A Study of some Rice Irrigation Waters of Ceylon

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ABSTRACT

THE irrigation waters used by 15 experiment stations of the Department of Agriculture in different parts of the island are analysed for their chemical constituents.

The waters bring in large amounts of potassium and small quantities of nitrogen. The phosphoric acid cointent of the waters is almost neglegible. The silica contribution by irrigation water is also not very significant.

Some of the irrigation waters are moderately saline. None shows danger of causing alkalinity.

The dry zone irrigation waters are markedly different from the wet zone irrigation waters with regard to the presence of some chemical consitituents.

INTRODUCTION

Rice is one of the few crops of economic value which grows under submerged conditions and requires an abundant supply of water. The rice fields in the dry zone of Ceylon receive an annaul rainfall of less than 75 inches most of which is brought about by short spells of heavy precipitation. Very often this quantity represents only a fraction of the water requirements for a double cropped rice and the rice fields of these areas are therefore heavily dependent on supplementary irrigation from tanks and reservoirs. The intermediate zone and the wet zone however receive higher rainfall which is fairly evenly distributed throughout the year. This condition permits the growth of rice in certain areas without supplementary irrigation. Nevertheless, there are many rice fields in the wet zone which are irrigated from streams and channels flowing from the adjoining residual lands.

Although irrigation waters are used extensively in Ceylon in rice cultivation, no information is available regarding their chemical characteristics.

Continuous use of irrigation waters will affect the chemical and physical properties of the soil. The irrigation waters may bring in significant quantities of plant nutrients such as potassium, nitrogen and silica. It may also give rise to undesirable effects by bringing in excessive amounts of toxic substances.

A knowledge of the chemical constituents of irrigation waters will serve as a basis in evaluating dosage of fertiliser use, in studies on reclamation of soil or in a plant breeding programme which seeks to evolve varieties able to withstand certain adverse conditions caused by irrigation water.

This paper describes the chemical characteristics of some rice irrigation waters of Ceylon and their effects on rice cultivation.

MATERIALS AND METHODS

Places and Frequency of Sampling

Rice irrigation waters used by 15 Farms and experiment stations of the Department of Agriculture were collected at the point of entry to the rice fields, once a month beginning in May 1964 and analysed for pH, electrical conductivity, Na^+, K^+,Ca^{++}, Mg^{++}, $Fe^{++} + Fe^{+++}$, Al^{+++}, SiO_2, HCO_3^- Cl^-,PO_4^{---}, NO^-_3 and NH_4^+. The sampling and analysis were continued until April 1965.

The locations at which samples were collected were as follows: Bombuwela Rice Experiment Station, Labuduwa Boys-Girls Farm School, Muthurajawela Paddy Station, Pussellawa Rice Experiment Station, Wagolla Farm School, Peradeniya Agricultural Research Station, Karapincha Farm School, Nalanda Rice Experiment Station, Batalagoda Central Rice Breeding Station, Pelwehera Agricultural Station, Ambalantota Seed Paddy Station, Puliyankulama Experiment Station, Maha Illuppallama Dry Zone Agricultural Research Station, Hingurakgoda Seed Paddy and Mango Station and Polonnaruwa Seed Paddy Station.

The samples were collected in 3 litre polythene flasks. On reaching the laboratory the water was filtered and the filtrate was used for analysis. 5 ml. chloroform was added to prevent any fungal growth.

Methods of Analysis

pH—The pH of the water was determined soon after reaching the laboratory using a Beckman pH meter.

Electrical Conductivity—This was determined at 25°C using a Mullard Conductivity Bridge.

Sodium and Potassium

Sodium and potassium were determined using a Gallenkamp Flame Photometer.

Calcium and Magnesium

The method of Cheng and Bray (1951) using Versenate with indicators Murexide and Eriochrome Black T was employed for determination of calcium and magnesium.

Iron

Ferrous and Ferric iron were determined colorimetrically using Dipyridyl as outlined by Rainwater and Thatcher (1960).

Aluminium

The method of Hsu (1963) was used in which Aluminium is determined colorimetrically after treatment with Aluminon Acetate Buffer.

Silica

The Molybdenum Blue method of Kahler (1941) was used for the determination of silica.

Bicarbonate and Carbonate

Bicarbonate and carbonate were determined by titration with N/50 sulphuric acid using Methyl Orange—Indigo Carmine and Phenolphthalein as indicators.

Chloride

Chloride was estimated by titration with silver nitrate using potassium chromate as indicator.

Phosphoric acid

Phosphoric acid content was determined by the Molybdenum Blue method of Dickman and Bray (1940).

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Ammonium Nitrogen and Nitrate Nitrogen

Ammonium nitrogen and nitrate nitrogen were determined colorimetrically using Nessler's reagent and Brucine respectively.

RESULTS AND DISCUSSION

The results of analysis of the irrigation waters are given in Table 1.

pH

The pH varies from the lowest value of 5.75 at Pussellawa experiment station to 8.10 at Polonnaruwa Seed Paddy Station. An inverse relationship to degree of rainfall is generally apparent. However, an exception is the irrigation water at Ambalantota Seed Paddy Station where although the rainfall during the 12 months in which the study was conducted was about 25 inches, the water is more acidic than the Peradeniya water where the rainfall was 72 inches.

Electrical Conductivity

The electrical conductivity of irrigation water is a measure of the soluble salts present. It is seen that Pussellawa has the lowest electrical conductivity of 0.023 mmhos/cm. and Maha Illuppallama has the highest value of 0.632 mmhos/cm. Figure 1 gives the relationship between electrical conductivity and rainfall for the 15 stations.

Calcium and Magnesium

Three levels of concentration of calcium and magnesium are noticed in the results. The lowest concentration is found in the wet zone regions such as Labuduwa and Bombuwela whereas the highest concentration occurs in the dry zone areas. Intermediate levels of calcium and magnesium occur at Nalanda, Peradeniya and Karapincha.

Figure 2 shows the relationship of magnesium to calcium in the irrigation waters. The magnesium to calcium ratio is low at low concentrations of calcium and magnesium and increases rapidly as the concentration of the two elements in the irrigation water increases.

Sodium and Potassium

Sodium shows a wide variation of concentration from Pussellawa which analyses 1.65 ppm Na to Maha Illuppallama with 62.50 ppm Na. Muthurajawela contains 20.75 ppm Na in the water. This value is quite high in comparison with other wet zone stations.

Large quantities of potassium are present in the irrigation waters of the dry zone. It is also observed that all irrigation waters contain more sodium than potassium.

Figure 3 shows the sodium to potassium relationship in the irrigation waters of the 15 locations. A uniform sodium to potassium ratio is seen for all the irrigation waters except for Muthurajawela and Maha Illuppallama waters which seem to be exceptionally rich in sodium. While the high sodium content of the former station can be explained as a result of intrusion of sea water, the value at Maha Illuppallama has to be attributed to sodium rich soil or parent rock material.

Iron (Ferrous and Ferric)

The iron concentration is high at Muthurajawela, Nalanda and at Peradeniya compared to other stations.

Aluminium

The quantity of aluminium present in the waters is less than the quantity of iron. The waters of the dry zone experimental stations contain less aluminium than the waters of other experiment stations.

Silica

The silica content of the irrigation waters of the present study ranges from 0.90 ppm Si at Muthurajawela to 21.35 ppm Si at Peradeniya and seems to have no bearing to the climatic conditions of the location. However, this quantity is fairly related to the model values of available silica of the rice soils in the corresponding areas reported by Panabokke and Nagarajah (1964).

The average value for silica content of the river waters of the world is reported by Yamada (1965) as 5 ppm Si. Thus irrigation waters of Muthurajawela, Pelwehera, Puliyankulama and Bombuwela show relatively low amounts of silica.

Bicarbonate

The bicarbonate content which may lead to the formation of an alkali soil is distributed from the lowest value of 12 ppm HCO_3 at Pussellawa to 247.25 ppm HCO_3 at Maha Illuppallama.

The areas receiving low rainfall have high values of bicarbonate in the irrigation waters and vice versa.

Carbonates are not found in significant amounts in the irrigation waters.

Chloride

Tagawa and Ishizaka (1963) have reported that the accumulation of chloride ion by rice plants plays an important part in the physiological activity of the organs of rice plants.

Puliyankulama water analyses the highest chloride content of 127.95 ppm C1. Muthurajawela water recorded a high chlodire concentration of 47.00 ppm Cl compared with other stations having similar climate and parent material, probably as a result of entry of sea water.

Nitrate Nitrogen and Ammonium Nitrogen

The total nitrogen content in irrigation waters expressed as the sum of nitrate nitrogen and ammonium nitrogen is low. It is to be noted that irrigation waters contain more ammonium nitrogen than nitrate nitrogen. In fact, analysis of rain water by Koch (1943) reveals that the rain water too contains more ammonium nitrogen than nitrate nitrogen. Further, the nitrogen content of rain water at Peradeniya determined by Koch (1943) is greater than the nitrogen content of the irrigation waters at Peradeniya determined presently.

Phosphorous

Phosphoric acid content is very low in all the irrigation waters.

Salinity of the Irrigation Waters

Irrigation with waters containing an excessive amount of soluble salts can increase the concentration of salts in the soil solution to an extent to bring about salinity. Instances are reported where fertile lands have been rendered useless as a result of irrigation with such waters over a number of years.

It has been reported by Fireman and Hayward (1955) that the retardation of plant growth increases with the salt concentration of the soil solution and is largely independent of the nature of salts present.

Physiological studies on the tolerance of rice plants to salinity by Tagawa and Ishizaka (1963) have indicated that salinity affects the number of roots and rooting activity.

It has been shown by Pan (1964) that salinity of irrigation water affects not only the yield of rice but also the milling out turn of paddy.

The United States Department of Agriculture (1954) has classified irrigation waters on the basis of electrical conductivity as follows.

Conductivity mmhos/cm. at 25°C		*Class*
0—0.25	..	low salinity water
0.25—0.75	..	medium salinity water
0.75—2.25	..	high salinity water
>2.25	..	very high salinity water

If this classification is adopted for the present study, it would be apparent that the irrigation waters of Maha Illuppallama Agricultural Station, Puliyankulama Experiment Station, Hingurakgoda Seed Paddy Station and Pelwehera Agricultural Station are of medium salinity.

Such waters could be used if satisfactory drainage is provided and moderately saline resistant crops are grown.

Sodium Hazard of the Irrigation Waters

Irrigation with waters of high sodium content may lead to the formation of a sodium saturated soil with an alkaline reaction. Such soils are sticky and do not permit the passage of air and water through them readily. These soils are difficult to reclaim. Further, sodium is supposed to have toxic effects on plants. However, an irrigation water containing high sodium content may be safe if it also contains calcium and magnesium in high proportion.

The United States Department of Agriculture (1954) classifies irrigation waters with respect to its Sodium Absorption Ratio (SAR) defined as

$$\frac{Na^{+}}{\sqrt{[\frac{1}{2}(Ca^{++}+Mg^{++})]}}$$

in the following manner.

SAR		*Class*
0—10	..	low sodium water
10—18	..	medium sodium water
18—26	..	high sodium water
>26	..	very high sodium water

It is evident from Table 2 that all the waters of the present study are safe.

However, it is not strictly valid to classify irrigation waters for sodium hazard only by determination of SAR, since this factor does not take into account the presence of large amounts of anions such as HCO_3. An irrigation water with high HCO_3 content may as a result of concentration by evaporation precipitate calcium and magnesium thereby increasing the sodium concentration in the water with respect to calcium and magnesium.

This consideration led to the introduction of the concept of 'Residual Sodium Carbonate' by Eaton (1950). This is defined as $[(CO_3^{--} + HCO_3^{-}) — (Ca^{++} + Mg^{++})]$ concentrations expressed in milliequivalents per litre. This is a more useful index of measuring sodium hazard than SAR. Wilcox, Blair and Bower (1954) after carrying out leaching experiments have arrived at the following tentative classification of irrigation waters.

Residual Sodium Carbonate		*Remarks*
0—1.25	..	safe
1.25—2.50	..	marginal
>2.50	..	not suitable

From the values for Residual Sodium Carbonate given in Table 2 it is clear that the values are not high to cause concern.

Amount of Fertilising Substances Supplied by Irrigation Waters

To ascertain the amounts of fertilising substances supplied by irrigation waters to the paddy fields per season, it is necessary to know the concentration of the particular nutrient in the irrigation water and the volume of irrigation water used per season. The latter however cannot be ascertained with a great degree of accuracy.

Balfour (1915) conducting experiments in the North Central Province has estimated the irrigation water requirement for a three month rice crop as 31.5 inches. Kobayashi (1955) has assumed the quantity of irrigation water necessary for a rice crop in Japan to be 58 inches.

The results in Table 3 give the amounts of fertiliser brought in by irrigation water assuming a supply of 4 acre feet of irrigation water per season for a four month crop. More accurate results may be obtained when precise data is available in this respect. Only the dry zone stations are considered since it is a difficult task to work out the quantity of irrigation water used else where. Although it is difficult to assess what percentage of these nutrients in the water is utilized by the plants, it nevertheless indicates the relative contributions made by the irrigation water of different parts of the island.

Nitrogen

The quantity of nitrogen supplied by irrigation water varies from 1.65 lbs. N per acre at Polonnaruwa Seed Paddy Station to 4.05 Lbs. N per acre at Puliyankulama Experiment Station. The latter figure represents about 10 per cent. of the quantity of fertiliser presently recommended for rice.

Phosphorus

The amount of phosphorus supplied by the irrigation waters is small for all the stations and represents a minute fraction of phosphorus required by the rice crop.

Potassium

Very large quantities of potassium are supplied by the irrigation waters. Puliyankulama Experiment Station receives the highest amount of potassium equivalent to 105.25 lbs. K_2O per acre.

Ponnamperuma (1952) considers the presence of 0.2me exchangeable potassium per 100g soil to be quite satisfactory for a rice crop. This quantity is equivalent to about 187.5 lbs. K_20 per acre. It can be seen from Table 3 that irrigation waters themselves supply a large fraction of this requirement. Furthermore, quantities of potash brought in by irrigation waters to certain stations are far in excess of the amount of fertiliser presently recommended for the rice crop.

Abeyratne (1956) after carrying out experiments on irrigated rice at Maha Illuppallama reports a lack of response to potash in any year.

A knowledge of the potash content in irrigation water may be useful in explaining the lack of response for the application of potash in certain areas and also to formulate levels of application of potash fertiliser.

Silica

Ambalantota receives the highest amount of silica of 214.80 lbs per acre. Polonnaruwa also receives a high amount of silica. Puliyankulama Experiment Station which receives the highest amounts of nitrogen and potassium in the dry zone, receives the lowest quantity of 65.00 lbs. per acre.

Since the quantity of irrigation water used by the wet zone stations is less than that used in the dry zone, the contribution of silica from irrigation water at Muthurajawela, Bombuwela, Labuduwa, Pussellawa and Karapincha can be expected to be low.

Assuming the paddy grain, straw and husk to contain 3 per cent. 10 per cent. and 20 per cent. available silica respectively, a 50 Bushel/ acre rice crop with a 70 per cent. extraction ratio will remove about 300 lbs. SiO_2 per acre. Thus the supply of silica by irrigation water may not be very significant in most areas. As the role of silca in producing stiff strawed rice plants and in increasing the resistance to disease has been identified and since the exploitation of the nitrogen response in the tropics, is perhaps limited by these two factors, it may be necessary to find out whether silica in an available form has to be added to some of our rice fields regularly.

Comparison of Dry Zone Irrigation Waters with Wet Zone Irrigation Waters

Considering Maha Illuppallama, Puliyankulama, Hingurakgoda, Polonnaruwa, Pelwehera and Ambalantota Experiment Stations as representative of the dry zone and Labuduwa, Bombuwela, Wagolla, Pussellawa and Karapincha as representative of the wet zone, the average values for the chemical constituents for the dry zone and wet zone irrigation waters are given below in ppm.

	Na	*K*	*Ca*	*Mg*	*Fe*	*Al*	*Si*
Dry Zone	26·15	4·35	25·05	15·85	0·05	0·04	6·30
Wet Zone	3·00	1·00	3·65	1·50	0·09	0·07	6·15

	HCO_3	*Cl*	*P*	*N*
Dry Zone	154·55	52·00	0·04	0·23
Wet Zone	27·70	9·35	0·03	0·20

It is observed that the dry zone irrigation waters are richer in Na, K, Ca, Mg, HCO_3 and C1. The elements P, N, and Si appear to occur in similar quantities in both waters whereas Fe and A1 are found more in the wet zone waters.

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TABLE 1.—Average Values for the period May, 1964 to April, 1965

Location of sampling		*pH*	*Conductivity mmhos/cm. at 25°C*	*Na ppm*	*K ppm*	*Ca ppm*	*Mg ppm*	*(Ferrous + Ferric) ppm Fe*	*Al ppm*	*Si ppm*	*HCO_3 ppm*	*Cl ppm*	*NO_3-N ppm*	*NH_4-N ppm*	*P ppm*	*Total rainfall May, 64–April, 65 inches*
1. Bombuwela	..	5·90..	0·029..	2·60..	0·80..	1·05..	0·80..	0·06..	0·06..	3·30..	14·00..	9·35..	0·04..	0·11..	0·03..	106·30
2. Labuduwa	..	6·35..	0·056..	4·45..	1·85..	3·10..	1·10..	0·12..	0·08..	4·95..	23·90..	12·15..	0·12..	0·22..	0·02..	102·06
3. Muthurajawela	..	6·00..	0·168..	20·75..	2·65..	2·50..	2·85..	0·30..	0·09..	0·90..	20·40..	47·00..	0·10..	0·50..	0·02..	79·04
4. Pussellawa	..	5·75..	0·023..	1·65..	0·55..	1·35..	0·40..	0·04..	0·04..	4·80..	12·20..	8·80..	0·04..	0·11..	0·02..	140·01
5. Wagolla	..	5·95..	0·043..	4·00..	0·60..	3·05..	1·05..	0·15..	0·07..	12·30..	29·25..	8·35..	0·03..	0·12..	0·05..	91·98
6. Peradeniya	..	7·25..	0·127..	11·60..	2·05..	8·50..	3·65..	0·36..	0·16..	21·35..	77·60..	10·45..	0·03..	0·14..	0·03..	71·95
7. Karapincha	..	6·90..	0·097..	2·20..	1·25..	9·65..	4·10..	0·09..	0·08..	5·30..	59·20..	8·00..	0·08..	0·12..	0·02..	111·15
8. Nalanda	..	7·60..	0·103..	6·00..	1·80..	7·75..	4·05..	0·24..	0·19..	8·55..	55·05..	11·15..	0·14..	0·18..	0·03..	75·93
9. Batalagoda	..	7·50..	0·172..	10·05..	2·35..	15·80..	5·80..	0·05..	0·04..	7·70..	98·80..	13·55..	0·02..	0·17..	0·03..	66·99
10. Pelwehera	..	7·90..	0·341..	20·40..	5·00..	26·40..	15·35..	0·04..	0·04..	3·60..	175·10..	32·45..	0·04..	0·14..	0·02..	53·68
11. Ambalantota	..	7·15..	0·218..	11·35..	4·00..	19·30..	8·05..	0·07..	0·06..	9·25..	105·30..	21·90..	0·02..	0·19..	0·04..	25·18
12. Puliyankulama	..	7·45..	0·516..	40·50..	8·05..	28·60..	19·70..	0·04..	0·02..	2·80..	108·35..	127·95..	0·04..	0·33..	0·04..	50·09
13. Maha Illuppallama	..	8·05..	0·632..	62·50..	4·65..	32·65..	28·15..	0·06..	0·03..	6·75..	247·25..	97·40..	0·03..	0·17..	0·05..	46·18
14. Hingurakgoda	..	8·00..	0·272..	13·30..	3·10..	22·30..	13·70..	0·04..	0·05..	6·35..	154·05..	19·30..	0·03..	0·26..	0·05..	48·05
15. Polonnaruwa	..	8·10..	0·225..	8·70..	2·35..	21·30..	10·25..	0·02..	0·02..	8·90..	137·30..	12·85..	0·02..	0·13..	0·04..	56·57

TABLE 2

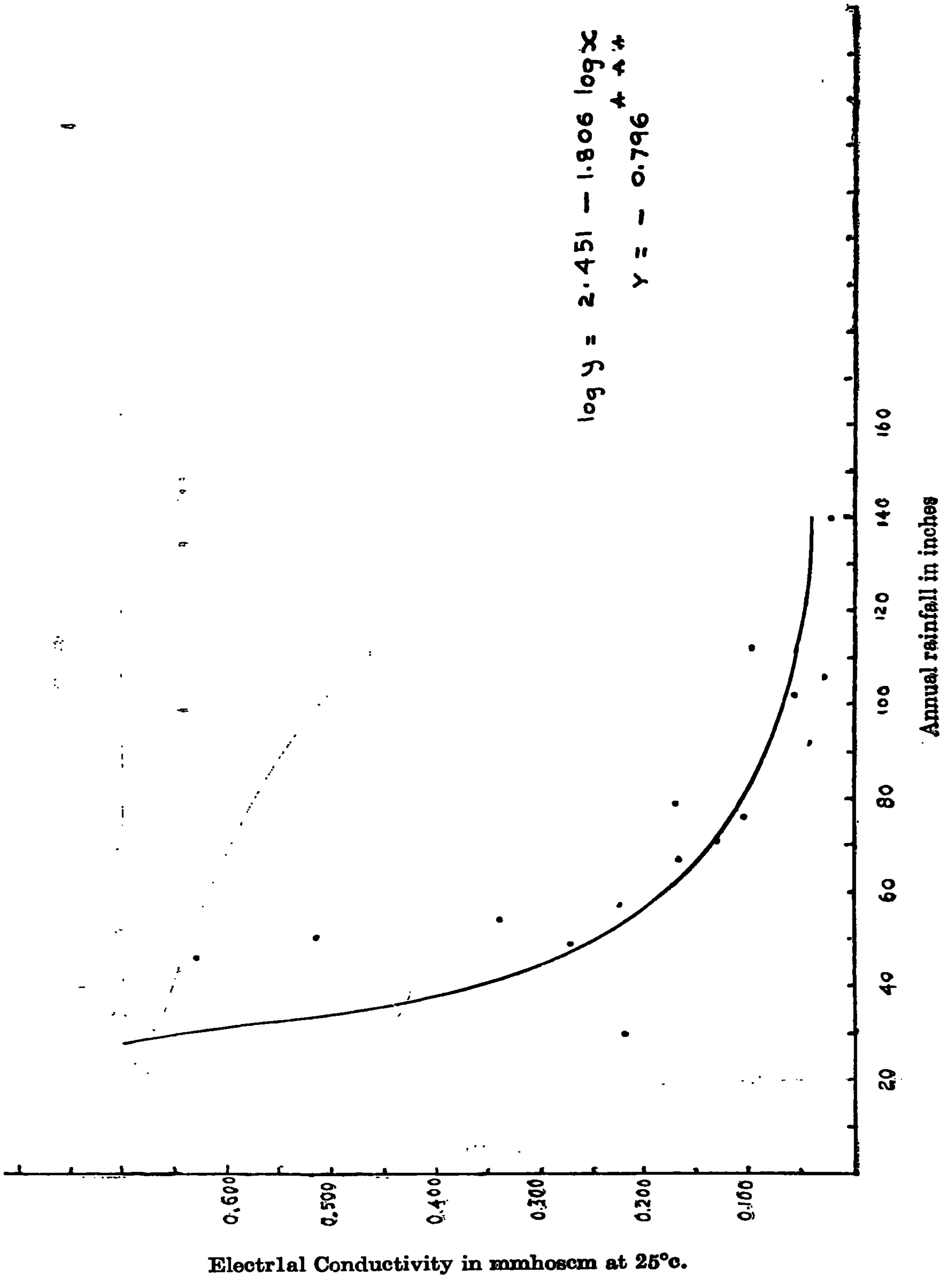
Location of sampling	*Sodium Absorption Ratio*	*Residual Sodium Carbonate (me/litre)*
1. Bombuwela	0·46	0·11
2. Labuduwa	0·55	0 15
3. Muthurajawela	2·13	— *
4. Pussellawa	0·32	0·10
5. Wagolla	0·50	0·24
6. Peradeniya	0·84	0·55
7. Karapincha	0·15	0·15
8. Nalanda	0·44	0·18
9. Batalagoda	0·55	0·35
10. Pelwehera	0·78	0·29
11. Ambalantota	0·55	0·10
12. Puliyankulama	1·43	—*
13. Maha Illuppalama	1·93	0·10
14. Hingurakgoda	0·55	0·28
15. Polonnaruwa	0·39	0·34

* Indicates negative value

TABLE 3.—Nutrients supplied by irrigation water (lbs/acre)

Location of sampling	N	P_2O_5	K_2O	Silica
1. Batalagoda	2·05	0·75	30·75	178.75
2. Pelwehera	1·95	0·50	65·35	83.60
3. Ambalantota	2·25	1·00	52·30	214.80
4. Puliyankulama	4·05	1·00	105·25	65.00
5. Maha Illuppallama	2·15	1·25	60·80	156.70
6. Hingurakgoda	3·15	1·25	40·50	147.45
7. Polonnaruwa	1·65	1·00	30·75	206.65

Fig. 1 — Regulationship between electrical conductivity and rainfall.



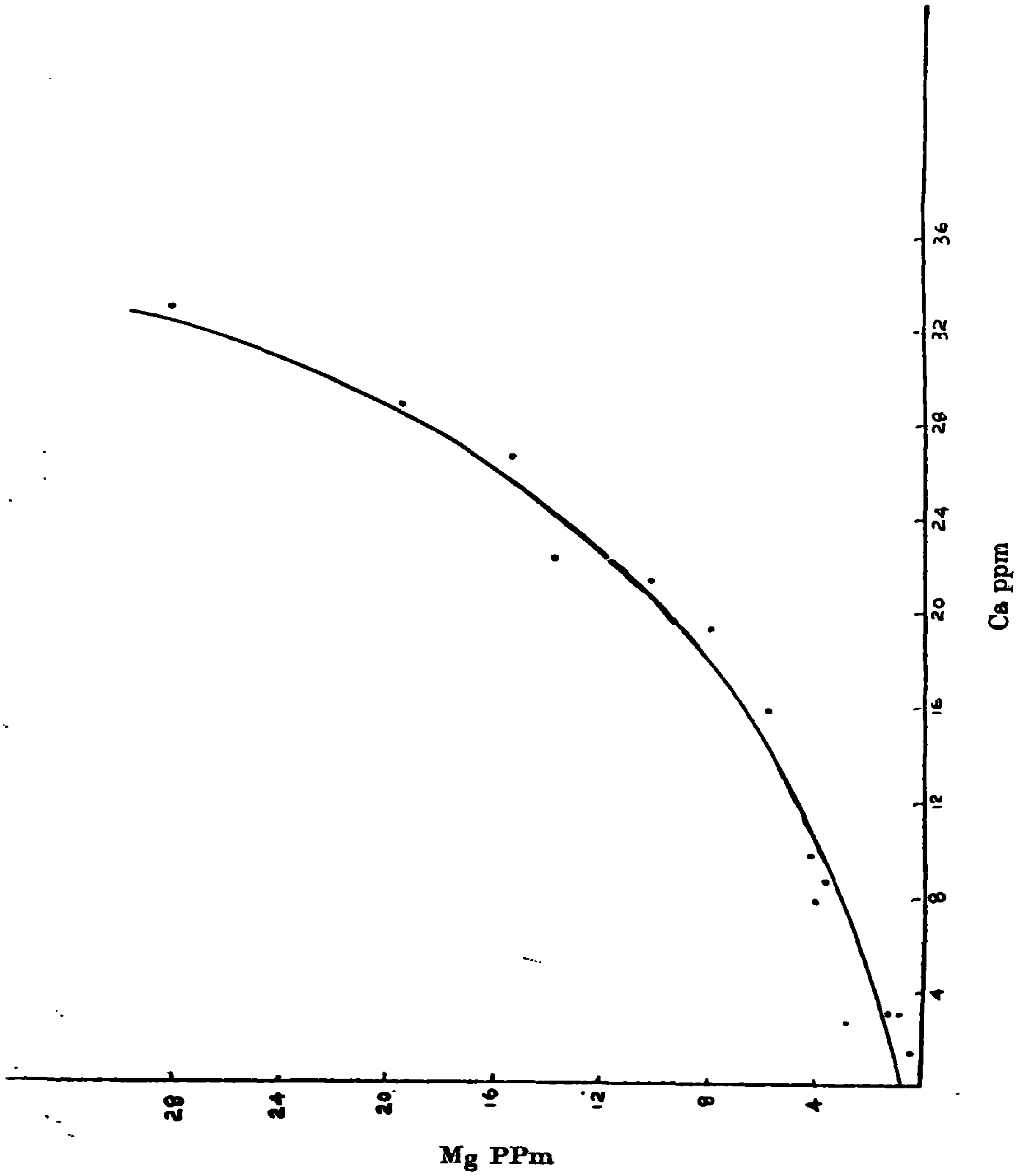


Fig. 2—Magnesium—Calcium relationship

Fig. 3—Sodium—Potassium relationship