1 : 256 (27.9.72) ; IHA 1 : 1024, IFA 1 : 512 (26.10.72). He made an uneventful recovery.

He was seen again on 20.2.73 when he had no symptoms. IHA 1 : 256 and IFA 1 : 256. The electrocardiogram showed right bundle branch block, QS waves in V2-V6, X'ray revealed no cardiac enlargement.

Case C2 : Father of C1 aged 65 years with no symptoms. There was no history of chest pain. IHA 1 : 64, IFA 1 : 256 (16.10.72) and IHA-ve, IFA 1 : 64 (22.2.73). The electrocardiogram showed QS waves in L3, AVF, V1, V2, Q in V4, notched T waves in V1 and V2. T inversion in L1, AVL, V4-V6.

Case C3 : Mother aged 55 years with no symptoms. IGA 1 : 128, IFA 1 : 128 (16.10.72) and IHA 1 : 64, IFA 1 : 64 (20.2.73). Electrocardiogram was within normal limits.

Case C4 : Elder sister aged 35 years with no symptoms. IHA 1 : 64, IFA 1 : 64 (6.10.72).

Case C5 : Younger sister aged 23 years with no symptoms. IHA 1 : 64, IFA 1 : 64 (16.10.72) and IHA -ve, IFA 1 : 128 (20.2.73). ECG was within normal limits.

Cases C6 and C7 : Children of *C4* aged 5 and 4 years. Serology negative.

Case C8 : Servant aged 15 years with no symptoms. Serology negative.

The patients *D1*, *E1* and *F1* have been described in detail elswehere.[14,15] Only brief mention of the salient features will be made here.

2.1.4. *Family D*

Case D1 : A 29-year old male was seen on 5.7.71 in congestive heart failure. He had been in good health until 10 months earlier when he began to develop breathlessness on exertion followed by oedema of his lower limbs. Examination revealed a patient in congestive heart failure. Electrocardiogram showed sinus rhythm, right axis deviation, broad P waves, slurred QRS complexes, QS waves in L1, AVL and V4 with low T waves. X'ray showed enlargement of his cardiac shadow. IHA 1 : 512, IFA 1 : 32 (5.6.71) and IHA 1 : 1024, IFA 1 : 256 (28.7.71).

2.1.5. *Family E*

Case E1 : Female aged 32 years was seen in cardiac failure. She gave a history of breathlessness and swelling of legs over the last 3-4 years. Electrocardiogram showed complete left bundle branch block and left ventricular hypertrophy. X'ray showed cardiac enlargement CTR 12.5.22. IHA 1 : 512 (9.11.69) and 1 : 486 (22.12.69. She died a few months later following a cerebral embolus.

2.1.6. *Family F*

Case F1 : A 30-year old male (S) was admitted with a history of breathlessness of about 4 months duration. A diagnosis of old myocardial infarction and cardiomegaly had been made in another hospital. He was not in congestive heart failure. Electrocardiogram showed Q waves in L1, AVL and T inversion in L2, L3 AVF, V2 and V4. X'ray showed an enlarged heart shadow (CTR 15 : 22) and pulmonary congestion IHA 1 : 164 (9.11.69) and 1 : 162 (22.12.69).

The serological finding and electrocardiographic changes of the members of Families *D*, *E* and *F* are shown in Table 1.

TABLE 1. Serological and electrocardiographic findings in Families D,E,F.

Relationship	Serology IHA	Serology IFA	Electrocardiographic findings
Family D			
Patient *D1*	1 : 2048	1 : 256	RAD, broad P waves, slurred QRS complexes, QS waves in L1, AVL, V4 low T waves
Wife (24) *D2*	-ve	-ve	low flattened T waves.
Son (2½) *D3*	-ve	1:2	ND
Daughter (1½) *D4*	-ve	-ve	Q waves in L3, notched T waves V2 V4.
Family E			
Patient *E1*	1 : 512	ND	LBBB and LVH
Husband (40) *E2*	1 : 64	ND	normal limits
Son (14) *E3*	-ve	ND	prominent Q waves
Daughter (12) *E4*	-ve	ND	T inversion in L3, AVF, LVH
Son (9) E5	-ve	ND	prominent Q waves
Family F			
Patient *F1*	1 : 164	ND	Q waves and inverted T waves
Wife (25) *F2*	-ve	ND	not done

ND not done.

2.1.7. *Family G*

Case G1 : A 40-year old single male was admitted on 3.3.72, with pain in chest from 8.2.72. The pain was inframammary with no relation to effort. There was no abnormality in the heart or lungs. Electrocardiogram showed Q waves in L3, AVF, low and flattened T waves in L2, L3, AVL and AVF. X'ray showed minimal cardiac enlargement with hilar congestion. WBC 6,400 mm^3, N 69%, L 28%, E 3%, ESR 15 mm, SGOT 60 units, IHA 1 : 128, IFA 1 : 128 (16.3.72) and IFA 1 : 64 (18.4.72).

2.1.8. *Family H*

*Case H*1 : A 30-year old single male (USA) was admitted with retrosternal pain of 4 days duration. No abnormality was detected in his heart or lungs. SGOT 90 units (23-110 units). ESR 3 mm, WBC 11,200 mm^3, N 50%, L 39%, E 11%. Electrocardiogram showed low voltage complexes, widened QRS complexes, low T waves in L1, L2, AVL with T inversion in AVF. IHA 1 : 128, IFA 1 : 32 (10.4.72) and IHA 1 : 64, IFA 1 : 64 (11.5.72).

2.1.9. *Family I*

Case I 1 : (*GS.*) This case has been described in detail elsewhere.[16] Male aged 22 years was admitted with breathlessness, fever and cough. On admission he was febrile with an extensive pericardial rub. A tentative diagnosis of tuberculous pericarditis was made. ESR 15 mm, WBC 5,400 mm^3, N 51%, L 46%, E 3%, Mantoux negative, ECG revealed auricular fibrillation with non-specific T wave changes. X'ray showed an enlarged heart shadow, the lung fields were clear. IHA 1 : 64, IFA 1 : 32 (23.5.71) and IHA 1 : 64, IFA 1 : 4096 (4.7.71). Five months later, a diagnosis of constrictive pericarditis was made and was referred to the Thoracic Surgeon and a pericardectomy was done. Histology of the pericardium revealed non-specific changes.

Case I 2 : Grandmother. IHA 1 : 128, IFA 1 : 32.

Case I 3 : Mother. IHA, IFA -ve.

Case I 4 : Brother. IHA 1 : 128, IFA 1 : 256.

2.1.10. *Family J*

*Case J*1 : This case has been described in another communication.[15] A 23-year old male was admitted on 9.9.69 with a hemiplegia of sudden onset. Clinically there was no abnormality in the heart. Electrocardiogram showed prominent Q waves in L2, L3, AVF with notched inversion of T waves in L2, L3, AVF, V2-V6. X'ray of chest and skull revealed no abnormality. IHA 1 : 512 (1.10.69) 1 : 4096 (9.11.69) 1 : 1456 (22.12.69) 1 : 128 (21.12.70) and -ve (25.5.71) and IFA 1 : 32.

The serological findings and electrocardiographic changes of some members in this family over a period of 21 months are shown in Table 2.

TABLE 2. Serological and electrocardiographic findings in Family J.

Relationship	Serology* IHA	Serology* IFA	ECG	Serology** IHA	Serology** IFA	ECG
Patient	1 : 4096	ND	Prominent Q waves, notched T waves	-ve	1 : 32	Prominent Q waves, T waves normal
Step-brother	1 : 4374	ND	same changes	1 : 64	1 : 256	same changes
Step-brother	-ve	ND	same changes	ND	ND	same changes
Father	1 : 162	ND	normal	1 : 32	1 : 4	normal
Step-brother	1 : 2	ND	Prominent Q waves, inverted T waves	-ve	1 : 64	Prominent Q waves, inverted T waves

* done at onset of illness (1.10.69)
* 21 months later (25.5.71)
ND not done.

2.1.11. *Family K*

Case K1 : A 48-year old male (SPRW) was admitted with hypertension. He complained of right-sided headache. Examination revealed a blood pressure of 190/95 mm Hg. There was no abnormality in the heart or lungs. The femoral arterial pulsations could not be felt on both sides. No bruit was heard over the abdomen or back. Ocular fundi : Grade 0-1 retinopathy. ESR 22 mm, Blood urea 40 mgm 100 ml, WBC 14,200 mm^3, N 76%, L 20%, E 4%, total proteins 6.7 gm 100 ml, Albumin 4.2 and globulin 2.5, Serum cholesterol 210 mg 100 ml, Latex flocculation test -ve ECG : low voltage complexes with widened and slurred QRS complexes in most leads. X'ray revealed no cardiac enlargement of the cardiac shadow with slight unfolding of the aorta. Arteriogram could not be done as he was sensitive to the dye. IHA 1 : 128, IFA 1 : 256.

2.1.12. *Family L*

Case L1 : A 45-year old male (NGF) was admitted with a history of palpitations of sudden onset. He had had similar epsiodes 2 years earlier. Examination revealed that he had auricular fibrillation and a mid-diastolic murmur, ECG showed auricular fibrillation and ischaemic T wave changes. X'ray showed enlargement of the heart shadow with 'mitralisation'. Screening revealed an enlarged left auricle, right ventricle and a quiet heart. IHA 1 : 256.

Case L2 : Wife aged 35 years had no complaints. Electrocardiogram showed rSR complexes in L3, AVF with fiat T waves. IHA 1 : 64.

3. Results

The study revealed a spectrum of clinical manifestations of varying severity. The following classification of the disease spectrum to include the various clinical forms encountered has been adopted (Table 3).

TABLE 3. Classification.

Acute myocardial involvement
Chronic myocardial involvement
Pericardial involvement, acute, chronic, constrictive
Asymptomatic
i. abnormal ECG, + ve serology
ii. abnormal ECG, — ve serology
iii. normal ECG, + ve serology
Extracardiac-vascular manifestation— 'stroke', arteritis
Familial heart disease
Summation with other heart disease

3.1. Clinical features

3.1.1. *Acute:* There were 3 patients in this group (*A*1, *B*1 and *C* 1). They were all relatively young and were admitted with severe pain in the chest simulating an acute myocardial infarction. Their electrocardiograms showed sinus tachycardia, low electrical complexes, Q waves, ST-T wave changes and bundle branch block. In 2 patients the transaminase levels were elevated. Their cholesterol levels were normal. The significance of their serological titres will be discussed.

3.1.2. *Chronic:* There were 5 patients in this group (*D*1, *E*1, *F*1, *Q*1 and *H*1). They were all below 40 years. Two had pain in chest, 4 were in cardiac failure when first seen. Laboratory investigations revealed normal erythrocyte sedimentation rates, normal white cell counts and transaminases. Electrocardiograms revealed low voltage complexes conduction defects, Q waves, ST-T wave changes. The cardiac shadow was enlarged in 4 on X'ray with pulmonary congestion in 3. Their IHA titres ranged from 1 : 64 to 1 : 1024 and IFA 1 : 32 to 1 : 256.

3.1.3. *Pericardial involvement:* There were 2 patients (*C*1 and *I*1) who had pericarditis. Case *I*1 subsequently went on to constrictive pericarditis requiring surgery after an illness lasting 8 months. His ESR was normal repeatedly, Mantoux negative and normal white cell counts. There was a rise in the IFA titre from 1 : 32 to 1 : 4069.

3.1.4. *Asymptomatic:* A study of the family members of patients with myocardial toxoplasmosis revealed that the majority had no clinical symptoms though they showed abnormal electrocardiograms with positive serology, abnormal electrocardiograms with negative serology and normal electrocardiograms with positive serology.

3.1.5 *Extra-cardiac manifestations:* *J*1 in this study was a male aged 23 years who was admitted with a stroke. Electrocardiograms showed prominent Q waves in L2, L3, AVF with notched inversion of T. waves in the anterior chest leads. X'ray of the chest showed no abnormality. IHA 1 : 512 and rose to 1 : 4096. In another (*K*1) the femoval arteries were occluded.

3.1.6. *Summation with other heart disease:* Patient (*L*1) who had evidence of chronic rheumatic heart disease on screening had a quiet heart. His wife (*L*2) had a serological titre with minute changes in her electrocardiogram.

3.1.7. *Familial heart disease:* As mentioned earlier, several members had either positive serology with or without electrocardiographic changes. One (*A*2) had repeated still-births and the 7th pregnancy ended in a Caesarian Section. The baby was normal at birth and the placenta revealed no abnormality. Bistologically *A*2 had electrocardiographic changes while her sister had a serological titre of 1 : 1024. but a normal electrocardiogram. In Family *B*, the father and mother had a positive titre and electrocardiographic changes and the child born to them had a meningo-myelocele. A study of other patients in this series show that several members had evidence of infection (past or present) together with electrocardiographic abnormalities.

3.2 Electrocardiographic abnormalities

Table 4 shows the frequency of the electrocardigraphic findings. All 12 patients had ECG abnormalities. Of the 27 family members on whom ECG had been done, 11 had normal records. Little more than half had abnormal electrocardiograms with Q waves and T wave changes being most frequently encountered.

TABLE 4. Frequency of electrocardiographic findings.

Findings	Patients	Family members	Total	
	12	26	38	
Normal	0	11	11	
Atrial fibrillation	2	0	2	
Leftbundle branch block	1	0	1	
Intraventricular conduction defect	3	3	6	
Low voltage complexes	3	3	6	
Q waves	7	11	18	
P wave abnormalities	2	0	2	
L.V.H.	1	1	2	
T wave abnormalities				
Notched	1	7	8	22
Biphasic, inverted flat or low	8	6	14	

4. Discussion

In this study much reliance has been placed on the serological findings in the diagnosis. Testing for toxoplasmosis frequently yields positive results. Only a small number of the patients infected manifest the disease. A purely serological diagnosis can only be made in a current infection when 2 samples show a 4-fold rise or fall in titre. When a single specimen shows a titre above that found in the 'normal' person, a presumptive diagnosis may be made. Though only a rise in antibody titre is proof of active infection, it is unusual for this to be seen in toxoplasmosis because by the time a test is done the patient has often developed a steady high antibody titre. Reliance cannot be placed entirely on serological tests alone for a percentage of adult population shows titres depending on past exposure to toxoplasmic infection. However, very high titres have more significance than low ones.

In Sri Lanka, Kulasiri *et al.*[10] in a study of 1069 sera from predominantly male blood donors aged between 17 to 48 years found a titre of the highest frequency of distribution for IHA to be 1 : 128 and for IFA 1 : 64. According to them, if the titres in both tests were below the respective titres of the highest frequency of distribution the infection could be considered to be at its early stages or it had spent itself. If the values were at or above the respective titre of the highest frequency, a further determination a few weeks later is indicated. An increase of at least a 4-fold dilution would indicate a recent infection. Values of both IFA and IHA over 1 : 4096 would indicate acute or convalescent phase.

Though the IHA appears to be deficient in detecting antibodies in the acute stage of the infection, a good qualitative correlation of this test with the dye test has been reported.[20] However, in evaluating the reliability of the dye test in the laboratory diagnosis of toxoplasmosis, De Saram, *et al.*[4] compared two sets of sera and performed the dye test, complement fixation test, haemagglutination test and indirect fluorescent antibody test in all of them. In the 1st set of 100 sera where the illness was established, aetiology other than toxoplasmosis, 21 sera from 15 patients gave a positive dye test ranging from 1 : 16 to 1 : 512. All 100 sera, however, were negative by the other 3 tests. The 2nd set of sera was from 110 patients unrelated to toxoplasmosis but with dye test ranging from 1 : 16 to 1 : 1024. Only 15 of the sera gave a positive reaction with the other 3 tests (CFT 1:8-1:32, IHA 1:8-1:128, IFA 1:16-1:64). Since there was no clinical evidence of toxoplasmosis in them they were assumed to be the result of past infections. The titres they report are very much lower than those found in this study.

According to Ludlam and Beattie[11] high toxoplasmic antibody level can be due to an anamnestic increase brought about by another infection and vice versa. In a case described by Sabin[22] with pneumonitis due to histoplasmosis the toxoplasma dye test rose from 1:16 - 1:1024.

The antibody titres tend to wane with time and be no higher than in the 'normal' population and according to Beattie[1] normal titres do not exclude the diagnosis of toxoplasmosis as is seen in Family *J* where the antibody titres had fallen to normal after 21 months.

Besides the serological titres there was clinical, electrocardiographic and radiological evidence and this together with the results of the family studies are in support of the diagnosis.

Potts and Wilkinson[19] reported an acute fatal case of myocardial toxoplasmosis in a 30-year old male. He had a febrile illness with bronchitis and was seen in acute pulmonary oedema. X'ray revealed moderate cardiac enlargement and electrocardiogram showed left bundle branch block. Patients (*A*1, *B*1and *C*1) in this study simulated myocardial infarction. Such changes in electrocardiogram, however, are known to occur in conditions other than ischaemia. Gau *et al.*[6] in a study showed that Q wave pattern on the electrocardiogram provided insufficient evidence of ischaemic heart disease. In 6 of their 10 patients with congestive cardiomyopathy and 3 of 8 with hypertrophic obstructive cardiomyopathy the electrocardiograms were misleading. Two had elevated transaminase levels. Coltman[3] has drawn attention to the place of SGOT in the diagnosis of myocarditis. The question is whether serological titres imply that their illness was due to toxoplasmic infection or whether they in fact have acute myocardial infarction due to coronary atherosclerosis or both. It could also be surmised that an infection could precipitate an attack of acute myocardial infarction in a person at risk ; for instance it could alter the fibrinolytic activity of the blood thereby causing clotting. There has been a rise in the titre in patients *B*1 and *C*1 and several members of their families had serological titres with electrocardiographic abnormalities.

The more usual picture is that of chronic heart disease.[15] Pericarditis has been observed as part of a generalised infection[9] or as an isolated infection.[7] That toxoplasmosis can lead to constriction is not yet certain[24] but Jones *et al.*[9] reported a case where at pericardiotomy for cardiac tamponade there was pericardial thickening.

Paulley *et al.*[17,18] described 5 cases. One of them was a young man of 24 whose mode of presentation was that of patient *J*1 in this study. His sister too died of an embolus. Toxoplasmosis may be one cause of a 'stroke' in a young adult (Cases *E*1 and *J*1) and of sudden death. Intracardiac thrombi and embolisation are not uncommon in cardiomyopathies. Ready *et al.*[21] suggested that toxoplasma infection may be an aetiological factor in nonspecific aortitis when the aorta and branches may be involved.

Very little is known about the effect of various infections in a patient with pre-existing heart disease. Toxoplasma may be contributing to the 'myocardial factor' associated with other forms of heart disease.

A familial incidence with cardiomegaly, electrocardiographic changes and serological titres in several members is seen at times.[15,17,18] In one of the families studied by Paulley *et al.*[17,18] the mother of the patient and a brother had died at 39 and 16 years respectively and at autopsy the hearts were enlarged. One other sister who had a right bundle branch block on the electrocardiogram died suddenly with embolism. Two other sisters had abnormal electrocardiograms, one with positive, the other negative serology. Similar findings were seen in the families studied by others. Paulley *et al.* [17,18] have stressed that toxoplasmosis should be excluded in all forms of obscure cardiomyopathy especially familial cardiomegaly.

The electrocardiogram shows disturbances of rates, rhythm, conduction defects and abnormalities such as ventricular hypertrophy, Q waves and low electrical complexes. Notched T waves and Q waves were encountered in several patients and members of their families.

Clinical and pathological studies over several years indicate that coronary artery disease in general and myocardial infarction in particular are relatively uncommon in Jamaica. Population studies, however, have shown that the findings of 'ischaemic' ECG changes are common. It is also known that electrocardiographic changes characteristic of infarction can occur in Jamaican cardiomyopathy. Further population studies have revealed that Q waves show an invariably high proportion in which muscle damage is in the anteroseptal region possibly suggesting focal ischaemic necrosis associated with disorder of the small coronary arteries. It was considered possible that some other myocardial disease simulating ischaemia contributed to these epidemiological findings.[25]

More recently, in a reappraisal of cardiovascular surveys in Jamaica by Miller and Ashcroft[12] it was found that many who were thought to have idiopathic cardiomegaly or an obscure form of ischaemic heart disease based on unexplained electrocardiographic abnormalities were subsequently found to have no clinical abnormalities. They were of the opinion that in their study there was no evidence as to whether the electrocardiographic changes were related to ethnic or to environmental factors.

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Cyanogenic Glucoside Content of Manioc
II. Detoxification of Manioc Chips and Flour

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Abstract : *Manihot esculenta* Crantz contains cyanogenic glucosides which remain unhydrolysed even after processing to manioc flour unless special precautions are taken. This paper presents a method by which the total cyanide content of manioc chips and flour can be reduced to approimately 5% of the original value. All assays of bound cyanide and total cyanide were done after the enzymic release of cyanide from linamarin.

1. Introduction

Manioc, *Manihot esculenta* Crantz, contains cyanogenic glucosides (linamarin and lotaustralin) which on interaction with the enzyme linamarase liberate hydrogen cyanide. Most methods of detoxification[2] are based either on destroying linamarase (boiling) or by allowing enzyme and substrate to interact (crushing, grinding, etc.) and driving off the HCN formed. The former method has the disadvantage that considerable quantities of cyanogenic glucosides may remain unhydrolysed;[4] the toxicity (direct or indirect) of these glucosides on ingestion is difficult to evaluate.[3] The second method is enzyme dependent and as the quantity of enzyme in the edible part of the tuber varies considerably from variety to variety,[1] on occasion long incubation periods have to be given in order to reduce the total cyanide content to relatively low values. In addition, handling and redrying crushed or ground material is a rather troublesome operation.

Recently, Rajaguru[5] outlined a process by which manioc chips can be detoxified. His process as described involved drying chips at 100 to 120°C, soaking the dried chips in water (18 to 24 h) and redrying at the same temperatures. This resulted in a product with very low total cyanide content, but it had an undesirable appearance caused by the harsh conditions of processing.

This paper describes a modification of the Rajaguru[5] method, data being presented on the detoxification of manioc chips by the use of different conditions of drying and varying periods of soaking. As a result of this study, it is possible to predict the minimum conditions required for processing manioc chips such that the total cyanide

*Studies in connection with Section 3.2 will form part of a M.Sc. dissertation (University of Sri Lanka, Colombo Campus) of Nirmala Pieris.

content of the chips is reduced to the relatively low levels of 5 to 10 p.p.m. In addition, the study has given some insight into the mechanism of detoxification of this " dry-soak-dry " technique. Measurements of total cyanide and bound cyanide were done after *enzymic* release of cyanide;[4] this analytical technique confers an added advantage over previous studies concerned with the detoxification of manioc.

2. Experimental

2.1. Preparation of material

The edible part of raw manioc (20 to 40 kg) was chipped into slices approximately 3 mm thick. These were dried (unless otherwise specified) in a forced-draft oven at different temperatures.

Manioc flour was prepared by grinding the dried chips (6 to 14% moisture) in an edge runner mill.

2.2. Sampling

The chips were sampled at random and the adequacy of sampling tested by determination of the cyanide content of a series of samples followed by the determination of the standard deviation of the sampling procedure. Sample size was in the order of 100 to 250 g (dried chips) or 200 to 500 g (wet chips) ; the total number of chips was 50 to 125.

2.3. Detoxification procedure and assays

Chips dried as described in text were soaked in 10 times their weight of water in an open vessel for 2 to 24 h ; duplicate experiments were carried out for each soaking time. The soak water (200 ml) was examined for free cyanide and bound cyanide.[4] The total cyanide[4] of the homogenised wet chip (samples of 15 to 20 g dry weight) was also determined. The soaked chips were then dried under various conditions (see 3 Results) for 24 h, ground into flour and the total residual cyanide determined (15 g samples). This method of assay is not reliable for values below 8 p.p.m.

3. Results

3.1. Sampling

Batches of dried chips sampled by the procedure outlined gave the results shown in Table 1, which show that the sampling procedure adopted was adequate.

TABLE 1. Sampling of dried manioc chips.

Batch No.	Cyanide content (p.p.m. dry wt)
1	209 ± 11
2	64 ± 4
3	138 ± 7
4	101 ± 6
5	135 ± 13

See Section 2.2 for details.

3.2. Effect of conditions of drying of fresh chips on total cyanide content

Studies on this aspect showed, as expected, that drying conditions (temperature and rate of drying) have effect on the cyanide content of the dried chip (Table 2). Use of a forced-draft oven induces a faster rate of drying and generally less loss of cyanide when compared with the still oven at the same temperatures.

TABLE 2. Effect of drying conditions on cyanide content of chips.

Batch		1			2			3		
Type of oven		A	B	B	A	B	B	A	A*	A
Temperature		55°	80°	100°	70°	70°	100°	60°	65°	100°
Cyanide content	1	142	254	155	273	116	85	496	504	480
(p.p.m. dry wt)	2	133	267	164	253	127	99	461	482	475

Original total cyanide (p.p.m. dry wt) of fresh chips was 207 ± 25, 270 ± 55 and 426 ± 39 for batches 1, 2 and 3 respectively.

A Forced draft oven
B Still oven
A* Dried for 7 h, left overnight and redried.

Other results show that sun drying of chips gives about the same total cyanide as drying at 55° in a forced draft oven. It is likely that the values obtained for fresh manioc are low, due to losses during homogenisation of the large samples used. The large standard deviations obtained for the fresh material probably arise as a result of difficulties in handling the large samples of homogenised material, a part of which has to be introduced into the distillation flask as quickly as possible.

3.3. Effect of soaking time of the dried chip on total cyanide content

Chips from separate batches of manioc were sun-dried (3 days) or oven dried (24 h) at 55°, 75° and 95°C. Results (Tables 3 — 6) showed that : (1) whatever the drying conditions, both free cyanide and glucoside diffuse out of the cells, (2) as soaking time increases there is a gradual conversion of bound cyanide to free cyanide, (3) increase in soaking time results in lower cyanide content in the redried chip and (4) the higher the temperature of the second drying, the lower the cyanide content of the dried chip.

TABLE 3. Cyanide distribution after soaking in water.

	Cyanide content (p.p.m. relative to original dry wt)					
	Wash water		Wet chip	Dry chip* (total CN)		
Soak time (h)	Free	Bound	(total CN⁻)	Sun	55°	100°
3	25	50	34			23
6	46	63	27	24		10
9	53	41	11 (?)	14	8	
12	60	24	24	5		
18	71	12	14		10	

Chips used were sun dried. For experimental details see Section 2.3.
*The second drying was performed at the given conditions.

TABLE 4. Cyanide distribution after soaking in water.

Soak time (h)	Cyanide content (p.p.m. relative to original dry wt)			
	Wash water		Wet chip	Dry chip
	Free	Bound	(total CN⁻)	(total CN⁻) (55°)
2	15	21	21	10
4	39	11	15	14
8	46	3(?)	21	08
12	46	9	15	11
16	41	5	21	06
20	34	3	14	05
24	25	2	11	05

Chips used were dried at 55°C. For experimental details see Section **2.3**.

TABLE 5. Distribution of cyanide after soaking in water.

Soak time (h)	Cyanide content (p.p.m. relative to original dry wt)				
	Wash water		Wet chip	Dry chip	
	Free	Bound	(total CN⁻)	(total CN⁻) 55°	95°
3	39	44	38	16	
6	62	29	28		9
9	64	17	28		5
13	79	05	28		2
18	75	05	25	6	

Chips used for the experiment were dried at 75°C. For further experimental details see Section **2.3**.

TABLE 6. Distribution of cyanide after soaking in water.

Soak time (h)	Cyanide content (p.p.m. relative to original dry wt)			
	Wash water		Wet chip	Dry chip
	Free	Bound	(total CN⁻)	(total CN⁻) 60°
3	67	20(?)	21	11
6	78	22	20	9
10	98	10	16	7
14	96	08	19	6
24	88	08	19	

Chips used were dried at 95°C. For further experimental details see Section **2.3.**

The ratio of free cyanide to bound cyanide (a reflection of enzyme activity) appears to depend mainly on the material rather than the drying temperature. In other words, the original level of enzyme in the plant material appears to be more important than the variation in the extent of enzyme denaturation during the different drying conditions used in the preparation of chips. This is easily seen when the data in Table 4 are compared with those in Table 7 where although in both sets of data the chips have been dried at 55°C the bound cyanide in the latter is converted to free cyanide very slowly.

TABLE 7. Nature of cyanide in wash water using chips dried at 55°C.

	Cyanide content of wash water (p.p.m. relative to original dry wt)	
Soak time (h)	Free	Bound
6	32	149
12	104	133
18	169	70
24	152	83

For further experimental details see Section **2.3.**

4. Discussion

The level of cyanide in dried chips (of the same batch) depends on the extent of interaction between enzyme and substrate. Increase in drying temperature will affect this interaction by : (1) increasing disorganisation of the intracellular structure of cells and hence promoting contact between enzyme and substrate, (2) increasing rate of reaction over the range of temperature where the enzyme is not deactivated and (3) increasing rate of drying of tissue and therefore reducing interaction. It appears from this study that rate of drying is the vital factor. Quick drying in a forced draft oven results in very little loss of cyanide. Results using the closed oven (slower drying) are more difficult to interpret. These results are interesting and deserve further investigation.

These studies have also cleary shown that the "dry-soak-dry" technique can be used to reduce the total cyanide in chips to only 5 to 10 p.p.m. (about 5% the original levels).

The mechanism appears to operate as follows :—

(i) Loss of moisture from the chips (initial drying) causes an increase in permeability of the cell membrane.

(ii) Soaking in water (3 to 6 h) results in the loss of diffusible material (redrying of soaked chips have shown a 7 to 10% loss in dry weight) including free cyanide and cyanogenic glucosides; the loss of total cyanide is therefore largely enzyme independent.

(iii) Continued soaking in water does not significantly alter the residual total cyanide in the chip but has been shown to result in a conversion of bound cyanide to free cyanide in the wash water (a similar situation probably exists in the state of cyanide within the chip). This conversion is probably brought about by released linamarase. This happens even in the chips dried at 95°C showing that although isolated linamarase in solution is deactivated within 3 min at this temperature it is much more stable within the tissue.

(iv) Redrying of the chip brings about further loss of free cyanide. Raising the drying temperature lowers the total cyanide content still further. This is probably due to facilitation of the decomposition of acetone cyanohydrin.

On the basis of these studies we predict that sun drying, soaking in water for 9 to 12 h and sun drying again would reduce the total cyanide content of chips to about 10 p.p.m. A short oven drying at 100°C is likely to halve this value. The advantages of such a process would be : (1) it is largely enzyme independent and variation in internal levels of linamarase will not appreciably affect the final result, (2) the quality of the flour produced is satisfactory and (3) the process is cheap and can be carried out with minimum machinery at the site of production.

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A Shortened Method for the Separation and Estimation of Plasma Phenylalanine and the Establishment of the Clinical Norm for Ceylonese Subjects

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Abstract : A method is described by which phenylalanine in blood can be separated and quantitatively estimated with reliability using thin layer chromatography. Silica Gel-G was used as the adsorbent and n-butanol/acetic acid/water (4 : 1 : 1) as the developing solvent. The method was sensitive enough to detect quantities as low as 0.5 μ; the volume of serum required was 4 μ (0.004 ml) and the time taken for the entire estimation was less than 3 h. The clinical norm for Ceylonese children, determined by using this method, is reported. The values of serum phenylalanine range from 0 to 16 mg/100 ml with a mean of 7.07 $\pm$ 4.86. Two positive cases of phenylketonuria, belonging to the members of a single family are also reported.

1. Introduction

Phenylketonuria is an inborn error of metabolism characterised by the failure to metabolise the amino acid, phenylalanine. The serum phenylalanine rises and neurotoxic metabolites are formed which cause mental deficiency. Phenylketonuria is treated by a low phenylalanine diet which should be started at the age of a few weeks. This condition is detected by testing of the urine for phenylpyruvic acid and finally confirmed by the testing of the serum for phenylalanine levels.

The basic screening test is the detection of excess of phenylpyruvic acid in urine with ferric chloride.[9] This test should be carried out with fresh urine since atmospheric oxygen oxidizes the acid. Further, as phenylpyruvate only appears in the urine 2 or 3 weeks after birth, the test is done up to 4 to 6 weeks. Therefore, an increase in the blood phenylalanine gives an earlier indication of the deficiency and is used in the case of new born siblings of identified cases.

The methods available at present are the agar diffusion microbiological method,[4] thin layer chromatography on cellulose layers impregnated with cyclohexylamine,[7] paper chromatographic method,[9] Colorimetric method,[1] the fluorimetric method,[2] and the enzymic method.[6]

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There is a need for a rapid method suitable for very small quantities of serum/plasma to separate and estimate quantitatively phenylalanine without deprotenizing or desalting. This paper describes the successful application of the thin layer chromatographic technique in a new solvent system and its value for the separation of phenylalanine in particular and its probable value for many other amino acids.

Some of the findings have been previously reported.[8]

2. Materials and Methods

2.1 Chromatoplates

The chromatographic plates used for thin layer were of glass (20 cm × 20 cm) with Kiesel Gel G (Nach Stahl) as the adsorbent. The Gel (30 g) was made into a slurry using a mixture of ethanol (72 ml) and water (8 ml). With this quantity we were able to obtain 5 plates of 0.2 mm thick gel layer ; the slurry was spread on the glass plates using a Desaga Spreader.[5] The plates were then dried at room temperature in the open, for 30 min and subsequently dried at 110°C for another $\frac{1}{2}$ h before storing in a Desaga drying cabinet. A sharp boundary of 2 mm of each edge of the layer was made possible by wiping the edges with a grooved cork ; a line 10 cm from the edge was also marked.

2.2. Application of sample

Standard solutions of the amino acids were prepared in double distilled water (500μg/ml); the insoluble amino acids were dissolved with the aid of dilute Na_2CO_3 solution and subsequently neutralised with dilute HCl. The chromatoplate was divided into 9 equal strips using a fine needle and then the standard solution of the amino acid was applied on each strip using a 10μl pipette to deliver the sample. With phenylalanine varying amounts ranging from 0.5 to 2.0 μg were applied with care so that the diameter of the spot was less than 4 mm and the spots were in one horizontal line. The plates were irrigated with n-butanol/acetic acid/H_2O (4 : 1 : 1) for about 1 h during which period the solvent front moved 10 cm from the starting line ; the tank was equilibrated with the same solvent system over-night before use. The plates were dried and the amino acid detected by spraying with ninhydrin (BDH ninhydrin spray can) and drying at 120°C for 10 min. The spots appeared reddish on the white background. The intensity of the colours of the spots was found directly proportional to the amount of phenylalanine. However, with more than 3μg (6μl) of the amino acid it was difficult to estimate the quantity by the intensity of the colour produced by the spot.

Among various types of adsorbent and different solvent systems tried, Kiesel-Gel G adsorbent with n-butanol/acetic acid/water in the proportion of 4 : 1 : 1 was found to give the best separation for this particular purpose, because most amino acids present in the serum of human blood either had very low or very high R_F values, whereas phenylalanine had an R_F value in the region of 0.65 to 0.68.

2.3. Quantitative estimation of phenylalanine in human blood

In the 4 strips of the chromatoplate were placed phenylalanine standards, viz 1, 2, 3 and 4 μl of a solution of phenylalanine ($1\mu l = 0.5\mu g$) while in the next 5 strips were placed samples of serum ($4\mu l$) to be tested. The plates were then subjected to ascending chromatography using the solvent system described above. After the solvent front reached the 10 cm mark the plates were removed and the spots located. Normal samples of serum (4 μl) produced the same intensity of the spot obtained with 1 μl or less of the standard ; i.e. the normal value of phenylalanine in the serum is 12.5 mg%.

3. Results and Discussion

The one dimensional thin layer chromatographic separation of phenylalanine is shown in Figure 1. The amount of phenylalanine present in $4.0\mu l$ (0.004 ml) serum was estimated by this procedure. The quantitative estimation was made possible by comparing the intensity of the spots of the unknown with the intensities of known quantities of the phenylalanine. Attempts made to quantitate the method, by scraping off the spots, eluting, centrifuging and measuring in a colorimeter, have been unsuccessful. This was mainly due to the small amounts of standards used (0.2 to 1.0 μg) in the method.

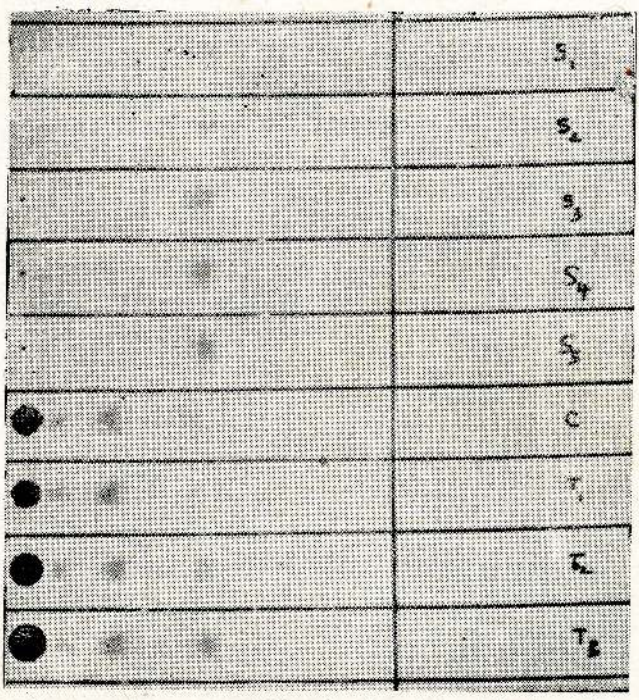

FIGURE 1. Thin layer chromatographic separation of phenylalanine in human serum.

Adsorbent Kiesel-Gel G, Solvent -n-butanol/acetic acid/water (4 : 1 : 1). Amino acids detected by spraying with ninhydrin and drying at 120°C.

S Standard phenylalanine expressed in mg%.
S_1, S_2, S_3, S_4, and S_5 = 12.5, 25.0, 37.5, 50.0 and 62.5 mg%.
C Control serum
T_1 Test sample of case (1), Table 1. Phenylalanine deficient diet for 7 days.
T_2 Patient fed on full cream milk for 12 days.
T_3 Patient again on phenylalanine deficient diet for 2 weeks.
(c.f. Table 1, case (1), experiments II, III and IV).

Among the many methods which are available for the estimation of phenylalanine of blood, the paper chromatographic method[9] needs comparison with the thin layer method described in this paper. The experimental details of the 2 methods are tabulated below.

	Chromatography	
	Thin layer	Paper
1. Solvent system	Butonal/acetic acid/H_2O (4:1:1)	Butonal/acetic acid/H_2O (4:1:5)
2. Number of runs	One dimentional	Two dimentional
3. Volume of serum requried	4 μl (0.004ml)	250 μl (0.25 ml)
4. Sensitivity of the method	0.5 to 2.0 μg	10 to 50 μg
5. Time taken to develop the chromatogram	90 min	48 h
6. Time taken for the whole estimation	3 h	54 h

The above tabulation reveals that the thin-layer method although open to errors associated with "eye estimation" of colour and not made quantitative by calorimetry, yet is very rapid and requires only one sixtieth of the serum necessary in the paper method. It should be emphasized that this test is normally carried out on new born babies and hence the volume of blood necessary is a key factor. The 4 µl serum necessary for the test can be obtained from the finger prick while the 250 μl serum necessary for the paper could only be obtained by venepuncture. This method is therefore very simple and can be adopted routinely in most of the provincial pathological laboratories.

The validity of the method was checked by 2 procedures : (1) by carrying out the clinical norms ; no sample gave more than 16 mg% (w/v) and (2) two children in the same family with phenylketonuriya were investigated for phenylalanine levels before and after feeding with phenylalanine rich and deficient milk. The results (Table 2) show that when the children were fed with phenylalanine deficient milk, the phenylalanine levels of the blood fell to 6 and 8 mg%. However, when they were fed with the normal full cream milk, the values rose to 50 and 40 mg%. Therefore this method is quite accurate enough to detect small changes in the phenylalanine levels of blood.

3.1. Clinical norms for Ceylonese children

All blood samples tested were obtained from children of both sexes of the age group 3 months to 6 years, who were warded at the Lady Ridgeway Hospital, Colombo, for various ailments ; the group did not include those who showed any signs of phenylketonuria. Fifty samples of blood were estimated for phenylalanine content. The value of serum phenylalanine ranges from 0 to 16 mg/100 ml with a mean of 7.07 ± 4.86 mg/100 ml.

3.2. Changes in serum phenylalanine content with diet of cases of phenylketonuria

Two cases of phenylketonuria in the same family were investigated. The changes in serum phenylalanine of these 2 subjects with diets deficient in phenylalanine (Lofenalac) is reported in Table I.

TABLE 1. Cases of phenylketonuria and changes in serum phenylalanine content with diet.

Case (1)

	Age	Date of collection of blood	Diet	Serum Phenylalanine (mg/100 ml)
(i)	1 yr 7 months	5.6.69.	Full Cream milk	25
(ii)	1 yr 7 months	12.6.69.	*Phenylalanine deficient milk	6
(iii)	—	24.6.69.	Full Cream milk	50
(iv)	—	8.7.69.	*Phenylalaine deficient milk	12.5
(v)	—	13.7.69.	—do—	10
(vi)	—	2.8.69.	—do—	10

Case (2)—Sister of Case (1)

	Age	Date of collection of blood	Diet	Serum phenylalanine (mg/100 ml)
(i)	5 days old	26.6.69	Breast fed	25
(ii)	8 days old	1.7.69	Breast fed	40
(iii)	15 days old	13.7.69	*Phenylalanine deficient diet	16
(iv)	40 days	30.7.69	—do—	8

Clinical norm for Ceylonese children 7.07 ± 4.86
Range : 0—16 mg phenylalanine/100 ml.
*(Lofenalac)

3.3. R_F values of other amino acids

In order to ascertain that the other amino acids had no effects on the separation, pure samples of 24 amino acids were tested. Of these 24 amino acids, 10 are known to be concerned in metabolic diseases.[3] The R_F values are provided in Table 2 Of the 24 amino acids tested only phenylalanine had an R_F of 0.67 while all others had values ranging from 0 to 0.73.

TABLE 2. R_F — Values of amino acids in human plasma after spraying with Ninhydrin — Thin layer

Amino Acid	RF — Values
Asparagine	0.22
Alanine	0.29
Aspartic acid	0.24
Amino-butyric acid	0.33
Arginine	0.09
Cystine	0.11
*Citrulline	0.22
Glutamic acid	0.36
*Glycine	0.23
Glutamine	0.20
*Histidine	0.09
*Leucine	0.62
*Iso-Leucine	0.57
Lysine	0.09
*Methionine	Did not move
Ornithine	0.07
*Phenylalanine	0.67
*Proline	0.21
Serine	0.24
Threonine	0.31
Taurine	0.30
Tryptophane	0.72
*Tyrosine	0.60
*Valine	0.44

* Amino acids known to be concerned in metabolic diseases.

Acknowledgements

The authors are indebted to Drs. Stella de Silva and F. Jayakoddy of the Lady Ridgeway Hospital, Colombo for the supply of blood samples for this investigation, Mr. D. D. Jayatillake for carrying out the statistical analysis, and to Mr. Surenthiranathan for taking the photograph of the chromatogram.

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Essential Oils

III. Chemical Constituents of the Volatile Oil from the Bark of a Rare Variety of Cinnamon †

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Abstract : Gas liquid chromatographic studies on the steam-volatile bark oil of an exotic variety of cinnamon (probably *Cinnamomum capparu-coronde* Bl.) have revealed the presence in it of linalool (29%), eugenol (23%) and 1 : 8 cineole (16%) as major constituents. This variety has a totally different chemical composition to the bark oil of traditional cinnamon (*C. zevlanicum*). The plant is of interest with respect to the biosynthesis of these compounds and to the potential use of this oil and its constitutents in perfumery.

1. Introduction

The study of the steam-volatile bark oil of an exotic variety of cinnamon was initiated during a detailed study of the chemistry of the steam volatile oils from commercial cinnamon viz : *Cinnamomum zeylanicum* Blume.[7] During the collection of samples for this study,[7] bark of this exotic variety was supplied to us by a collector in the Karandeniya area in the Ambalangoda district. Authentic samples used for the present study were collected from the Bambarawana hills in the same district by one of us (A. L. Jayewardene). The exact botanical identification of the specimen was not available at this stage but it was introduced to us by the Sinhala name *Kapuru kurundu*. Recently, Kostermans[3] has described the botanical features of " a forgotton Ceylon cinnamon tree " to which he attributes the botanical name *Cinnamomum capparu-coronde* Bl., a variety first described by Blume in 1836. Kostermans has identified this variety as that bearing the Sinhala name *Kapuru kurundu* (or camphoraceous cinnamon) which name he contends had been distorted to " capparu-coronde " by Blume. Incidentally the odour attributed to the bark of this tree was that of " cloves " and strangely not that of camphor, which the Sinhala name would lead one to expect. The description of the leaf given by Kostermans tallies with our own herbarium pressing of the variety *Kapuru kurundu* investigated by us. However, Kostermans collected his specimens from Rasagalle near Balangoda, and along the Laxapana-Maskeliya road.

It is interesting that medicinal properties too have been attributed to this plant. The bark of the plant has an odour distinctly reminiscent of cloves and coriander and is quite different to that of commercial cinnamon.

† Part II: This Journal 2 (1): 35 - 49, (Reference 5).

*This work will form a part of a Ph.D. thesis requirement (University of Sri Lanka, Vidyodaya Campus) of A. L. Jayewardene.

2. Experimental

2.1. Distillation of the bark

The bark was finely ground and the essential oil obtained by water-distillation. Both fresh bark and aged bark (stored for long periods after peeling) were distilled for oil. A Clevenger type apparatus was employed for fresh bark samples. A larger type still was used for distilling the older bark samples. The oil obtained was pale yellow, with a pleasant odour.

2.2. Gas-liquid chromatography

Gas liquid chromatographic analyses of the oil were carried out according to the methods previously described.[6,7] The typical chromatogram (Figure 1) was run on Carbowax 20 M phase (3m x 6 mm column). Gas liquid chromatography was performed on the dried neat oil and also the residual oil after treatment with sodium hydroxide and silica gel slurry.[7]

2.2.1. *Parameters employed for analytical GLC*

Instrument	—	*Varion* 1740 *Moduline*:
Column and packing	—	(i) 3m x 3mm ss with 10% FFAP
	—	(ii) 3m x 3mm ss with 15 %SE—30
Carrier gas	—	Argon 30 ml/min
Sample size	—	0.2 ul.
Detector dual	—	FID
Detector temperature	—	220°C
Injectors temperature	—	200°C
Column oven initial	—	70°C
Column oven final	—	210°C
Programme rate	—	2°/min linear
Chart speed	—	15″/h

Instrument	—	*Varian* 90 *P*—3:
Column and packing	—	3m x 6mm ss with 10% Carbowaz 20 M
Carrier gas	—	Helium 60 ml/min
Sample size	—	10 ul.
Detector Katharometer	—	(TC)
Detector temperature	—	220°C
Injector temperature	—	220°C
Column oven initial	—	60°C
Column oven final	—	220°C
Programme rate	—	4°/min
Chart	—	15″/h

2.2.2. *Operating parameters for preparative GLC — on a Varian 90/P3/TC instrument*

Column and packing	—	3m x 6mm 10% Carbowax 20M
Sample size	—	50 ul.
Carrier gas	—	55 ml/in Helium
Detector Katharometer	—	(TC)
Detector temperature	—	230°C
Injector temperature	—	200°C
Column oven temperature initial	—	80°C
Column oven temperature final	—	210°C
Programme rate	—	4°/min

2.3. Infra-Red Spectroscopy

IR spectroscopy of compounds isolated by preparative GLC was carried out as described previously.[6,7]

3. Results and Discussion

Kapuru kurundu bark oil had a most acceptable odour. The chromatogram of the oil was quite different to that of commercial cinnamon. There were 3 major peaks which were quite readily identified as 1 : 8 cineole, linalool and eugenol (in order of elution) by comparison with a chart of commercial cinnamon bark oil.[7] These identifications were confirmed by trapping the eluates in precooled capillary tubes followed by IR spectroscopy.[6] Apart from these 3 major constituents, there were over 40 comparatively minor ones. These were identified by peak enhancement, retention data, chemical reaction on tlc, etc. as previously described.[6,7] Table 1 gives the percentage composition and the peak identities based on resolution on 2 different liquid phases of the constituents of the bark oil of *Kapuru kurundu*.

The oil of *Kapuru kurundu* displayed several remarkable features. It possessed a relatively large percentage of terpenoid constituents (> 60%) when compared with *C. zeylanicum* (7.0%). The major constituent is linalool and this contributes markedly to the pleasant odour of the oil. The high content of eugenol as well as the significantly small amount of cinnamaldehyde — the major constituent of the bark oil of *C. zeylanicum* — is also evidence of the operation of a rather different biogenetic system to that of normal cinnamon. The biosynthesis of linalool in the *Cinnamomum camphora var. linalooliferum* has recently received attention.[4] It has been found that the labelling pattern in linalool biosynthesised from mevalonic [2 — ^{14}C] acid in this plant was consistent with the predicted biosynthetic pathway involving the condensation of isopentenyl pyrophosphate with 3,3 — dimethylallylpyrophosphate.[2]

TABLE 1. Chemical composition of *Kapuru kurundu* and *C. zeylanicum*.

Component	*Kapuru kurundu* bark	*Cinnamomum zeylanicum*
α Pinene	2.1	0.2
Camphene	0.25	—
β Pinene	1.1	+
Sabinene		+
α Phellandrene	2.2	+
α Terpinene	4.0	+
Limonene	15.8	+
1 : 8 Cineole		1.65
Ocimene	1.6	+
γ Terpinene		
p - Cymene	4.00	0.55
α Ylangene	0.4	+
Camphor	0.3	trace
Linalool	29.1	2.3
β Caryophyllene	3.0	1.35
4 - Terpineol	0.65	—
Piperitone	+	+
α Terpineol	2.4	0.4
Cuminaldehyde	1.05	0.25
Safrole	0.25	+
Cinnamaldehyde	0.55	74.0
Eugenol	23.0	8.8

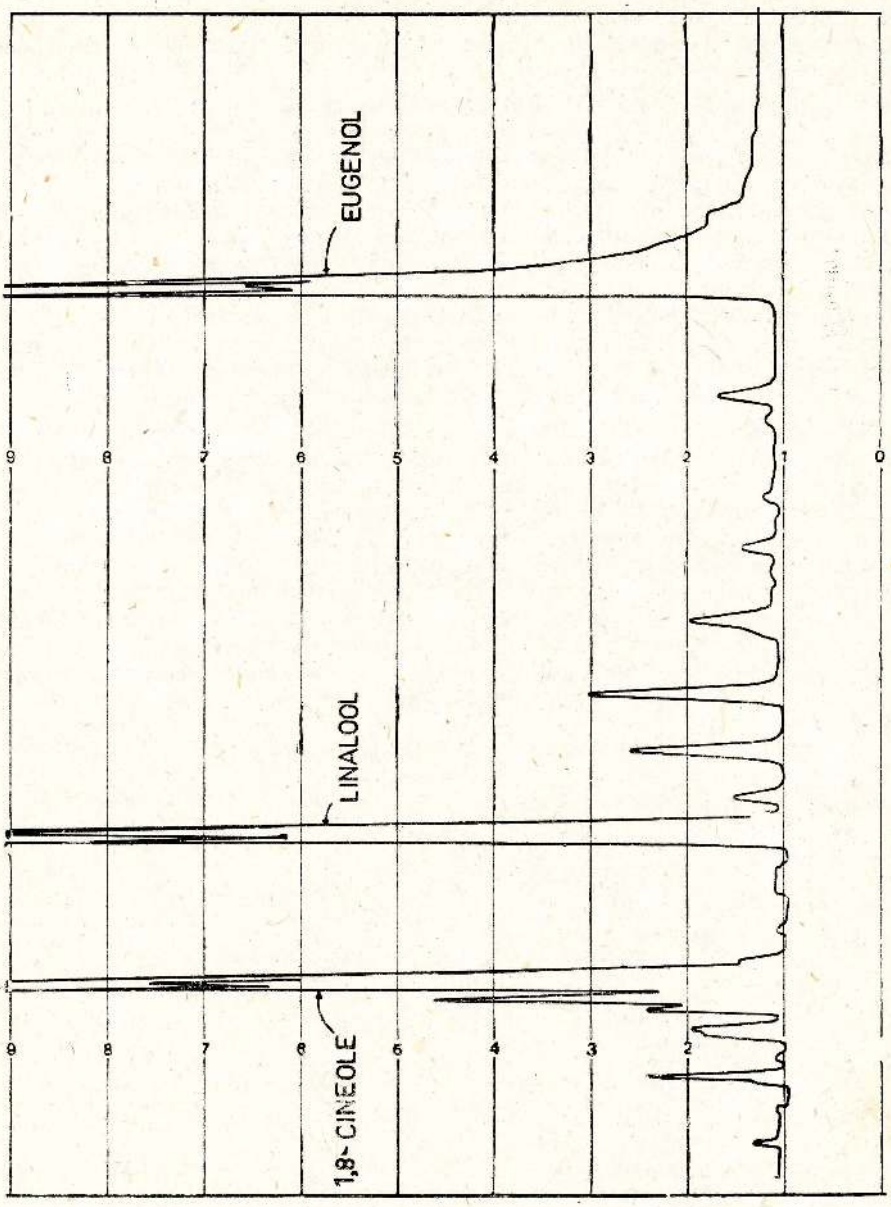

FIGURE 1. Gas-liquid chromatogram of bark oil.

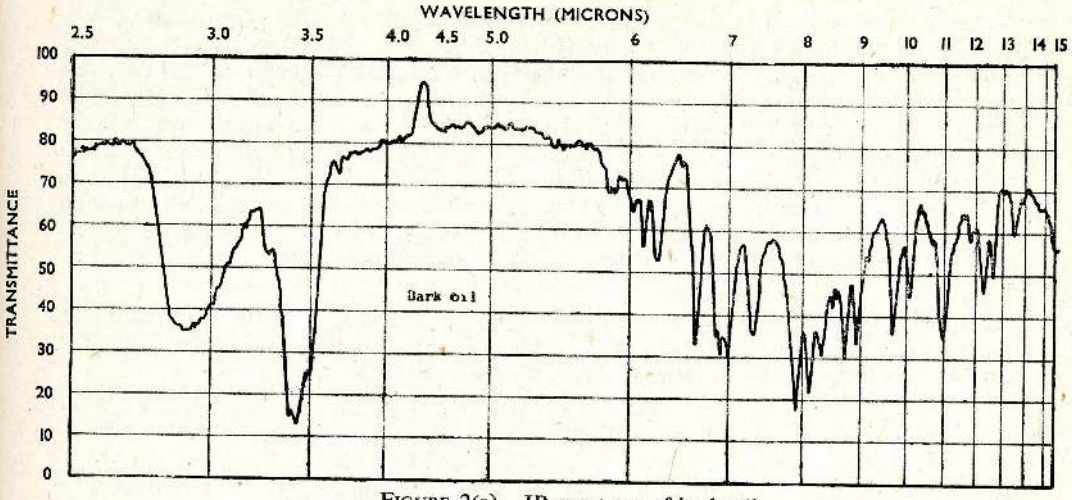

FIGURE 2(a). IR spectrum of bark oil.

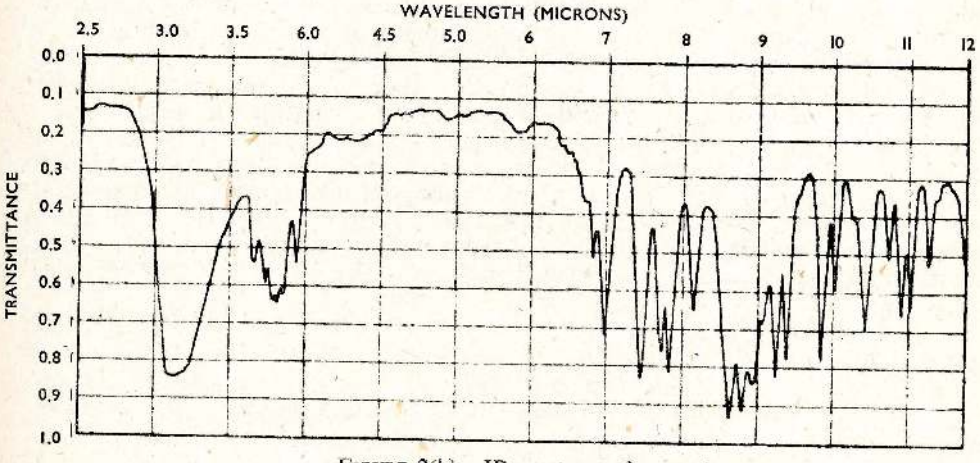

FIGURE 2(b). IR spectrum of eugenol.

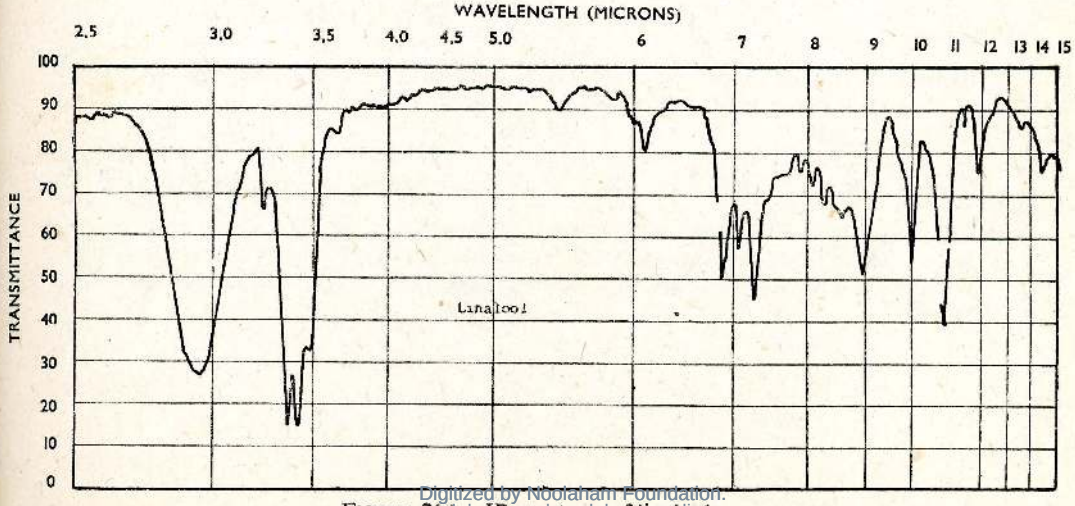

FIGURE 2(c). IR spectrum of linalool.

It has been accepted that geranylpyrophosphate or nerylpyrophosphate is the phosphorylated intermediate which by hydrolysis leads to the common constituent of essential oils, geraniol ; under other conditions and via a different mode of enzymie hydrolysis it also leads to linalool.[1,2,3] It is evident that in *C.capparu-coronde* Bl. the enzyme system that operates the hydrolysis to linalool is the predominant one. Aside of linalool, the phenolic constituent eugenol is the major component but cinnamaldehyde is found only to the extent of about 1 %. The IR spectrum of the oil (Figure 2) displays the characteristics of both linalool and eugenol. The peaks due to each major constituent can be identified by differential IR spectrophotometry and employed to estimate each constituent in a sample of the oil by the technique recently described.[5]

The leaf oil of the new variety was also examined and this again was quite different from the leaf oil of *C. zeylanicum*.[7] The major constituent of this leaf oil was 1:8 cineole and the eugenol content, in contrast, was negligible.

4. Conclusion

The exotic variety of cinnamon investigated, which is in all probability identical with Kostermans' sample, has a bark oil with interesting possibilities. Biosynthetic considerations apart, the oil has a pleasant odour and affords a new source of the important perfumery ingredient linalool. The main source of linalool presently is oil of coriander which is expensive, particularly so, in Sri Lanka. This variety of cinnamon according to Kostermans[3] has medicinal uses. There is also the grave possibility of the variety going extinct ; presently it is rare and occurs only in remote areas. There is a case for its cultivation. The presence of linalool poses the possibility that its use in native medicine may be analogous to the use of coriander whose major constituent is also linalool. The pleasant smelling oil itself may have possibilities as a soap perfume, particularly due to its linalool — eugenol mixed notes. Preliminary attempts to use it as such directly revealed that the odour was somewhat fugitive. Work on the identification of the minor constituents of the bark and leaf oil are in progress.

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Generalised Gauss-Laguerre Quadrature Formnlae

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Abstract : Gauss-Laguerre formulae for the computation of integrals of functions of a given class are widely used in modern computer programmes. These formulae are restricted to the single weight function exp(—*ax*). However, in calculations involving vibrations of many modes in transients, as well as in atomic and molecular physics, several exponential functions, eg. exp(—*ax*), exp(—bx), etc., are needed to economically describe the spectrum of characteristic functions of the physical system. The standard Gauss-Laguerre approach, based on the theory of orthogonal polynomials cannot be easily generalised to yield a theory of quadrature for the multi-exponent case. Using a more direct approach to the problem, this study presents a general method for obtaining quadrature formulae for multi-exponential systems. Numerical results are given for a number of cases.

1. Introduction

The well known quadrature formulae[1,3] of Gauss, Hermite, Legendre and Laguerre treat the case

$$\int_a^b p(x) f(x)\, dr \sim \sum_{k=1}^{n} A_k f(x_k) \qquad (1)$$

where (a,b) is any finite or infinite segment of the real line, and f(x) is an arbitrary function of a certain class. The weight function p(x) is fixed, measurable on (a,b) and is not the identically zero function. Further, p(x) f(x) is summable on (a,b). The r.h.s. of equation (1) contains 2n+1 parameters, viz., the n nodes x_k, the n coefficients (weights) A_k and the number ' n '. Let us assume that f(x) belongs to the class of functions F, for which ϕ_m (x), m = 1,2,... form a basis set. Then, for any linear form L_n,

$$L_n(x) = \sum_{k=1}^{n} a_k \phi_k(x)$$

we define

$$\rho(f, L_n) = \int_a^b | p(x) (f - L_n) | dx.$$

Then, for each fϵF and any $\varepsilon > 0$, there exists an L_n such that

$$\rho(f, L_n) < \varepsilon.$$

$$\text{Since } \left| \int_a^b p f\,dx - \int_a^b p L_n dx \right| \leqslant \int_a^b | p\,(f - L_n) |\,dx = \rho\,(f, L_n),$$

it is clear that $\int_a^b p f\,dx$ can be calculated to as high a degree of accuracy as desired if f(x) is replaced by the appropriate linear combination.

If the nodes x_k and the coefficients A_k in equation (1) give good precision in integrating functions of the basis set, then the formulae must also give good precision for all f ε F. The formula (1) is said to have a degree of precision m with respect to the set ϕ_k if it is exact when $f(x) = \phi_k(x)$ for $k = 1,2\ldots,m$. Formulae of the highest precision for a given n, and for the case $p(x) = 1$ were first given by Gauss. The n nodes are found to be the roots of the Legendre polynomial of degree n, viz., the roots of the equation :

$$P_n(x) = 0 \qquad (2)$$

where P_n is the orthogonal Legendre polynomial of degree n. The Hermite and Laguerre polynomials give the integration formulae for the weight functions $\exp(-x^2)$ and $\exp(-x)$, in the ranges $-\infty$ to $+\infty$ and 0 to ∞ respectively.

Numerical integration of atomic and molecular wave-functions usually involve linear combinations of S,P,D, and higher functions which involve different Slater exponents.[6] Similarly, even in classical systems, vibrational processes involving a number of modes, or processes involving several different transients would require several exponential functions for their adequate description. Attempts to interpolate such functions with a set of Laguerre functions (polynomials multiplied by a single exponential function) become computationally uneconomical owing to the large number of basis functions needed to achieve good accuracy. An economical basis set will always consist of a number of exponential functions. If a set of integration points and weights suitable for multi-exponential basis could be found, numerical integration of atomic and molecular wavefunctions could be carried out to good accuracy with a single integration grid. This avoids the messy change-overs of the integration grid for different regions, etc. during the process of integration, and adds to the accuracy as well as to the efficiency and tidiness of the computer programme.

However, a formula for a multi-exponent basis set cannot be directly formulated in terms of the usual Gauss-Legendre approach via orthogonal polynomials. We shall follow an alternative procedure.

2. Alternative formulation

Let $\psi(x)$ be a function of the sort encountered in atomic and molecular wave-function calculations. $\psi(x)$ can thus be regarded as being most economically expandable in terms of Slater functions.[6] We may consider, as an example, the set $\phi_k(x)$, given by

$$\begin{array}{l} \exp(-x),\quad x.\exp(-x),\quad x^2.\exp(-x),\ldots \\ \exp(-ax),\ x.\exp(-ax),\ x^2.\exp(-ax),\ldots \\ \exp(-bx),\ x.\exp(-bx),\ x^2.\exp(-bx),\ldots \end{array} \qquad (3\,a)$$

to form a multi-exponential generalisation of the Laguerre set. Indeed, such a set has a characteristic of being over-complete but this is of no practical consequence as only finite sets of functions are considered. In the following we shall, for simplicity, limit ourselves to the bi-exponential case $(1, \alpha)$ where the exponential parameters are 1 and α. We are interested in a p point integration formula in E_1, such that the members of the set $(1, \alpha)$ with a total of n functions is exactly intergrated, n being equal to 2p.

3. The method of localised functions

Let $\phi_k(x)$ be a set of basis functions which span the space of functions to be intergrated. We define linear combinations $g_i(x)$, $\bar{g}_i(x)$ such that[2]

$$g_i(x) = \sum_{j=1}^{2p} a_{ij}\,\phi_j(x),\ i = 1, 2, \ldots p;$$

$$\bar{g}_i(x) = \sum_{j=1}^{2p} \bar{a}_{ij}\,\phi_j(x) \qquad (3\,b)$$

and

$$g_i(x_s) = \delta_{is}\ ;\ g'_i(x_s) = 0 \qquad (4)$$

$$\bar{g}_i(x_s) = 0\ ;\ \bar{g}'_i(x_s) = \delta_{is} \qquad (5)$$

where x_s is a given set of points in (a,b). In equations (4) and (5) the derivative with respect to x is indicated by a prime on g. A discrete set of points x_s, $s = 1,2 \ldots p$ is used to define the properties of the g and $\bar{g}$ functions indicated in equations (4) and (5). This discrete set will play the role of the trial set of integration points once the theory is developed. From equations (4) and (5), it is seen that g_k is zero at all x_s except at x_k where it is unity. Further, g_k is stationary at all x_s. The set $\bar{g}_k$ is zero at every point x_s but the gradient becomes unity at x_k, whilst remaining zero at all other points in the set x_s.

The functions $g_i(x)$, $\bar{g}_i(x)$ exist only if the determinants associated with the solution of the sets of equations (4) and (5) given above do not become identically zero. Using the standard theory of orthogonal polynomials and re-expanding $g_i(x)$ and $\bar{g}_i(x)$, it can be shown that a_{ij} and $\bar{a}_{ij}$ exist for the one dimensional case as long as no two points coincide. In higher dimensions, no general results on existence are known. However, the case of two points in two dimensions can be trivially shown to lead to a determinant which is identically zero. Some other singular cases involving higher numbers of points in two-dimensions are discussed by Salzar.[4] In this publication we shall be concerned with the one-dimensional case only ; in this case the equations are non-singular and a_{ij}, $\bar{a}_{ij}$ can be obtained by standard matrix inversion methods used for the solution of simultaneous linear equations.[1]

Any function f expandable in the set ϕ_k can also be expanded in terms of the set g. Thus,

$$f(x) = \sum_{i=1}^{\rho} (b_i g_i + \bar{b}_i \bar{g}_i), \quad \textit{and} \tag{6}$$

using equations (4) and (5),

$$f(x_s) = b_s, \; f'(x_s) = \bar{b}_s .$$

Hence,

$$f(x) = \sum \left\{ f(x_i) g_i + f'(x_i) \bar{g}_i \right\}$$

and

$$\int_a^b f(x)\, dx = \sum_{i=1}^{p} \left\{ f(x_i) \int_a^b g_i\, dx + f'(x_i) \int_a^b \bar{g}_i\, dx \right\}.$$

Let

$$I = \int_a^b f(x)\, dx; \; h_i = \int_a^b g_i\, dx, \; \bar{h}_i = \int_a^b \bar{g}_i\, dx. \tag{7}$$

Then

$$I = \sum_{i=1}^{p} h_i f(x_i) + \bar{h}_i f'(x_i). \tag{8}$$

Equation (8) appearing above can be written as

$$I = \sum h_i \left[f(x_i) + (\bar{h}_i/h_i) f'(x_i) \right]$$

and hence, if $\bar{h}_i/h_i$ is small, using the Taylor theorem, we have

$$I = \sum h_i f(x_i + \bar{h}_i/h_i). \qquad (9)$$

Thus if (x_i) is a moderately good integration grid for f(x), then $\{ x_i + \bar{h}_i/h_i \}$ is an improved grid to the extent that the correction $\bar{h}_i/h_i$ is small enough for a Taylor expansion of f(x) up to only the linear term being valid. Thus we have an algorithm for determining the nodes x_s and the weights h_s of the p–point quadrature formula of the highest precision in the set ϕ_k. The computational steps involved are as follows :—

1. Choose the set of n expansion functions ϕ_k.
2. Choose an initial set of integration points x_i, i = 1,2,...p, where n = 2 p.
3. Construct the sets g and $\bar{g}$ by solving the sets of linear equations (4) and (5).
4. Evaluate $\bar{h}_i/h_i$ using the analytically known values of the integrals of the basis functions.
5. Calculate $\bar{h}_i/h_i$.
6. Hence calculate the new set of points x_i possibly using a scale factor to dampen the adjustments $\bar{h}_i/h_i$.
7. The process is iterated till $\left| \frac{\bar{h}_i}{h_i} \right| < \varepsilon$ where ε is a given refinement criterion.

The above method rapidly converged to the standard Gauss-Laguerre roots when it was used with a single exponential basis set. Similarly, the Gauss-Legendre and Hermite sets could be reproduced very rapidly using the appropriate basis sets. With the multi-exponent case, convergence was slower. Since the integration weights h_i are known to be positive, the use of $\bar{h}_i/|h_i|$ instead of $\bar{h}_i/h_i$, together with a damping factor of about 0.5 led to better convergence. Further, the selection of the trial set of points became an important factor in regard to convergence for formulae with $p \geq 4$. The following method was used to determine a trial set of points to initiate the programme. Let x_i be the Laguerre set of points (p–point formula) in the Gauss-Laguerre formula. We base our formula for the trial set X_i on the previously obtained p–1 point formula whose first and last points are y_1 and y_2.

Let $U = y_1/L_1$ and $V = y_2/L_2$ where L_1 and L_2 are the first and last values of the p–1 point Laguerre formula. Then the trial set is taken to be

$$X_i = U x_i + ((V x_p - U x_1)/(x_p - x_i))(x_i - x_1) \qquad (10)$$

Using equation (10) we were able to obtain integration formulae for exponent pairs (1,2), (1,3), (1,4), (1,5) etc., without much difficulty. The resulting integration grids and weights up to a six–point formula are given in Tables 1 to 4; they yield percentage errors of about 10^{-10} in the basis integrals. This error was of the same order of magnitude as the rounding off errors in the computing machine used.

TABLE 1. Exponents (1, 2)

pts	wts
n = 2	
3.92766343569*–1	1.03897236687
2.42705067525	3.38063976925
n = 3	
2.77803885220*–1	7.23353213086*–1
1.56697120948	1.93998244272
4.51515738393	4.32020560176
n = 4	
2.15261994855*–1	5.57160311743*–1
1.17861236353	1.40292149670
3.13847432710	2.61464697291
6.78421272104	5.05193377099
n = 5	
1.75807107797*–1	4.53716182149*–1
9.49590333516*–1	1.110708448147
2.45114720406	1.93338900711
4.94755460834	3.16301081329
9.16563020285	5.65980065613
n = 6	
1.48612567792*–1	3.82907845062*–1
7.96776753329*–1	9.23233266628*–1
2.02475158315	1.55409307082
3.96768950661	2.37688369354
6.91714984147	3.62909694264
1.16248181338*1	6.18448230547
n = 7	
1.28891391018*–1	3.31761250935*–1
6.87950624077*–1	7.92643279769*–1
1.73246219048	1.30911724136
3.34169809601	1.93354102779
5.66762678122	2.76594157498
1.41620456118*–1	6.65672844588

Mean error in basis integrals : 1*–10 per cent.
* at the end of each number indicates a power of ten.

TABLE 2. Exponents (1, 3)

pts	wts
n = 2	
2.95042873895*–1	7.89685538507*–1
2.00577425563	3.06251041260
n = 3	
2.08422880584*–1	5.45656103877*–1
1.21265818788	1.56989946293
3.78984370062	3.98708422722
n = 4	
1.61370337418*–1	4.18946018487*–1
8.96929464663*–1	1.08918854920
2.48352139537	2.20783787409
5.74610575758	4.71089862717
n = 5	
1.31762781941*–1	3.40713666567*–1
7.18215773264*–1	8.50031331495*–1
1.89289130049	1.54864188033
3.97810828075	2.74659714964
7.81035517600	5.31295574631
n = 6	
1.11372833135*–1	2.87347919245*–1
6.00812593777*–1	7.01653034117*–1
1.54680574887	1.21451578484
3.10471395024	1.95690312426
5.62795699898	5.83252435437

Mean percentage error in basis integrals : 1*–9

TABLE 3. Exponents (1, 4)

pts	wts
n = 2	
2.34727932956*–1	6.32926695504*–1
1.76683343289	2.92316412661
n = 3.	
1.66466463630*–1	4.37598553487*–1
9.96365796716*–1	1.35302815142
3.39053798660	3.85696304910
n = 4.	
1.28858032106*–1	3.35302734366*–1
7.25015489476*–1	8.95708563365*–1
2.09265847320	1.99185741858
5.18385867367	4.58691900163
n = 5.	
1.05233681391*–1	2.72518252288*–1
5.77793482717*–1	6.90518426392*–1
1.55268775060	1.31776819900
3.41178513591	2.54479304440
7.08435976045	5.19305056464
n = 6.	
8.89626835065*–2	2.29767135647*–1
4.82260269270*–1	5.66784354735*–1
1.25574225785	1.00652481779
2.58363625904	1.71772160757
4.88818874215	3.02479590730
9.05956200871	5.71531620205

Mean percentage error in basis integrals: 2*–10

TABLE 4. Exponents (1, 5)

pts	wts
n = 2.	
1.93647537723*–1	5.24303275819*–1
1.61327908973	2.85093607654
n = 3.	
1.38447873728*–1	3.65047814536*–1
8.49532250408*–1	1.21067172441
3.13891919374	3.79529077236
n = 4.	
1.07125716659*–1	2.79211641792*–1
6.08384056716*–1	7.62006957751*–1
1.83136094557	1.86239914247
4.83249728691	4.53118938455
n = 5.	
8.75191314856*–2	2.26891208975*–1
4.83202597639*–1	5.81896003059*–1
1.32110205585 —	1.16164472649
3.03952821284	2.43366000046
6.63364638407	5.14109772282
n = 6.	
7.40060682329*–2	1.91285243538*–1
4.02664850004*–1	4.75559311803*–1
1.05831374211	8.63409358670*–1
2.23122903889	1.56433270651
4.40847609927	2.92825525455
8.50951417896	5.66583153184

Mean percentage error in basis integrals: 2*–10.

4. Discussion

The generalisation of the Gauss-Laguerre quadrature formulae to cases which include multi-exponential basis sets will be found useful in a variety of engineering and scientific calculations. The formulae given, (up to 6 points) would be adequate for accuracies demanded by most problems, though much higher accuracies may be needed in correlation energy calculations of atoms and molecules. However, attempts to go to higher sets of points in widely differing exponentials are bound to be more difficult. In any case, it is very rarely that two widely different exponentials appear with close coupling in a realistic physical problem.

The present method can be used for obtaining generalised Gauss-Hermite quadrature formulae as well and would be of interest in treating multi-Gaussian basis sets which are currently in vogue in nuclear, atomic and molecular calculations[5] as well as in the theory of stochastic processes.

Acknowledgements

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Growth of Nursery Rootstock Seedlings of *Hevea brasiliensis* Muell. Arg. *Cv.* Tjir 1. Part III*

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Abstract : A trial was conducted to determine the nature of growth of seedlings of rubber (*Hevea brasiliensis cv.* Tjir 1) a cultivar which has been widely used as a rootstock. At 32 months, a sample of seedlings which represented all the germination classes was removed from the nursery and the dry weights of their roots, stems and leaves were determined. Three parameters of growth namely, the plant height and stem diameter at first measurement and root lengths showed a high positive correlation with the dry weights of the plants and their component parts. Rootgrowth even had an influence on the dry matter production of the leaves. It is suggested that the variation in the growth of the budlings could be caused by the genetic heterozygosity of the roots which would also cause differential growth of the aerial parts of the plant.

1. Introduction

Plantation rubber, *Hevea brasiliensis* is multiplied vegetatively by budgrafting proven cultivars on to recognised seedling rootstocks. The expectation of obtaining uniform growth and yields from among the trees of a vegetatively propagated population is not realised even under the best conditions of management. There is variation in growth and yield between trees even in small monoclonal blocks. The low yielders which contribute to part of this variation reduce the profitability of estates as they would increase the cost of tapping per tapping task. In small holdings, they reduce the total yield of latex per tapping day and consequently lower the income of small holders.

McIndoe,[2] and Senanayake and Wijewanthe[4] have suggested that part of the variation in growth and yields may be associated with the inherent variability of the heterozygous, seedling rootstocks. To examine this view, an investigation was conducted to study initially the nature of variation in the growth of rootstock seedlings in a nursery. The nature of variation in the growth of such seedlings has been reported recently by Jayasekera and Senanayake[1] and Senanayake *et al.*[3] This paper examines the inter-relationships which were recognised among some parameters of growth at the time of removal of the seedlings from the nursery at maturity.

* For details regarding publication of parts I and II, see **References.**

2. Materials and Methods

Descriptions of the experimental material and the nursery management methods have been reported earlier.[1] When the plants were 32 months old, 190 of them that were derived from different germination periods that ranged from 12 to 34 days (Table 1) were uprooted from the nursery carefully to expose the entire main root and all the branch roots. The plants were then removed immediately to Peradeniya where the total dry weight of the root, stem and leaves was determined by drying the plants to constant weight in a Unitherm drying oven. The plants were removed for dry matter determination in 3 batches on 18 July, 27 July and 8 August 1972.

TABLE 1. Nature of sample used to determine dry weight.

Germination class (days)	12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-34
No. of plants analysed	4	5	10	44	40	25	28	15	11	6	2

3. Results

The associations between 4 parameters of growth namely : (1) germination period, (2) plant height at first measurement, (3) stem diameter at first measurement and (4) root length and the nature of growth such as (*a*) root length ; (*b*) root dry weight ; (*c*) stem dry weight ; (*d*) leaf dry weight and (*e*) the total plant dry weight are presented in Table 2.

TABLE 2. Correlation between parameters of growth and nature of growth.

Parameter \ Nature of growth	Root length	Root dry wt	Stem dry wt	Leaf dry wt	Total plant dry wt
Period of germination	0.0010	—0.0661	—0.0334	—0.0449	—0.0451
Plant height at first measurement (1969-10-15)	0.1121	0.2096*	0.2156*	0.2045*	0.2189*
Stem diameter at first measurement (1969-10-15)	0.1485	0.2258*	0.2105*	0.2720**	0.2263*
Root length		0.5872***	0.5028***	0.4015***	0.5364***

*, **, *** – Significant at 5%, 1% and 0.1% respectively.

Negative and non significant low correlations were obtained between the period of germination and the dry weights of the plant parts. During growth, a positive and significant correlation was found between the height of the seedlings recorded during the first measurement on 15 October 1969 and the total dry weight of the plant or the dry weights of the different plant parts such as the root, stem and leaf. The stem

diameter of seedlings recorded during the first measurements on 15 November 1969 also showed similar correlations. The height or the diameter of the seedlings during the first measurement showed low positive correlations of 0.1121 and 0.1485 respectively with the root length.

Positive and very highly significant correlations of 0.5872, 0.5028, 0.4015 and 0.5364 were obtained between root length and the dry weights of the root, stem, leaf and the whole plant respectively.

4. Discussion

The illegitimate seeds which were used in this experiment germinated during a period extending from 12 to 34 days. During this period, the proportion of plants which germinated within the different germination classes was found to fit a normal curve which was skewed to the left.[1] The sample used for analysis in the present study was representative of these germination classes.

The negative correlations of the period of germination with the dry weights of the root, stem and leaves suggest that if the germination period is small, the dry weights of the plants or their components are large. It could be suspected, therefore, that this relationship is genetical and that the early germinators had an inherent capacity for higher production of dry matter.

The positive and significant correlation of either the plant height or the stem diameter at first measurement with the dry weight of the plant or its parts indicates that the more vigorous plants have a higher dry matter production. The data show that such plants also had larger roots although the association was not significant. The intervening period between the first measurement of the seedlings in the nursery and uprooting the plants for the determination of dry matter was 32 months. Early vigour, therefore, had not arisen because of the seed environment but it was due to superior vigour which was probably associated with genetical causes. From previous results, Jayasekera and Senanayake[1] have suggested that either the plant height or the stem diameter could be used as a measurable parameter because of their high positive correlation. The results reported here confirm this relationship.

A strong positive correlation between the root length and the root dry weight of a plant is not unexpected. An interesting result in this study, however, was the strong association between the root length and the dry weight of the stem and even the leaves. Such an influence could therefore contribute to the variability of the growth of the scions of budded rubber plants even within small monoclonal blocks. Root growth was associated with the germination period. Moreover, it has been shown in a previous report by Senanayake *et al.*[3] that seedlings which germinated early continued to have a higher growth rate in the nursery. These results, therefore, lend support to the viewpoint that genetic heterozygosity of the rootstocks is the cause of part of the plant to plant variation that is recognisable during the growth of budded trees.

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SHORT COMMUNICATION

Evaluation of Herbicides for Rain-fed Upland Rice, *Oryza sativa* L.

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Under puddled conditions of rice culture, both the nature of land preparation as well as the presence of standing water effectively prevents the growth of weeds in rice fields at least for 3 weeks, after which further weedings have to be done.[3] In upland rice culture, however, rice and weed seeds germinate alike and weeds offer severe competition to rice from very early stages of growth. Rice is very sensitive to weed competition in the early stages of growth and the failure to control weeds during the first 3 weeks after planting reduces the yield by 50%.[2] Often a combination of several methods is required for controlling the weed growth in upland paddy culture and the use of pre-emergent herbicides appear to be most promising. This paper reports the results of an experiment conducted to evaluate herbicides for upland rice grown under upland rain-fed conditions.

The experiment was carried out on the upland rice fields of the Agricultural Research Station, Maha Illuppallama during the period October 1973 to January 1974. The soil was a sandy loam containing 1.3% organic matter, 72 kg/ha available phosphate (Olsen's) and 0.52 me (%) exchangeable potassium. The pH was 5.5.

The weed control treatments consisted of Benthiocarb, Butachlor, C—288, Prefo-ran, A—820, USB 3153, Hand weeding and Unweeded control. The herbicides in liquid form were applied at the rate of 2 kg/ha a.i. 15 days after sowing. The hand weeded plots were weeded on 4 occasions after rice emergence.

The treatments were arranged in randomized complete blocks, replicated 3 times. Each plot measured 15 m^2. The plots were equally divided and plants from one half of each plot were used for sampling while those of the other half were kept for recording the final grain yield.

The land was thoroughly prepared to eliminate all existing weeds. Nitrogen as ammonium sulphate (20%N) was applied at the rate of 25 kg/ha and 50.2 kg/ha at 17 and 40 days after rice emergence (DARE) respectively. 37.6 kg/ha of potassium as

muriate of potash (60%K_2O) was applied 4 days before sowing and 18.8 kg/ha was top dressed 42 DARE. The total dressing of phosphate (54.5 kg/ha as Concentrated super phosphate) was applied 4 days before sowing.

Immediately before sowing rice, a mixture of seeds of the following weeds commonly found in the upland rice fields in the dry zone were sown at the rate of 10g/15m², *Echinochloa colonum* L, *Echinochloa crusgalli* L, *Cyanodon dactylon* L, *Eleucine indica* Gaertn, *Celosia argentea* L, *Trianthema portalacastrum* L, *Mimosa pudica* L, *Acanthesperma hispidia* L. Unsprouted seeds of the 3-months aged rice variety BG—34—8 were sown in furrows 25 cm apart and covered lightly with soil on 5 October.

The weeds within each plot were sampled at 14, 25, 42 and 82 DARE from a sampling area of 7,500 cm². All weeds within the sampling area were grouped into monocotyledonous and dicotyledonous species, identified and counted. The final grain yield of rice was harvested from an area of 5.625 m², 105 DARE. Visual observations on crop injury and weed control rating were made at the same sampling dates using a 0—100% scale.

Herbicide toxicity, weed control rating and weed occurence

The herbicides had no phytotoxic effect on rice plants. All herbicides except Preforan, Benthiocarb and A—820 controlled over 93% of the weeds up to 25 DARE. At 42 DARE, C—288 gave 95% weed control, followed by USB 3153 (65%) and Butachlor (63%), while Preforan controlled only 15% of the weeds. In the subsequent samplings only C—288 controlled over 77% of the weeds, whereas the other herbicides controlled less than 30% of the weeds.

Weed count was high from early stages of growth and the unweeded control had 1141 weeds/m² at 14 DARE (Table 1). The maximum weed count for all treatments was recorded during a period of between 42 — 65 DARE. The herbicides controlled both mono and dicotyledonous weeds to a considerable extent when compared with the unweeded control. C—288 completely controlled both mono and dicotyledonous weeds up to 25 DARE and in the later growth, a few weed species (*Echinochloa Spp. Eleusine indica* Gaertn and *Panicum Spp.*) appeared in the plots treated with this herbicide. Butachlor and USB 3153 had a higher percentage of dicotyledonous weeds up to 14 days while this effect was maintained for Butachlor at 25, 65 and 82 DARE. Of the dicotyledonous weeds found in these treatments *Mimosa pudica* L, *Celosia argentea* L, *Acanthesperma hispidia* L and *Aeschynomene indica* L were the most prominent.

In all other treatments, the proportion of monocotyledonous weeds was higher than dicotyledonous weeds. The unweeded control contained over 81% of monocotyledonous weeds at all samplings. In all treatments *Cyperus iria* L, *Echinochloa colonum* L,

TABLE 1. The effect of treatments on weed number/m² and the percentage of dicotyledonous and monocotyledonous weeds.

Treatments	14 DARE			25 DARE			42 DARE			65 DARE			82 DARE		
	No.	Mon.	Dic.	No.	Mon.	Dic.	No.	Mon.	Dic.	No.	Mon.	Dic.	No.	Mon.	Dic.
Benthiocarb	78	66	33	90	28	72	177	66	35	124	35	65	253	73	27
Butachlor	27	22	78	82	7	93	269	76	24	72	21	79	78	33	67
C — 288	—	—	—	—	—	—	9	56	44	41	68	32	9	—	100
Preforan	144	59	41	207	66	54	233	78	22	253	82	18	239	72	28
A — 820	129	60	40	266	60	40	239	69	31	293	73	27	201	63	37
USB 3153	51	39	61	96	55	45	123	63	37	88	67	33	136	71	29
Hand weeded	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Untreated control	1141	81	19	1347	90	10	702	89	11	585	87	13	379	87	13

DARE = Days After Rice Emergence.

TABLE 2. The effects of treatments on yield components and final grain yield of rice.

	Panicle number/m²	Panicle weight g/m²	Panicle length, cm	Final grain yield, kg/ha.
Benthiocarb	183	97.8	17.8	762.50
Butachlor	211	92.3	17.6	840.27
C — 288	371	245.3	19.2	1774.00
Preforan	79	29.7	14.1	224.29
A — 820	152	66.3	16.2	524.27
USB 3153	229	116.1	18.2	1016.30
Hand weeded	345	305.0	18.0	2507.33
Untreated control	—	—	—	—
LSD (P = 0.05)	—	—	—	440.60

Echinochloa crusgalli L, *Echinochloa stagnina* L and *Cyanodon dactylon* L, were found up to 25 DARE whereas *Fimbristylis miliacea* Vhal., *Eleusine indica* Gaertn, *Cyperus rotundus* L, and *Panicum Spp.* were found at the later stages of growth of the rice crop.

Analysis of grain yield

The unweeded control failed to produce any grain yield due to heavy weed competition during all stages of growth (Table 2). Velmurugu[4] also found a yield reduction of 25 to 30% in tall medium-aged rice varieties (4 to 4½ months), while in the case of dwarf short-aged varieties (3 to 3½ months) the yield was reduced to zero by intensive weed competition. Hand weeding increased panicle weight/m^2 and this was reflected in a significantly higher grain yield compared with all other treatments. Of the herbicidal treatments, an increased yield was obtained with C 288 due to an 8% increase in panicle number/m^2 when compared with hand weeding. However, the increase in panicle number was associated with a reduction in the weight of panicles/m^2 by 25%. As reported by Auma and Gunasena[1] there was a significant linear correlation between final grain yield and panicle weight as represented by the equation $Y = 94.42 + 6.70$. The panicle weight accounted for 54% of the variation in grain yield.

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ලිපිවල සාරාංශ - සිංහල පරිවර්තන

ශ්‍රී ලංකාවේ වියැළි කලාපීය කෘෂිකර්ම කටයුතු පිළිබඳ බෝග ජල අවශ්‍යතා සඳහා වර්ෂාපතන විශ්වසනීය සීමා යෙදීම

පානබොක්කේ, සී. ආර්. සහ වල්ගම, ඒ.

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ශ්‍රී ලංකාවේ වියැළි කලාපයෙහි වැසි ජලයෙන් පෝෂිත කෘෂිකර්ම කටයුතු ස්ථායි කිරීමෙහි ලා මූහුණ පාන්ට සිදුවන වඩාත් වැදගත් ගැටලු අතුරෙන් එකක් නම් ආනුෂඩගිය වර්ෂාපතනයෙන් නිසැකවම උපරිම ප්‍රයෝජන ලබා ගත හැකි පද්ධති වර්ධනය කර ගැනීමයි. මෙහි ලා ප්‍රධාන වශයෙන් කරුණු දෙකක් බලපායි. වැව්මෙන් වැඩීමෙන් හැම අවස්ථාවකටම අවශ්‍ය වන බෝග ජලය ප්‍රමාණයට සරිලන වර්ෂාපතනයක් ලැබීමේ ඉඩකඩ වැඩිම වන සේ 1. වපුරන කාලය නිසි පරිදි තෝරා ගැනීම ද 2. බෝග වැපිරීමත් අස්වනු කැපීමත් අතර කාල සීමාව නිසි ලෙස තෝරා ගැනීම ද යනු ඒ දෙකරුණයි.

මේ පත්‍රිකාවෙහි වියැළි කලාපයේ විවිධ ප්‍රදේශවල වගා කන්න සඳහා වර්ෂාපතනය ලැබීමේ සම්භාවිතාව නියම කර ඇත්තේ මැනිං ක්‍රමයට ගණනය කළ 1 : 1 වර්ෂාපතන විශ්වසනීය සීමාවල තෙයකි චලන එකතුව භාවිත කිරීමෙනි. වියැළි කලාපය ඇතුළතම වුව විශේෂයෙන්ම ප්‍රධාන මහ කන්නයේ දී, කන්නය පටන් ගැනීමත් කන්නය අවසානවීමත් සම්බන්ධයෙන් ප්‍රදේශයෙන් ප්‍රදේශයට වැදගත් වෙනස්කම් පවත්නා බව පෙනී ගොස් ඇත. ඒ ඒ ප්‍රදේශ සඳහා නියම වපුරන දින තෝරා ගන්නා ආකාරය මෙහි දැක්වෙයි. අපේක්ෂිත වර්ෂාපතනයෙහි 1 : 1 විශ්වසනීය සීමා එල්ලේ බෝග ජල අවශ්‍යතා සිහිමෙන් කිසියම් බෝගයක් සඳහා වයස් පන්තියක් තෝරා ගත හැකි බවත් එවිට ඊට අවශ්‍ය ජලය ප්‍රමාණය වගා කන්නයේ දී ලද හැකි තෙතමන සැපැයුම් හා බොහෝ දුරට ගැලපෙනි. ඒ ඒ බෝග වියැළි කලාපයේ විවිධ ප්‍රදේශවලට ගැලපෙන පරිදි යොදා ගැනීමේ හැකියාවත් ඒවායේ ක්‍රියාකාරිත්වයත් ගැන මෙහි කරුණු දැක්වෙන අතර වෙනත් ප්‍රායෝගික යෙදුම් කිහිපයක් ගැන ද සාකච්ඡා කෙරෙයි.

ටොක්සොප්ලාස්මෝසිය හා හෘද රෝග

නාගරත්නම්, එන්.

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මේ අධ්‍යයනය වූකලී ටොක්සොප්ලාස්මෝසිය නිසා ඇති විණැයි විශ්වාස කරන හෘද රෝගයෙකින් පෙළෙන රෝගීන් 12 දෙනෙකු පිළිබඳ අධ්‍යයනයෙකි. ඔවුන්ගේ පවුල් වල සාමාජිකයන් කිහිපදෙනෙකු අතර කොලික කන්තුවහත්ව ලක්ෂණ පහළ වී ඇති බව ද ඉලෙක්ට්‍රෝකාඩියෝග්‍රාෆික (විද්‍යුත් කන්තු රේඛක) මස්තු වේදිය ලක්ෂණ තිබෙන බව ද පෙනිණි. මස්තුවේදිය සොයා ගැනීම වඩා පිළිගන්නා ලදී. සාමාන්‍යයෙන් දක්නට ලැබුනේ නිදන් ගත හෘද රෝගයෙක ලක්ෂණයි. ඇතැම් අයට තිබුණේ අවම සහපාතයි. යෙස්සෝ සම්පූර්ණයෙන් ම අසහපාතික වූහ. හදිසි 'ආඝාතයක්' හෙවත් ධමනි ප්‍රදාහයක් වැනි, හෘදයට බලපෑමක් ඇති වූ බවක් පැහැදිලිව නොපෙනෙන, වාහිනියක ලක්ෂණ ඇතැම් අය තුළ දක්නට ලැබිණි. මේ නිසා අනෙක් හෘද රෝග ආකාර ව්‍යාකූල විය. නිදන්ගත ස්වභාවයේ නො පැහැදිලි හෘද රෝගයෙන් පෙළෙන රෝගීන් තුළ පමණක් නොව වහිරුකන්තුක හා/හෝ පරිකන්තුක බලපෑමක් සහිත උග්‍ර හෘද රෝගයෙන් පෙළෙන රෝගීන් තුළ ද නිදාන සාධකයක් වශයෙන් ටොක්සොප්ලාස්මෝසිය ගැන සොයා බැලිය යුතුය. නොපැහැදිලි කන්තුක අවස්ථා සම්බන්ධයෙන් දැනට වටහා ගෙන ඇතිවාට වඩා බහුල වශයෙන් ටොක්සොප්ලාස්මෝසිය ශ්‍රී ලංකාවෙහි පවතිනු විය හැකි ය.

මයියොක්කාවල ඇති සයනොජනක ග්ලූකොසයිඩ ප්‍රමාණය

II. මයියොක්කා පෙති හා පිටිවල විෂ හැරීම

ජැන්ස්, ඊ. ආර්., පිරිස්, නිර්මලා, ජෙයරාජ්, ඊ. ඊ. සහ අබේරත්න, ඩී. ජේ.

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මැනිහොට් එස්කියුලෙන්ටා ක්‍රාන්ට්ස්වල සයනොජනක ග්ලූකොසයිඩ් අන්තර්ගතය. විශේෂ පූර්වෝපාය නොයෙදුවොත් මයියොක්කා පිටි බවට පත් කළ පසු ව පවා මේ සයනොජනක ග්ලූකොසයිඩය ජල විච්ඡේදනයට භාජන නොවෙයි. මයියොක්කා පෙති හා පිටිවල මුළු සයනයිඩ් ප්‍රමාණය ආසන්න වශයෙන් මුල් අගයෙන් 5% කට අඩු කර ගත හැකි ක්‍රමයක් මේ පත්‍රිකාවෙන් ඉදිරිපත් කැරෙයි. බැඳුණු සයනයිඩ්වල හා මුළු සයනයිඩ්වල සියලුම අර්සණ කරන ලද්දේ ලිනමරින්වලින් එන්සයිමීය ලෙස සයනයිඩ් මුදා හැරීමෙන් පසුවයි.

ප්ලාස්ම පෙනිල් ඇලනයින් වෙන් කිරීමෙන් නිමානය කිරීමත් ලාංකිකයන් සඳහා ශායනික න්‍යායක් පිහිටුවා ගැනීමත් සඳහා කෙටි ක්‍රමයක්

සෙන්තිෂන්මුගනාදන්, එස්., රැදිගු, සිනා අයි. සහ කමලනාදන්, එස්.

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ලේවල පෙනිල් ඇලනයින් වෙන් කර ගෙන, තුනී ස්ථර වර්ණකරේඛනය භාවිතයෙන් එය විශ්වසනීයතාවෙකින් යුතු ව ප්‍රමාණාත්මක ලෙස නිමානය කර ගත හැකි ක්‍රමයක් මෙහි විස්තර කැරෙයි. අභිශෝෂකය වශයෙන් සිලිකා ජෙල – G ද විකසන ද්‍රාවකය වශයෙන් n බියුටැනොල්/ඇසිටික් අම්ලය/ජලය (4 : 1 : 1) ද භාවිත කැරිණි. 0.5 μ තරම් ක්ෂුද්‍ර ප්‍රමාණ අනාවරණය කර ගැනීමට තරම් මේ ක්‍රමය සංවේදී විය ; අවශ්‍ය වූ මස්තු පරිමාව 4 μ (0.004 ml) විය. මුළු නිමානය ම සඳහා ගත වූ කාලය පැය 3 ට අඩු විය. මේ ක්‍රමය භාවිතයෙන් ලාංකික ළමුන් සඳහා නිර්ණය කර ගත් ශායනික න්‍යායිය ගැන ද මෙහි සඳහන් වෙයි. මස්තු පෙනිල් ඇලනයින්වල අගය, 7.07 ± 4.86 ක මධ්‍යන්‍යයක් සහිත ව, 0 සිට 16**mg**/100 ml තෙක් වෙනස් විය. තනි පවුලෙක සාමාජිකයන්ට අයත් පෙනිල්කීටෝනූරියාව පිළිබඳ නිසැක අවස්ථා දෙකක් ගැන ද මෙහි සඳහන් වෙයි.

සගන්ධ තෙල්

III. විරල කුරුඳු ප්‍රභේදයක පොත්තෙන් ගත් වාෂ්පශීල තෙල්වල අඩංගු රසායනික සංඝටක

විජේසේකර, ආර්. ඕ. බී. සහ ජයවර්ධන, ඒ. එල්.

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විදේශික කුරුඳු ප්‍රභෙදයක (සමහර විට සිනමොමුම් කැපරුකොරොන්ඩ හි) පොත්තෙන් ලබා ගත් භූමාල වාෂ්පශීල තෙල් පිළිබඳව කළ වායු ද්‍රව වර්ණකරේඛන අධ්‍යයනවලින් එහි ලිනැලූල් (29%) ද ඉයුජනෝල් (23%) ද 1 : 8 සිනියෝල් (16%) ද ප්‍රධාන සංඝටක වශයෙන් ඇති බව අනාවරණය වී තිබෙයි. මේ කුරුඳු තෙල් ප්‍රභෙදයෙහි සම්ප්‍රදායික කුරුඳු (c. සෙලැනිකුම්) පොත්තෙන් ලබා ගත් තෙල් වලට වඩා සම්පූර්ණයෙන්ම වෙනස් රසායනික සංයුතියක් ඇත. මෙකී සංයෝගවල ජෛවසංස්ලේෂණයත් මේ තෙල ද එහි සංඝටක ද සුවඳ ද්‍රව්‍ය නිපදවීම සඳහා ප්‍රයෝජනයට ගත හැකි වීමත් අතින් මේ ශාකය වැදගත් වෙයි.

සධාරිත ගවුස් - ලගෙයර් වාර්ගමාති සූත්‍ර
ධර්මවර්ධන, එම්. ඩබ්ලිව්. සී.

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දෙන ලද පන්තියකට අයත් ශ්‍රිතවල අනුකල ආගණය කිරීම පිළිබඳ ගවුස්—ලගෙයර් සූත්‍ර තූනන ප්‍රගණක (කොම්පියුටර) ප්‍රක්‍රම වල පුළුල් ලෙස භාවිත කැරෙයි. මේ සූත්‍ර තනි හාර ඝාත (-ax) ශ්‍රිතයට සීමා වෙයි. එහෙත් බොහෝ විධි හා අනිත්‍ය සහිත කම්පන පිළිබඳ ගණනය කිරීම් වල දී මෙන්ම පරමාණුක හා අනුක භෞතික විද්‍යාවේදීත් භෞතික පද්ධතියෙහි ලාක්ෂණික ශ්‍රිතවල ප්‍රේක්ෂාවලිය කෙටියෙන් විස්තර කිරීම සඳහා ඝාත (-ax), ඝාත (-bx) ආදිය වැනි ඝාතීය ශ්‍රිත කිහිපයක්ම අවශ්‍ය වෙයි. ප්‍රලම්භ බහුපද පිළිබඳ වාදය මත පදනම් වූ සම්මත ගවුස්-ලගෙයර් එලැඹුම බහු-ඝාත අවස්ථාව සඳහා වර්ගමාතිය පිළිබඳ වාදයක් ඇති කර ගන්නට තරම් ඝාධාරණ කිරීම පහසු නැත. මේ ගැටලුව දෙස කෙළින් ම බලා බහු-ඝාතිය පද්ධති සඳහා වර්ගමාති සූත්‍ර ලබා ගැනීමේ ඝාධාරණ ක්‍රමයක් මේ අධ්‍යයනයෙන් ඉදිරිපත් කැරෙයි.

හෙවෙයා බ්‍රසිලියෙන්සිස්
තවාන් මුලටි බීජපැල වැඩීම III කොටස
සේනානායක, වයි. ඩී. ඒ. සහ සමරනායක, පී.

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මුලටියක් වශයෙන් බෙහෙවින් යොදා ගෙන ඇති විශා-ප්‍රභෙදයක් වූ රබර් (හෙවෙයා බ්‍රසිලියෙන්-සිස් cv. Tjir 1) වල බීජපැල වැඩෙන ආකාරය නිර්ණය කිරීම සඳහා අත්හදා බැලීමක් කරන ලදී. මාස 32 කට පසු සියලුම ප්‍රරෝහණ අවස්ථා නිරූපණය කළ බීජපැල නියැදියක් තවානෙන් ඉවත් කරගෙන, ඒවායේ මුල්, දඬු හා පත්‍රවල වියැළි බර නිර්ණය කරන ලදී. වැඩීම පිළිබඳ පරාමිති තුන එනම් ශාකයේ උස, පළමු මැනීමේ දී දණ්ඩේ විෂ්කම්භය, මුල්වල දිග යන මේවා අනුව ශාකවලත් ඒවායේ සංරචක කොටස්වලත් වියැළි බරෙහි උසස් ධන සහසම්බන්ධ-යක් ඇති බව පෙණිනි. මුල්වල වැඩීම පත්‍රවල වියැළි ද්‍රව්‍ය සෑදීම කෙරෙහි පවා බලපෑය. අංකුර පැලවල වැඩීමෙහි ඇති වන වෙනස්කම් වලට හේතුව මුල්වල ප්‍රවේණි විෂමයෝගිතාව විය හැකි ය. මෙය ශාකයේ වායව කොටස් වල ආන්තර වැඩීමට ද හේතු වෙයි.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

இலங்கையின் உலர்வலயத்தில் பயிர்நீர் தேவைகள் தொடர்பில் மழைவீழ்ச்சிச் சாத்திய எல்லைகளின் உபயோகம்

பானபோக்கை, C. R. வல்கம A.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

இயற்கை மழைவீழ்ச்சியினை மிகச் சாதகமான முறையில் பயன்படுத்தற் குரிய சாதனங்களை அபிவிருத்தி செய்வது இலங்கையின் உலர்வலயத்தின் மானுவாரி விவசாயம் நிலையானமுறையில் பேணப்படுவதில் தொடர்புபட்ட பிரச்சினைகளுள் ஒன்றாக இருக்கின்றது. இந்நோக்கத்திற்குப் பின்வருவன செய்தல் வேண்டும் :— *(1)* விதைக்கும் காலங்களை ஐயமற ஆய்ந்தறிதல் ; *(2)* பயிர் வளர்ச்சியின் எல்லாக் கால கட்டங்களுக்கும் தேவையான பயிர் நீர் கிடைக்கக்கூடிய மழைபெய்யும் காலங்களை அறுதியிட்டு அதற்கேற்ப விதைத்தற்காலம் தொடக்கம் அறுவடைக்காலம் வரை நீடித்து நிற்கக்கூடிய பயிர்வகைகளைத் தேர்ந்தெடுத்தல்.

இக்கட்டுரையில், உலர்வலயத்தின் பல்வேறு பகுதிகளின் வளர்ச்சிப்பருவங்களுக்கான நேர்தகவு மழைவீழ்ச்சியானது '' மானிங் '' முறையினைப் பின்பற்றி 1 : 1 மழை வீழ்ச்சிச் சாத்திய எல்லைகளின் 3 வாரப் பெயரும் மொத்தங்களின் மூலம் குறித்துரைக்கப்பட்டுள்ளது. உலர்வலயத்தில் பருவப்பிறப்புக்கும் பருவ இறுதிக்குமிடையில் பிரதேசவாரியான வித்தியாசங்கள் உண்டென்பது அவதானிக்கப்பட்டுள்ளது. இவைகளைக் குறிப்பாக காலபோகத்திற் காணலாம். அந்தந்தப் பிரதேசங்களில் மிகப்பொருத்தமான விதைப்புக்காலங்களைத் தெரிவுசெய்யும் முறை இங்கு காட்டப்பட்டுள்ளது. எதிர்பார்க்கப்படும் 1 : 1 சாத்திய எல்லைகளோடு பயிர்நீர்த் தேவைகளை ஒப்புநோக்கப்படுவதன்மூலம் கிடைக்கக்கூடிய பருவகால ஈரத்தன்மைக்கேற்ப குறிப்பிட்ட ஒரு பயிரின் நீர்த் தேவைகளைப் பூர்த்தி செய்யத்தக்கவாறு வாழ்நாள் கொண்ட பயிர்வகைகளை ஒருவர் தெரிவுசெய்யும் முறை பற்றி இதில் விளக்கப்பட்டுள்ளது. உலர்வலயத்துப் பல்வேறு பிரதேசங்களுக்கும் மற்றும் செய்யும்முறை உபயோகங்களுக்கும் ஒரு தனிப்பட்ட பயிர் இசைவுறுந்தன்மையையும் அதன் வளர்ச்சி ஆற்றலையும் முன்னதாகவே அறியும் விதம் பற்றியும் இக்கட்டுரையில் ஆராயப்பட்டுள்ளது.

தொட்சோபிளாசமோசிசுவும் இதயநோயும்
நாகரத்தினம், N.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

இது தொட்சோபிளாசமோசிசு நோய் காரணமாக ஏற்பட்டதெனக் கருதிய இதயநோயுள்ள 12 நோயாளிகளை ஆராய்ந்த கட்டுரையாகும். இதயத் துடிப்புப்பதிகருவி மூலமும் ஊனீரியல் மூலமும் கிடைக்கப்பெற்ற சான்றுகளின்படி இந்த நோயாளிகள் பிறந்த குடும்பங்களில் வாழையடி வாழையாக வந்துறுத்தும் இதயவிரிவு நோயின் அறிகுறிகள் காணப்பட்டன. ஊனீரியல் சான்றுகள்மீது அதிக நம்பிக்கை வைக்கப்பட்டுள்ளது. இந்நோயாளிகள் பலர் நாட்பட்ட இதயநோய்களால் பீடிக்கப்பட்டவராவர். சிலர் ஆகக் குறைந்த நோய் அறிகுறிகள் உள்ளவர்களாகவே இருந்தனர். ஏனையோர் எந்த நோய் அறிகுறியும் அற்றவர்களாகவிருந்தனர். சிலர் நாடியழட்சி அல்லது திடீர் ' மாரடைப்பு ' போன்ற இதயநோய் அறிகுறிகள் அற்றவராகவிருந்தபோதிலும் செல்குழாய்நாளஞ் சார்ந்த வெளிப்பாடுகளால் தாக்கப்பட்டவராவர். இதனுற் பிற இதயநோய்களைக் கண்டுபிடிக்கமுடியாதநிலை ஏற்பட்டுள்ளது. தொட்சோபிளாசமோசிசு நோயின் தோற்றம் பற்றி ஆராயும் போது நாட்பட்ட மறைந்துபோன இதயநோய் உள்ளவர்களை மாத்திரம் சோதனைசெய்யாது இதயத்தசைக்குரிய அல்லது இதயவுறைக்குரிய கடும் வியாதிகளால் பீடிக்கப்பட்டவர்களையும் ஆராயவேண்டும். தற்போதுள்ள எமது அறிவிற்கு எட்டாத வகையில் தொட்சோபிளாசமோசிசு நோயானது இலங்கையில் மறைந்துகிடக்கும் இதயநோய் நிலைகளுக்குக் காரணமாக அமையலாம்.

மரவள்ளிக்கிழங்கின் சயனேட்டு அமிலத்தை உற்பத்திசெய்யும் குளுக்கோசைட்டுப்பொருள் II. மரவள்ளிக்கிழங்குச் சிராய்களிலும் மாவிலும் உள்ள நஞ்சை அகற்றுதல்
ஜான்ஸ், E. R., பீரிஸ், நிர்மலா, ஜெயராஜ், E. E., அபேரத்தினை D. J.

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'' மனிகொட் எஸ்கியுலென்ரு கிருன்ட்ஸ் '' இல் அதாவது மரவள்ளிக்கிழங்கில் சயனேட்டு அமிலத்தை உண்டாக்குகின்ற குளுக்கோசைட்டுப்பொருள் உண்டு. விசேட பாதுகாப்புமுறைகளைப் பின்பற்றினுலொழிய மரவள்ளிக்கிழங்கை மாவாக்கியபின்னரும் இப்பொருள் நீர்ப்பகுப்படையாது ஒட்டிநிற்கும் மரவள்ளிக்கிழங்குச் சிராய்களிலும் மாவிலும் உள்ள மொத்த சயனேட்டு நச்சுப்பொருளின் மூலத்தன்மையினை 5% சதவீதத்திற்குக் குறைக்கக்கூடிய முறையினைப் பற்றி இக்கட்டுரையில் விளக்கம் காணலாம். இலினமரின் ஊடாக நொதியங்கள் வழி சயனேட்டு அமிலத்தை விடுவிக்கும் பரீட்சைகள், ஒட்டிநிற்கும் சயனேட்டுக்களையும் மொத்த சயனேட்டுக்களையும் பற்றியதாக அமைந்துள்ளன.

இரத்தத்திலுள்ள ''பிளாசமா பெனிளளனீன்'' என்னும் பதார்த்தத்தினை வேருக் கலுக்கும் மதிப்பீடுசெய்வதற்குமான குறுகிய வழியும் இலங்கை வாசிகளுக்குரிய ''ஆய்வுமருத்துவ மாதிரி'' யொன்றை நிறுவுதலும்

செந்திசண்முகநாதன், S., ருத்ரிகோ, சீதா I., கமலநாதன், S.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

இரத்தத்திலுள்ள '' பெனிளளனீன் '' பதார்த்தத்தினை அடுக்கு நிறப் பதிவியல் முறையினைப் பயன்படுத்தி வேருக்கவும் நம்பிக்கை வாய்ந்த முறை யில் கணித்து மதிப்பீடு செய்யவும் இயலும் முறையினைப் பற்றி இக்கட்டுரை யில் விளக்கப்பட்டுள்ளது. புறத்துறிஞ்சியாக சிலிக்கா ஜெல்-ஜீ யும் விரிவுக் கரைப்பானுக என்-பியூதனோல்/அசற்றிக் கமிலம்/தண்ணீர் (4 : 1 : 1) உம் உபயோகிக்கப்பட்டன. இந்த முறையானது 0.5 μ கணியங்களையும் கண்டுபிடிக்கத்தக்கவாறு கூருணர்வுடையதாக அமைந்திருந்தது. தேவைப் பட்ட நீர்ப்பாயத்தின் கனவளவு 4 μ (0.004 மிலீ) ஆயிற்று. அத்துடன் முழு மதிப்பீட்டிற்குச் செலவிடப்பட்ட நேரம் 3 மணித்தியாலங்களுக்குக் குறைவாகவிருந்தது. இலங்கையின் குழந்தைகள் தொடர்பில் இம்முறை யினைப் பயன்படுத்தி முடிவுசெய்யப்பட்ட ஆய்வுமருத்துவ மாதிரியொன்று காட்டப்பட்டுள்ளது. நீர்ப்பாய பெனிளளனீயின் பெறுமானங்கள் 7.07* 4.86 சராசரியுடைய 0 முதல் 16 மிகி./100 மிலீ. வரை இருந்தன. ஒரே குடும்பத்திற் பிறந்த இருவர்களுக்குரிய நிச்சயமான பெனிள்கெ ளூரியா நோய் விடயங்களும் இக்கட்டுரையில் விளக்கப்பட்டுள்ளன.

எளிதில் ஆவியாகும் எண்ணெய்கள்

III. அரியவகை கறுவாப்பட்டையிலிருந்து பெறப்படும் நறுமண நெய்மத்தின் இரசாயனக் கூறுகள்

விஜேசேகர, R. O. B., ஜயவர்த்தனை, A. L.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

கறுவாமரத்தின் வேற்றுநாட்டு சாபபினமொன்றின் (சிலவேளை இவ்வி னம் '' சினமோமும் கப்பருகொறெண்டே பீளல் '' என்னும் இனமாகவிருக் கலாம்) நீராவியால் ஆவியாகும் நெய்மம் கெ7ண்ட பட்டை மீதான ஆவு திரவ நிறஆய்வியற் கல்விகள் மேற்கொள்ளப்பட்டபின்னர் அப்பட்டையி லுள்ள எண்ணெயின் பிரதான கூறுகளாக லினலூல் (29%) வீதமும் இயிஜி னோல் (23%) வீதமும் 1 : 8 சினயோல் (16%) வீதமும் இருப்பதைக் கண்டு பிடித்துள்ளனர். இலங்கையில் சாதாரணமாகக் காணப்படும் கறுவாமரங் களின் பட்டையிலிருந்து பெறப்படும் நெய்மத்திற்கு முற்றும் வேறுபா டுடைய இரசாயன அமைப்பு இந்தக் கறுவா வகையில் உண்டு. இச்சேர்வை களுக்கான உயிர்தொகுப்புவியல் சம்பந்தமாகவும் இந்த எண்ணெயை உப யோகிப்பதில் உள்ள வாய்ப்புகளையும் அதன் நறுமணப்பொருட் கூறுகளை யும் ஆராய்தல் சம்பந்தமாகவும் இத்தாவரம் முக்கியத்துவம் வாய்ந்ததாகும்.

பொதுவிதிமுறைக்கமைந்த கவுஸ்–லேகர் சதுரிப்பு வாய்பாடுகள்

தர்மவர்த்தனு, M. W. C.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

தரப்பட்ட ஒரு வகுப்புக்குரிய சார்புப் பூரணிகளைக் கணித்தற்கான கவுஸ்—லேகர் வாய்பாடுகள் இன்றைய நவீன கம்பியூட்டர் செயற்திட்டங்களில் பெரிதும் பயன்படுத்தப்பட்டுவருகின்றன. இந்த வாய்பாடுகள் அனேகமாக விசைக்குறி Exp (–ax) தனிநிறைச் சார்புகளில் மட்டுமே பயன்படுத்தப்பட்டுவருகின்றன. எனினும் பலதிறப்பட்ட வகைகள், கணநிலைகள் ஆகியவற்றின் அதிர்வுகளுடன் தொடர்புடைய கணிப்புகளிலும் அணுபௌதிகவியல், மூலக்கூற்றுப்பௌதிகவியல் போன்றவற்றிலும் பௌதிக அமைப்பின் சிறப்பியல்புச்சார்புத் திருசியத்தினைச் சிக்கனமாக விளக்கிக் கூறுவதற்கு பல்–விசைக்குறிச் சார்புகள், (உதாரணமாக Exp (–ax), Exp (-bx) முதலியன) தேவைப்படுகின்றன. நிமிர்கோண பல்லுறுப்பிகள் கோட்பாட்டின் மீது இயக்கும் நியம கவுஸ்–லேகர் அணுகுமுறையானது பல்–விசைக்குறி விடயத் தொடர்பில் சதுரிப்புக் கோட்பாடொன்றினைப் பெறக்கூடியவாறு பொதுவிதிமுறைக்கு அமையுமாறு எளிதில் வகுத்தலாகாது. மிகவும் நேரான அணுகுமுறையினைப் பயன்படுத்தி இப்பிரச்சினைக்குத் தீர்வுகாணும்வகையில் பல்–விசைக்குறி முறைகள் தொடர்பில் சதுரிப்பு வாய்பாடுகளைப் பெறக்கூடிய பொதுவான முறையொன்று இக்கட்டுரையில் விளக்கப்பட்டுள்ளது. பல மேற்கோள்களுக்குரிய எண் விளைவுகளும் தரப்பட்டுள்ளன.

Hevea brasiliensis Muell. Arg. c. v. Tjir 1. பகுதின் III நாற்றுமேடை வேர்க்கட்டை நாற்றுக்களில் வளர்ச்சி

சேனநாயக்கா, Y. D. A., சமரநாயக்கா P.

J. Natn. Sci. Coun. Sri Lanka 1974 **2** (2) :

பரவலான முறையில் வேர்க்கட்டையாகப் பயன்படுத்தப்பட்ட வளரியான இறப்பர் (Hevea brasiliensis cv. Jjir. 1) நாற்றுக்கன்றின் வளருந்தன்மையினை அறுதியிட்டுக் கூறுவதற்கு ஒரு பரீட்சை நடாத்தப்பட்டுள்ளது. 32 மாதங்களுக்குப்பின்னர் எல்லா முனைத்தல் இனங்களுக்குமுரியதான நாற்றுக் கன்றுகளின் மாதிரியொன்று நாற்றுமேடையிலிருந்து நீக்கப்பட்டு அவற்றின் வேர்கள், தண்டுகள், இலைகள் ஆகியவற்றின் உலர் நிறைகள் கணிக்கப்பட்டன. வளர்ச்சியின் மூன்று பரமானங்களான (1) தாவரத்தின் உயரம், (2) முதல் அளவெடுப்பின் போதிருந்த தண்டின் விட்டம், (3) வேர் நீளங்கள் ஆகியன தாவரங்களினதும் அவற்றின் கூறுறுப்புக்களினதும் உலர்நிறைவோடு அதிக அளவில் இணைந்திருந்தமையை நிரூபித்துவிட்டன. இலைகளின் உலர்ப்பதார்த்தங்களை உருவாக்கும் பணிக்கும் வேர் வளர்ச்சிக்கும் இடையில் ஒரு தொடர்பு இருந்தது. வேர்களின் பிறப்பு மூலப் பல்வினப்புணரிதருகின்ற தன்மையானது சின்ன அரும்புகளின் மாறுபட்ட வளர்ச்சிக்கும் அதேபோன்று செடியின் காற்றுப்படுகின்ற பகுதிகளின் மாறுபட்ட வளர்ச்சிக்கும் காரணமாகவிருக்கலாமெனக் கருதப்படுகின்றது.

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