STUDIES ON THE SALT-AFFECTED RICE SOILS OF KERALA

By

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CERTIFICATE

This is to certify that the thesis herewith contains the results of bona fide research work carried out by Shri P. Gopalakrishnan Nair, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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C O N T E N T S

INTRODUCTION

Almost all soils have at least small amounts of soluble salts in them. In places from where the sea has receded or in places where frequent saline water inundation is occurring, there will invariably be an accumulation of soluble salts. This is brought about mainly through tidal waters. Soluble salts in soils may also arise from processes of nitrification and acidification as well as from the addition of fertilisers. Soil salinity falls into the following three classes:

(1) Natural occurrence of excess of salts in the soils in the absence of adequate drainage,

(2) Occurrence of excess of salts through marine waters, and

(3) Occurrence of excess of salts as a result of continued fertilisation.

The saline soils of Kerala have originated mainly as a result of salt water ingress from the sea and the back waters. There are vast areas in Kerala which are subject to inundation with sea water. Particular mention may be made of the region known as Kuttanad which is also called the rice bowl of Kerala. The soils of these salt affected areas are very unique in their characteristics. They generally contain a high percentage of organic matter and are extremely acidic in reaction. The electrical conductivity of the saturation extract is often very high and the nutrient status is generally satisfactory.

Unlike the saline soils of the other parts of the world, the origin, genesis and development of these soils are under peculiar environmental and climatic conditions such as high rainfall, low pH and alternate flooding with saline and fresh water. The hydrology of these areas is also unique. During the rainy season these lands are swept by flood waters and the surface soils are partly desalinised. During the cropping season the water channels get salinised due to tidal influence from sea or back waters.

Rice is the major crop in these areas and the specialised farming practice resorted to is known locally as Kaipad or Pokali. According to this practice mounds or heaps of soil are made when the level of water is low and sprouted rice seeds are sown on them. After a month's growth the mounds are broken up and the seedlings are distributed all over the field along with the soil. This practice is followed to safe-guard the seedlings from high salt concentration during early stages of growth.

Much work has not been done on the chemical properties of these salt-affected soils except the fertility investigations on the highly organic Kari soils by Subramoney (1947). He has shown that the high acidity of these soils is due to the production of sulphuric acid by the sulphur oxidising bacteria. Subramoney (1966) has also established the existence of a sulphur bacterial cycle in these soils. Except for these studies no attempt has hitherto been made to investigate the nature of the soluble salts present in these salt-affected soils and to interpret them in relation to their chemical properties. The present investigation was therefore undertaken to bridge this lacuna. It is attempted to correlate salinity, measured as electrical conductivity, with the chemical and mechanical properties of the salt-affected soils.

The present study is intended to throw more light on the characteristics of the salt-affected soils of Kerala and to compare the nature of the soluble salts with the commonly conceived notions of saline soils. An attempt has also been made to make a reconnaissance survey of the salt-affected areas in the State.

REVIEW OF LITERATURE

A. Salt Tolerence of Crops

(1) Effect of soluble salts

The available literature on the injurious as well as beneficial effects of salt affected soils dates back as early as 1912. Lipman (1912) studied the effect of alkali salts on soil bacteria. He found that one per cent sodium chloride inhibited ammonification.

Lipman and Gericke (1919) pointed out that manure exerted protection against salt injury in soils on barley plants.

Lipman *et al* (1926) proved the salt tolerence of certain plants for sodium chloride. A study was made in solution cultures on the effects of a wide range of concentrations of sodium chloride on the growth of wheat, barley and peas. They observed that all plants tested showed a very high resistance to sodium chloride. All plants tested made stunted growth even at very high concentrations of sodium chloride such as 10,000 ppm. or more.

Magistad *et al* (1943) studied the effect of salt concentration, kind of salt and climate on plant growth in sand cultures. They found that the total salt concentration was a greater factor in determining the amount of reduced growth than effects caused by special ions. Growth reduction was in most cases linear with increasing osmotic concentration of the substrate. Conductance of the nutrient solution characterised the total salt effect as well as osmotic concentration. Chloride and sulphate salts when compared on an equal osmotic basis decreased growth to an equal extent with a number of crops. In the case of other crops chlorides were less toxic than sulphates at equal osmotic concentrations. Sodium did not appear to be an unduly toxic cation in sand cultures. Crops did not behave alike in their reaction to the combined effect of salt and climate. A number of crops died in a culture solution having an osmotic concentration of 4.5 atmospheres.

Wadleigh *et al* (1946) investigated the root penetration and moisture absorption in saline soils by crops. Bean, corn, alfalfa and cotton plants were grown in containers filled with soil varying in salt content with depth, from none at the surface and 0.25 per cent at the bottom. Observations showed that a few bean roots penetrated the layer containing 0.1 per cent sodium chloride and virtually none was found in the layers containing more than 0.15 per cent sodium chloride. Only a few corn roots penetrated the 0.2 per cent sodium chloride layer and none was found at a salt concentration of 0.25 per cent. As the salt content of the soil strata increased the roots of the various crops showed a decrease in their ability to absorb water.

Del Valle and Babe (1947) studied the sodium chloride tolerence of rice on inundated soil. In pot experiments, using a clay loam soil, rice plants 30, 60 and 90 days old were subjected until 164 days old to one of the five steady concentrations of sodium chloride (0.15 to 1.0 per cent) the pH remaining at 7.0. The treatments retarded flowering by 5-13 days depending upon the salt concentration. Concentrations of 0.15 to 0.25 per cent greatly lowered the number of grains produced by 30 and 60 day groups respectively. 0.25 to 0.35 per cent decreased gain size in 2 groups while 0.5 per cent prevented grain formation and killed some plants in 60-110 days. 90-day plants were hardly affected by these concentrations used. Symptoms of sodium chloride toxicity exhibited by plants were characterised by withering of the leaf tips, yellowing and death.

Iwaki and Ota (1953) studied the influence of varying concentrations of sodium chloride on the growth, heading and ripening of rice. They found that salinity did not affect the vegetative growth of plants, whereas the reproductive growth was seriously affected.

Bernstein et al (1955) investigated the interaction of salinity and planting practice on germination of irrigated row crops on a series of artificially salinised plots.

Iwaki (1956) dealt with the effect of sodium chloride concentrations at different stages of growth and the mechanism of salt injury on rice. The germination was reduced with 1-1.5 per cent sodium chloride and prevented with more than 2.5 per cent sodium chloride whereas 0.1-0.3 per cent delayed the growth and 0.5 per cent eventually caused death during the vegetative period.

Ting and Fang (1957) made preliminary investigations on the salt tolerence of rice. They used sodium chloride solutions of varying concentrations at different stages of growth. The grain yield was not at all affected when 1 per cent sodium chloride was used, but it caused the production of abnormal spikelets, and non-productive shoots. A higher concentration of 1.5 per cent, when given at an early tillering stage, killed the plants. A marked decrease in yield was observed when a concentration of 2 per cent was applied at the shooting stage. In general, higher concentration of sodium chloride solutions progressively decreased the normal development of the stem, leaf sheaths, blades, roots and grains.

Kofranek _et al_ (1957) found that Geraniums were very sensitive to saline conditions caused by additions of sodium and calcium chlorides. By increasing the salt concentration in the root zone from 15 me./l to 75 me./l, the terminal production was reduced by 43 per cent. Foliar symptoms such as marginal necrosis were observed on plants treated with 195 me./l of salts. Leaf width decreased with increased concentration of salts.

According to Iwaki et al (1958) the variation in the nitrogen and carbohydrate content in rice was affected by salt solutions of various concentrations. They found that in sand cultures 0.5-0.6 per cent sodium chloride solutions increased the nitrogen content and decreased the carbohydrate content of plants.

Pearson and Bernstein (1959) investigated the effect of salinity (conductivities ranging from 0 to 8 m.mhos/cm.) of the soil solution at tillering, heading etc. of caloro rice. Salinity inhibited growth more severely in the earlier than in the later stages of growth. The relationship between growth and conductivity (salinity) could be expressed by a multiple regression equation.

Mehta and Desai (1959) studied the effect of soil salinity on the growth and chemical composition of plants. Cotton, tobacco and bajra showed strong tolerence to salinity, while cabbage exhibited only very weak tolerence. With calcium chloride treatment the sodium, potassium and magnesium contents of leaves decreased.

Pirusyan (1959) made detailed study on the effect of salinisation on the development of maize. Yields on slightly saline soil, soil of average salinity and solonchak were 62 per cent, 50 per cent and 13 per cent of the yield on non-saline soil respectively. Plants in soils containing more than 1 per cent salts showed morphological adaptations to salinity. The salt resistance of maize increased throughout the vegetative period.

Pearson (1959) studied the factors influencing the salinity of submerged soil and growth of caloro rice. He found that the plants were adversely affected by increasing levels of salinity.

Ehling (1960) studied the effect of salinity on varieties of table grapes grown in sand cultures.

Lunin and Gallatin (1960) studied the effect of saline water on the growth and chemical composition of beans. Dilution of clay with an equal volume of sand decreased exchangeable cations in the soil. Yield of bean decreased linearly with increasing salinity.

Pearson and Ayers (1960) found that rice tolerated salt during germination and was sensitive to it during early seedling stage, tolerent during the tillering and maturation stages, but was sensitive at the time of flowering. A field to be seeded with rice by drilling must be non-saline at the surface but slight salinity was tolerated if the seed was broadcast in water, or otherwise should be followed by immediate flooding.

Ehrler (1960) studied the effects of salinity on rice, and showed that the additions of sodium chloride, sodium sulphate or calcium chloride to a nutrient solution depressed grain yield much more than growth.

Petrasovits and Darab (1960) investigated the salt tolerence of rice. Germination trials were conducted with seven varieties on solonetz soil in pots and treated with sodium sulphate (0.3-1.5 per cent) sodium bicarbonate (0.3-1 per cent) and sodium carbonate (0.1-0.5 per cent) in increasing order of toxicity. Treatment with sodium sulphate significantly increased the salt content of the soil while sodium bicarbonate and sodium carbonate unfavourably affected the physical properties of the soil and increased the pH values. The height and dry weight of the aerial plant parts were reduced by increasing salt concentrations.

Lunin et al (1961) studied the effect of stage of growth at time of salinisation on the growth and composition of beans.

Kaddah and Fakhry (1961) studied the tolerence of Egyptian rice to salt salinity effects when applied continuously and intermittently at different stages of growth after transplanting. Their results showed that rice, in general, is moderately tolerent of salinity in the early stages of growth. All varieties tested had low tolerence to sodium and calcium chlorides applied together 15 days after transplanting. The weight of straw and the total number of tillers were less affected than the yield.

Bhardwaj and Rao (1962) conducted physiological studies on salt tolerence in crops.

(2) <u>Nature of salts</u>

Lipman and Gericke (1919) pointed out that manure exerted a certain amount of protection against salt injury for barley plants in alkali soils. The protective effect more pronounced in the case of sodium chloride and sodium sulphate than in the case of sodium carbonate.

Magistad <u>et al</u> (1913) studied the effect of salt concentration, kind of salt and climate on plant growth in sand cultures. Chlorides and sulphates of equal osmotic concentrations decreased growth to an equal extent with a number of crops.

Mibasher (1948) has reviewed the studies on the influence of ions such as calcium, magnesium, potassium, lithium, rubidium, caesium, sodium, chloride and sulphate on plant growth and concluded that no casual relationship existed between the presence of harmful salts of sodium on the one hand and the favourable action of added calcium and potassium on the other.

Hussan and Overstreet (1952) showed that the elongation of raddish seedlings could be used as a biological test for alkali soils. They have, further, shown that the depressing effect of certain salts on the elongation of raddish seedlings was not due to the increased osmotic pressure of the media only and that the nature of the salts may also be important. They found that significant reduction in elongation took place in low concentrations of certain salts, such as, the chlorides of lithium and caesium, and concluded that certain ions may exert specific effects on the nature of the growth process of raddish seedlings.

Elagabaly (1955) made studies on the specific effects of certain adsorbed cations either in homo-ionic or in bi-ionic systems on the growth and cationic accumulation in barley plants. He concluded that the uptake or depletion of a given ion by plants is modified along other things by the nature of the corresponding ion. Calcium depletion occurred at 82 per cent saturation when sodium was the complementary ion and at 28 per cent when magnesium was the complementary ion. Magnesium behaved in more or less the same way. This could be explained on the basis of the Donnan membrane theory and differences in the activities of adsorbed ions. Setting the lower limit of alkali soils at a sodium ion concentration of 15 per cent may not be justified as sodium stimulates barley growth at this percentage. The nature of the complementary ion and the type of plant grown should also be considered when specifying this limit.

Zachariah and Sankarasubramony (1960) conducted pot culture studies on salt tolerence of certain paddy varieties and concluded that the salt resistance increased with maturity for all varieties.

(3) Salts in irrigation water

Fraps (1927) studied the effect of salt water on rice. He showed that water containing 0.3 per cent salt or above was dangerous to rice and that water containing less than 0.3 per cent salt might also prove dangerous. He further advised that 0.5 per cent salt or more should not be used for irrigation. He has made the following suggestions regarding the use of irrigation water for rice:

(1) Water containing more than 35 grains of salt per gallon should not be used, if this amount of salt water was to remain in the field until the water evaporated or was diluted with fresh water;

(2) Flooding a second-time with water containing more than 15 grains of salt per gallon was not advisable; and

(3) It might or might not be harmful to use water containing 50 grains of salt on land which was wet at the time of application of the salt water, if it was possible to remove all of the salt water and replace it with fresh water within 2 weeks of application of salt water.

Van Den (1952) suggested that irrigation water for glass-house crops should not contain more than 0.5 g. per litre sodium chloride.

Yaalon (1958) studied the effect of saline irrigation water on calcareous soils. Since calcium sulphate was sufficiently soluble to prevent absorption of sodium from moderately saline waters it was a preventive conditioner on all soils where permanent irrigation with saline water was established.

Ravikovitch and Muravsky (1958) studied the effect of irrigation waters of varying degrees of salinity on soils and crops. Water containing 848, 1226, 1527 and 1980 ppm. of total salts were applied to grey white silty clay loams having a good physical condition and containing considerable amounts of calcium carbonate and medium levels of nutrients. The Na/Ca ratio in the soil solution fluctuated before irrigation, but after saline irrigation it exceeded the ratio in the irrigation water.

Kelley et al (1961) have investigated the effects of salts in irrigated waters on the growth of plants. They found that a considerable difference in the ratio between soluble ions in the soil compared with that of the corresponding ions in the irrigation water brought about differential rates of absorption of ions by plants.

Chang (1961) has studied the effects of saline irrigation water and exchangeable sodium on soil properties and the growth of alfalfa. Saline irrigation waters with salt concentrations ranging from 400 to 9,000 ppm. were used.

Irrigation water containing 3,000 ppm. salts did not depress the yield. It was suggested that after a good stand in the seed bed is established fair growth followed by reasonable yields may be expected.

B. Characteristics of salt-affected soils

Fireman and Reeve (1948) studied some chemical and physical characteristics of saline and alkali soils in Gem County, Idaho.

Richards, (1950) studied the chemical and physical characteristics of saline and alkaline soils of Western United States. He found that saline soils have a high soluble salt content and their saturation extract have an electrical conductivity greater than 4 m. mhos/cm at 25°C. Alkali soils have an exchangeable sodium percentage greater than 15. Saline alkali soils have a conductivity greater than 4 m. mhos/cm. at 25°C and the non-saline soils a conductivity less than 4 m.mhos/cm. at 25°C. Saline soils are usually flocculated and permeable and reclamation is carried out by leaching and drainage. Saline alkali soils are treated in the same way, provided sufficient gypsom is present.

Wang and Hsu (1952) illustrated the utility of electrical conductivity measurement in the investigation of sugarcane soils in Taiwan. Electrical conductivity was used as a measure of the total soluble salts in the soil.

Raychaudhuri and Sankaram (1952) have described some of the saline soils in the Delhi State. The profiles and the properties of four different soils representing the Jumna Khadar area showed varying degrees of salinity in addition to a slight tendency towards alkalinization. Further, these profiles were characterised by the absence of a well-defined horizon differentiation and structural formation. A progressive decrease of soluble salts and an increase in the pH with depth suggested that these soils belong to the Solonohak group. It was concluded that the origin of the salts in the profile was probably due to the upward movement of underground water.

Marillonnet (1953) studied the problems of land utilisation in Netherland polders. A comprehensive account is given of the different types of polders (marsh, lake and marine), their formations, soil drainage and general maintenance. Data were assembled on soil salinity and salt tolerence in plants and methods of desalinisation were described.

Agarwal and Yadav (1956) investigated the diagnostic techniques for the saline and alkaline soils of the Indian Gangetic alluvium in Uttar Pradesh.

Raychaudhuri and Sinha (1957) conducted studies on the saline and alkaline soils of the villages in Delhi State. Physical and chemical data were reported from various surface soils in the region. A characteristic profiles was described. The soils were primarily solonchak and were at various stages of salinisation or alkalinisation due to leaching of the saline constituents.

Wang et al (1958) studied the chemical characteristics and evolution of saline alluvial soils of the western coastal plain of Taiwan. The term saline alluvial was preferred to that of halomorphic.

Bonnet and Brenes (1958) conducted a detailed salinity survey of Lagon Valley. This survey included sampling, recording pH, calcium carbonate, saturation percentage, electrical conductivity, extractable calcium and magnesium and exchangeable sodium percentage.

Yoneda et al (1959) conducted studies on the chemical composition of glass-house vine soils with special reference to the accumulation of excess soluble salts.

Milgkovic et al (1959) studied characteristics of salt-affected soils of Yugoslavia. Profile characteristics of four representative locations have been given. High exchangeable sodium interior drainage and boron toxicity were the major problems of salinity.

Banerjee (1959) presented some aspects of salt-affected soils of West Bengal. An attempt has been made to see if any relationship existed between pH and exchangeable sodium percentage and between the soluble and exchangeable cations. Though some workers have found a good degree of correlation between pH and E.S.P., no such correlation existed between pH and E.S.P. of the soils investigated. On the other hand, a high degree of correlation existed between pH and organic carbon.

MATERIALS AND METHODS

A. Pot culture studies on conductivity as influenced by different salts and its effect on the growth of paddy.

Earthernware pots nine inches in diameter and one foot in height were used in this study. The pots were given an internal coating of wax to prevent the leakage of water. The soil used was a clay loam from the bad of Vellayani lake. The rice variety used was PTB 10 which is one of the most widely cultivated varieties in the salt-affected areas of Kerala.

Equal quantities of powdered dried leaves and farmyard manure were incorporated into the soil at the rate of 2500 kg. per acre as a basal dressing. The pots were filled with one kilogram quantities of this soil and kept flooded with water for a period of one month. After this period the following treatments were given;

(1) Sodium chloride,

(2) Potassium chloride,

(3) Magnesium chloride,

(4) Calcium chloride,

(5) Sodium chloride + magnesium chloride (1:1), and

(6) Sea water.

The treatments were given at eight different levels so as to obtain conductivities of 2, 4, 6, 8, 10, 12, 14 and 16 m. mhos/cm. for the 1:2 soil water extract. The amount of salt required for preparing solutions of desired conductivities was obtained from the graph relating concentrations of single salt solutions to electrical conductivity as given by Richards (1954). The desired conductivities of sea water were obtained by diluting it progressively with water and observing the resultant conductivity. A graph was drawn connecting dilution of sea water with conductivity from which the extent of dilution for the required conductivity could be easily obtained. The 1:2 soil water extracts were tested to ensure that the desired conductivities were obtained after the addition of the calculated amounts of salt solution and sea water. After treatment with the different sources of salinity three identical and healthy rice seedlings (14 days old) were transplanted into each pot.

The arrangement of pots along with details regarding treatments is presented in Table 1.

The experiment in two replications was started on 12--3--1963. The pots were irrigated with tap water to make up for the loss through evapo-transpiration. The soil in each pot was examined periodically to see that the desired conductivity was maintained. The growth characteristics of the plants were observed at intervals of one week until they were harvested

Table 1

Arrangement of pots

Conductivity (m.mhos/cm.)	Sources of salinity						
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water	Control
	Number on the pot						
0							50
2	2	10	18	26	34	42	
4	3	11	19	27	35	43	
6	4	12	20	28	36	44	
8	5	13	21	29	37	45	
10	6	14	22	30	38	46	
12	7	15	23	31	39	47	
14	8	16	24	32	40	48	
16	9	17	25	33	41	49	

on 27--6--1963. Details such as the number of tillers, number of earheads, height of plants and yield of grain and straw were recorded.

B. Correlation studies between chemical and mechanical properties of salt-affected soils of Kerala in relation to conductivity and soil reaction.

The salt-affected soils of Kerala are distributed mainly in the Districts of Quilon, Alleppey, Kottayam, Ernakulam, Trichur, Kozhikode and Cannanore. Fourteen typical soil samples representing these areas were collected and used in the study. The details regarding each sample of soil are furnished below:

Sample No. 1

This soil was collected from West Kallada in Quilon District where salt water inundation occurs from the Ashtamudi lake. An area of approximately 1500 acres is affected.in this manner. The surface soil is greyish brown is colour which tends to deepen with depth. There is no visible horizon differentiation in the soil profile. The rice varieties used are Kochuvithu and PTB 10, the average yield being 2000 lb./acre.

Sample No. 2

This sample, representing the Kari soils of Kuttanad, was collected from Thottappally in the Alleppey District. The Kari soils are distributed over an area of 50,000 acres. They are noted for their extreme acidity and high organic matter content. The surface layer generally consists of bluish black clay mixed with humus. The profile has no demarcations, but wood fossils may be observed at depths below 24 inches. Layers below 48 inches usually consist of greyish black peat mixed with sand and clay. The Kari area is a unique region where the soils remain submerged under water for the major part of the year and get exposed only during the cropping season of November to March. Saline water ingress is from the Arabian sea. Rice is grown by putting up bunds and pumping out the water during summer. The varieties generally grown are Athikera and PTB 10. The average yield is 1800 lb./acre.

Sample Nos. 3, 4 and 5

These soils were collected from Vechoor, Vaikom and Murinjapuzha respectively in Kottayam District. The approximate area of saline water inundation in this region is 9000 acres. The source of salinity is from the Vembanad lake. The soils from Vechoor and Vaikom are clayey and that from Murinjapuzha is sandy. There is no distinct horizon differentiation in the soil profiles of these areas. Local varieties of rice such as Athukrazhi and Mundakannan are generally grown. PTB 10 is also becoming popular. Average yield per acre is about 1500 lb.

Sample Nos. 6, 7 and 8

These samples were representative of the salt-affected areas of North Parur, Thrippunithura and Vyttila respectively in Ernakulam District. These soils cover an area of about 50,000 acres. In Thrippunithura and Vyttila the soils are sandy and in North Parur it is clayey. There is very little horizon differentiation in the soil profiles of these areas. The rice varities generally grown are Cheruvirippu, Chootupokali and PTB 10. Typical Pokali cultivation is followed in these areas. Mounds of soil are formed in the months of April-May and sprouted seeds are sown. In June the seedlings are distributed all over the field. The crop is harvested during September-October and the average yield is 1500 lb./acre.

Sample No.9

This soil represented the saline tract of Thalikulam in Trichur District. The area affected by sea-water inundation is 4790 acres. The soil type is clayey and horizon demarcations are practically absent in the soil profile. Some local varieties of rice and PTB 10 are used for cultivation. The rice crop in this region is very badly affected by salt water. Seedlings start drying up soon after transplantation and the yield is extremely low.

Sample No.10

This sample was collected from Cheruvannur in Kozhikode District. The approximate area of sea-water intrusion in this region is 2,500 acres. Sand and clay occur together in this area, with very little horizon differentiation. Local varieties of rice such as Orpandy and PTB 10 are generally cultivated. Average yield is only 1000 lb./acre.

Sample Nos. 11, 12, 13 and 14

These samples were typical of the soils of Kattampally, Tellicherry, Payyanur and Irikkur in Cannanore District. The area inundated by saline water covers approximately 2,500 acres. The soils of Tellicherry and Payyanur are sandy whereas those of Kattampally and Irikkur are clayey. No distinct profile characteristics are seen in these soils. A local rice variety known as Orkayama and PTB 10 are usually cultivated in these areas. The salt water intrusion is from back waters in Kattampally and from the sea in the other places. The usual method of cultivation is by transplanting. Another method of cultivation by raising mounds is also followed in some places. The average yield is 1000-1500 lb./acre.

Methods of analysis

The collection and preparation of the soil samples and their analysis were carried out by the methods suggested by Piper (1950) and are briefly indicated below.

1. Colour

The colour was designated using the Munsell notation by comparison with a colour chart.

2. pH.

The pH was determined with a Beckman pH meter using 1:2.5 soil water suspension.

3. Conductivity

The conductivity measurements were made with the help of a Solu Bridge soil Tester using a 1:2 soil water extract.

4. Moisture

A known weight of the soil was dried in an air-oven at 100-105°C for eight hours and the loss in weight was noted. This was expressed as per cent of the moisture free weight of the soil.

5. Loss on ignition

A known weight of the moisture-free soil was ignited at 600-900°C for about eight hours until all organic matter was oxidised. The loss in weight was noted and expressed as per cent of the moisture free weight of the soil.

6. Total sesquioxides

The sesquioxides were precipitated in an aliquot of the hydrochloric acid extract using ammonium chloride and ammonium hydroxide. The precipitate was filtered, washed free of chloride, dried and ignited and reported as total sesquioxides on moisture-free basis.

7. Total calcium

Calcium was precipitated in the filtrate from the separation of sesquioxides as calcium oxalate and estimated volumetrically by titration with standard potassium permanganate.

8. Total Magnesium

Magnesium was precipitated as magnesium ammonium phosphate in the filtrate from calcium separation, filtered, ignited and estimated as magnesium pyrophosphate.

9. Total Potassium

Potassium was precipitated in an aliquot of hydrochloric acid extract as potassium sodium cobaltinitrite in acetic acid medium and estimated volumetrically using standard potassium permanganate and oxalic acid.

10. Total Phosphorus

In an aliquot of the hydrochloric acid extract phosphorus was precipitated as ammonium phospho molybdate in nitric acid medium and estimated volumetrically.

11. Total Sodium

Sodium was precipitated in the water extract of the soil by adding magnesium uranyl acetate and estimated gravimetrically.

12. Chloride

Chloride was estimated volumetrically in an aliquot of the water extract by titration with standard silver nitrate.

13. Sulphate

In an aliquot of the water extract the sulphate was precipitated as barium sulphate and estimated gravimetrically.

14. Total Nitrogen

Total nitrogen was estimated by the Kjeldahl method using sulphuric-salicylic acid mixture.

15. Organic Carbon

Carbon was estimated by Walkley and Black's quick titration method. A known weight of the soil screened to pass through a 0.5 mm. screen was digested with a known excess of standard potassium dichromate and concentrated sulphuric acid making use of the heat of dilution of the sulphuric acid for digestion. The excess of chromic acid, not reduced by the organic matter of the soil, was then determined by titration with standard ferrous sulphate using diphenyl ammine as indicator. From the dichromate consumed the organic carbon content in the soil was calculated.

16. Available Phosphoric acid

Available phosphoric acid was extracted by Bray's No.1 reagent (0.03 N ammonium fluoride in 0.025 N hydrochloric acid) and estimated colourimetrically using a Klett Summerson colorimeter. To avoid interference of fluoride 0.8 molar boric acid was used.

17. Available Potassium

Morgan's reagent (sodium acetate and glacial acetic acid) was used as the extractant for available potassium. In the extract potassium was estimated turbidimetrically using a Klett Summerson colorimeter after developing turbidity by the addition of sodium cobaltinitrite in a medium of equal quantities of isopropyl and methyl alcohols.

18. Mechanical composition

The mechanical analysis of the soils was carried out by the International Pipette method after oxidising the organic matter with 6 per cent hydrogen peroxide.

R E S U L T S

A. Pot culture studies on conductivity as influenced by different salts and its effect on the growth of paddy.

I. General observations

The general observations made regarding the growth of the plants as influenced by salinity were as follows:

1. First week

During the first week after transplanting the plants treated with sodium chloride and potassium chloride at conductivities 14 and 16 m. mhos/cm. and those treated with calcium chloride and sea-water at conductivities 16 m.mhos/cm. exhibited signs of wilting. The plants in all the other treatments showed considerable tolerence to salinity.

2. Second week

During the second week the plants treated with sodium chloride at conductivities 10, 12, 14 and 16 m.mhos/cm. and with potassium chloride at conductivities 14 and 16 m.mhos/cm. wilted completely. With potassium chloride at 10 and 12 m.mhos/cm. the wilting was only partial. There was complete wilting with sea-water at conductivities 12, 14 and 16 m.mhos/cm. No wilting was observed in any of the other treatments.

The appearance of the plants during the second week may be noted from Plates 1 and 2.

3. Third week

Sodium chloride at conductivities 6 and 8 m.mhos/cm. as well as potassium chloride and calcium chloride at 10 and 12 m.mhos/cm. induced signs of wilting in the rice plants during the third week. The plants subjected to salinity from sea-water at conductivities 12, 14 and 16 m.mhos/cm. also exhibited signs of wilting. There was greater tolerence to the treatments with magnesium chloride. The plants subjected to magnesium chloride alone, or in combination with sodium chloride, started showing symptoms of wilting only at conductivities of 14 and 16 m.mhos/cm.

4. Fourth week

During the fourth week after transplanting only the plants subjected to sodium chloride treatment at conductivities of 2 and 4 m.mhos/cm. and those treated with potassium chloride and calcium chloride at conductivities less than 8 m. mhos/cm. survived. The plants in the pots treated with sea-water and with sodium chloride in conjunction with magnesium chloride at conductivities of 12, 14 and 16 m.mhos/cm. wilted completely. Excellent tolerence to magnesium chloride upto a conductivity of 12 m.mhos/cm. was exhibited by the plants.

The appearance of the plants at the end of the fourth week is given in Plates 3 and 4. It may be noted that the control plants in the pots showed no signs of wilting and remained quite healthy throughout this period. In the salt treated pots the plants which survived after the fourth week were those treated with sodium chloride at conductivities of 2 and 4 m.mhos/cm., and with potassium chloride and calcium chloride at conductivities less than 8 m.mhos/cm. Sea-water, as well as sodium chloride in combination with magnesium chloride, were tolerated upto a conductivity of 10 m.mhos/cm. The highest tolerence was shown to magnesium chloride and the plants treated with this compound at a conductivity as high as 12 m.mhos/cm. survived even after the fourth week.

The symptoms induced by salinity generally consisted of an yellowing of the leaves and marginal necrosis leading ultimately to death. With increase in concentration of the salts there was a deepening in the yellow colour of the plants. However, in the pots which received magnesium chloride the leaves developed a rich green colouration.

5. <u>After four weeks</u>

The plants which survived after the fourth week remained healthy thereafter and flowered. The growth was, however, considerably reduced in the case of plants subjected to higher levels of salinity. Similarly the earheads first appeared in the plants which received lower concentrations of salts and then gradually in the plants receiving higher concentrations.

The appearance of the plants on the 80th day after transplanting is presented in Plates 5, 6 and 7.

II. Yield and Growth characteristics

Details regarding the yield and growth characteristics of the plants at the time of harvest (101st day) are given below:

1. Height of plants

It may be noted from Table 2 that the plants subjected to a salinity of 2 m.mhos/cm. were even taller than those in the control. At this salinity level the maximum height was reached by plants subjected to magnesium chloride in combination with sodium chloride. Even at conductivities of 4, 6 and 8 m.mhos/cm. plants subjected to salinity with magnesium chloride in combination with sodium chloride were taller than those exposed to the other treatments. Sea-water appeared to be more beneficial than sodium chloride and potassium chloride at all conductivities as far as the height of plants was concerned.

2. Number of tillers and earheads

Data in Tables 3 and 4 reveal that the maximum number of tillers and earheads was produced at a conductivity of 2 m.mhos/cm. irrespective of the nature of the salt. However, among the different sources of salinity, sodium chloride, potassium chloride and calcium chloride tended to produce the least number of tillers and earheads. Plants subjected to magnesium chloride at 8 m.mhos/cm. produced almost as many

Table 2

Influence of different levels of salinity on the height of plants

Conductivity (m.mhos/cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water
	Height of plants (cm.)					
2	139.2	132.6	134.2	145.1	150.2	136.2
4	98.5	120.5	137.4	142.2	145.4	130.1
6	**	115.3	132.3	121.4	136.5	125.3
8	**	96.2	122.2	102.3	125.4	124.4
10	**	**	121.3	**	116.5	115.5
12	**	**	111.4	**	**	**
0	121.5					

** Plants completely wilted.

Table 3

Influence of different levels of salinity on the number of tillers

Conductivity (m.mhos/cm.)	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water
	Number of tillers per plant					
2	3	3	4	4	4	4
4	2	3	4	3	3	3
6	**	2	3	2	2	3
8	**	2	3	2	2	2
10	**	**	2	**	1	1
12	**	**	1	**	**	**
0	3					

** Plants completely wilted.

Table 4

Influence of different levels of salinity on the number of earheads

Conductivity (m.mhos/cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea Water
	Number of earheads per plant					
2	3	3	4	3	4	4
4	1	3	4	3	3	3
6	**	2	3	2	2	3
8	**	2	3	1	2	2
10	**	**	2	**	1	1
12	**	**	1	**	**	**
0	3					

**Plants completely wilted.

tillers and earheads as those in the control. With increase in the concentration of the salts the number of tillers and earheads tended to decrease.

3. Length of earheads

From Table 5 it may be noted that the earheads were longest in all the treatments at a conductivity of 2 m.mhos/cm. and were even longer than those in the control. The length of the earhead tended to decrease with increase in the concentration of salts.

4. Number of grains

It may be seen from Table 6 that the number of grains per ear head tended to decrease with increase in salinity. With calcium chloride, as well as with magnesium chloride alone and in combination with sodium chloride, at a conductivity of 2 m.mhos/cm. the number of grains per earhead was more than that of the control. At all levels of conductivity magnesium chloride treatment showed a more beneficial effect than other treatments.

5. Weight of grain and straw.

Data relating to the yield of grain and straw are presented in Tables 7 and 8. It may be noted that the highest yield of grain and straw was obtained with magnesium chloride

Table 5

Influence of different levels of salinity on the length of earhead

Conductivity (m.mhos/cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water
	Length of earhead (cm.)					
2	26.5	22.4	27.2	26.3	30.2	24.3
4	19.6	21.0	25.6	25.4	28.4	22.1
6	**	19.2	24.3	20.2	25.0	21.4
8	**	18.1	21.2	18.1	20.3	20.2
10	**	**	20.4	**	18.2	16.5
12	**	**	19.1	**	**	**
0	21.6					

**Plants completely wilted.

Table 6

Influence of different levels of salinity on the number of grains per earhead.

Conductivity (m.mhos/cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea Water
	Number of grains per earhead					
2	78	70	105	101	100	75
4	41	40	84	68	82	52
6	**	36	82	65	75	40
8	**	31	67	56	65	36
10	**	**	45	**	40	30
12	**	**	42	**	**	**
0	82					

** Plants completely wilted

Table 7

Influence of different levels of salinity on the yield

Conductivity (m.mhos/cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water
	Yield (g.) per pot					
2	5.2	4.6	7.2	6.8	6.7	5.0
4	3.1	3.0	5.5	4.5	5.4	3.5
6	**	2.6	5.3	4.3	5.0	3.1
8	**	2.1	4.4	4.0	4.3	2.1
10	**	**	3.4	**	3.0	2.0
12	**	**	3.0	**	**	**
0	5.0					

** Plants completely wilted

Table 8

Influence of different levels of salinity on the weight of straw

Conductivity (m.mhos/ cm.)	Sources of salinity					
	Sodium chloride	Potassium chloride	Magnesium chloride	Calcium chloride	Sodium chloride + Magnesium chloride	Sea water
	Weight of straw (g.) per pot					
2	24.5	18.2	35.2	25.2	28.8	25.0
4	12.2	14.5	26.4	17.0	25.5	16.2
6	**	7.2	25.2	16.5	24.8	15.1
8	**	7.0	17.1	15.8	17.2	10.1
10	**	**	12.5	**	12.0	9.5
12	**	**	12.0	**	**	**
0	25.2					

** Plants completely wilted.

at a conductivity of 2 m.mhos/cm. Even at a conductivity of 6 m.mhos/cm. magnesium chloride produced as good an yield as in the control and this yield was higher than that in all the other treatments. With increase in conductivity the weight of grain and straw decreased in all the treatments.

A negative correlation existed between all the yield and growth characteristics and the conductivity. Regression equations were derived and regression curves drawn for important characteristics (i.e. number of tillers, weight of grains, weight of straw and height of plants). The linear curves are presented on Plates 13, 14, 15 and 16. Regression equations for the different characteristics are as follows:-

(1) Number of tillers

Sodium chloride	$y = -0.25x + 3.17$
Potassium chloride	$y = -0.14x + 3.00$
Magnesium chloride	$y = -0.20x + 4.07$
Calcium chloride	$y = -0.20x + 3.60$
Sodium chloride + Magnesium chloride	$y = -0.24x + 3.72$
Sea water	$y = -0.23x + 3.81$

(2) Weight of grains

Sodium chloride	$y = -0.48x + 5.38$
Potassium chloride	$y = -0.39x + 5.02$
Magnesium chloride	$y = -0.26x + 6.40$
Calcium chloride	$y = -0.23x + 5.82$

	Sodium chloride + Magnesium chloride	y = - 0.25 x + 6.15
	Sea water	y = - 0.34 x + 5.17
(3)	<u>Weight of straw</u>	
	Sodium chloride	y = - 3.25 x + 27.13
	Potassium chloride	y = - 2.37 x + 23.92
	Magnesium chloride	y = - 1.73 x + 10.38
	Calcium chloride	y = - 1.38 x + 25.16
	Sodium chloride + Magnesium chloride	y = - 1.45 x + 29.50
	Sea water	y = - 1.83 x + 26.65
(4)	<u>Height of plants</u>	
	Sodium chloride	y = - 5.70 x + 131.12
	Potassium chloride	y = - 1.89 x + 124.80
	Magnesium chloride	y = - 1.27 x + 130.81
	Calcium chloride	y = - 3.11 x + 138.92
	Sodium chloride + Magnesium chloride	y = - 1.50 x + 140.63
	Sea water	y = - x + 130.00

B. Correlation studies between chemical and mechanical properties of salt-affected soils of Kerala in relation to conductivity and soil reaction.

I. Chemical composition

1. Soil reaction andn conductivity

From Table 9 it can be noted that the chemical composition of the fourteen samples differ considerably. They agree in one respect that all the soils have a high conductivity ranging from 4.2 m.mhos/cm. for West Kallada soil to 14 m.mhos/cm. for Kattampally soil. It is also noteworthy that even though the conductivity is very high, the soils are acidic in reaction, their pH ranging from 3.0 in Kattampally soil to 6.8 in Tellicherry soil. The conductivities of soil samples collected from Thottappally, Vechoor, North Parur and Kattampally were very high while those of West Kallada, Tellicherry, Payyanur and Thrippunithura were comparatively low. The conductivities of the other areas were intermediate between them.

2. Total Nitrogen

The general level of nitrogen in these salt-affected soils were rather high except in the samples collected from Vechoor, Cheruvannur, Tellicherry and Payyanur. The percentage of nitrogen ranged from 0.05 in Tellicherry soil to 0.38 in Kattampally soil. The soils from Thottappally, Vaikom, North

Table 9

Chemical Composition of Soils

Sample No.	pH	Conductivity m.mhos/cm.	Moisture %	Loss on ignition %	Total N %	Organic C %	Total P_2O_5 %	Total K_2O %	Total MgO %	Total CaO %	Total R_2O_3 %	Total Na %
1	3.45	4.20	1.98	19.09	0.18	5.40	0.068	0.145	0.109	0.050	11.20	0.213
2	4.50	12.00	7.49	34.50	0.24	6.20	0.166	0.211	0.218	0.210	13.12	0.312
3	3.40	7.50	6.81	36.91	0.21	4.10	0.085	0.186	0.109	0.168	17.11	0.216
4	5.50	10.00	1.27	11.10	0.07	0.82	0.093	0.175	0.136	0.187	11.03	0.265
5	6.10	7.00	1.42	9.89	0.16	3.30	0.059	0.149	0.105	0.055	1.15	0.134
6	3.15	13.00	4.64	21.48	0.20	3.80	0.089	0.245	0.169	0.066	18.59	0.184
7	3.75	4.50	0.75	6.08	0.15	3.20	0.096	0.166	0.166	0.100	7.20	0.201
8	4.90	8.50	0.67	5.78	0.12	2.08	0.088	0.107	0.196	0.120	11.51	0.221
9	5.50	6.50	2.49	13.83	0.12	2.20	0.099	0.141	0.180	0.161	14.51	0.212
10	5.00	4.50	2.15	11.31	0.08	1.20	0.076	0.149	0.103	0.060	10.43	0.156
11	3.00	14.00	4.99	28.61	0.38	4.75	0.119	0.286	0.315	0.115	19.18	0.345
12	6.80	4.50	0.13	1.37	0.05	1.20	0.088	0.104	0.098	0.185	1.87	0.102
13	5.80	4.60	0.55	2.23	0.06	2.30	0.038	0.087	0.110	0.061	11.20	0.142
14	5.50	8.50	5.17	16.68	0.36	4.50	0.057	0.174	0.176	0.125	12.20	0.200

Parur and Irikkur contained even more than 0.20 per cent of this element.

3. Total Phosphorus

The total phosphorus content ranged from 0.038 per cent in the Payyanur sample to 0.166 per cent in the Thottapally soil. The soils from Thottappaly and Kattampally contained more than 0.1 per cent total P_2O_5.

4. Total Potassium

The total potassium content was generally poor in these soils and ranged from 0.087 per cent in Payyanur soil to 0.286 per cent in Kattampally soil. The level of this nutrient was satisfactory only in the soils from Kattampally and North Parur.

5. Total Sesquioxides, Magnesium and Calcium

The soils from Kattampally, North Parur, Thalikulam and Vaikom contained fairly high amounts of total sesquioxides, while the soils from Tellicherry and Murinjapuzha contained only very low levels of this constituent. The total sesquioxide content varied from 1.87 per cent in the soil from Tellicherry to 19.18 per cent in the Kattampally soil.

The soils were generally low in both the calcium and magnesium contents. Calcium varied from 0.05 per cent CaO in the soil from West Kallada to 0.187 per cent CaO in the soil from Vechoor. The variation in the magnesium content was from 0.103 per cent MgO in Cheruvannur soil to as much as 0.315 per cent MgO in Kattampally soil.

6. Organic Carbon

Organic carbon content of all the samples was high except in the soils from Vechoor, Cheruvannur and Tellicherry. The values ranged from 0.82 per cent in Vechoor soil to 6.2 per cent in Thottappally soil.

7. Water soluble Chlorides and Sulphates

From Table 10 it can be seen that the contents of chlorides and sulphates were high in all the soils studied. The sulphate content varied from 0.21 per cent in the West Kallada soil to 0.52 per cent in the soil from Thottappally. The variation in the chloride content was from 0.10 per cent in the soil from Payyanur to 0.28 per cent in the soil from Kattampally. The soils from Thottappally, Vaikom, Vechoor, Murinjapuzha, North Parur and Kattampally were especially high in sulphates and chlorides. The level of sulphates was generally higher than that of the chlorides in all the samples investigated.

8. Total Sodium

The content of sodium was high in all the samples and ranged from 0.102 per cent in Tellicherry soil to 0.345 per cent in Kattampally soil.

Table 10

Soluble salts in soils

Sample No.	Locality		Chloride %	Sulphate %
1	West Kallada	..	0.12	0.21
2	Thottappally	..	0.22	0.52
3	Vaikom	..	0.24	0.41
4	Vechoor	..	0.18	0.44
5	Murinjapuzha	..	0.24	0.32
6	North Parur	..	0.26	0.44
7	Thripunithura	..	0.18	0.21
8	Vyttila	..	0.14	0.24
9	Thalikulam	..	0.11	0.22
10	Cheruvannur	..	0.16	0.28
11	Kattampally	..	0.28	0.42
12	Tellicherry	..	0.15	0.26
13	Payyanur	..	0.10	0.20
14	Irikkur	..	0.12	0.28

9. Available Phosphorus and Potassium

In Table 11 the distribution of available phosphorus and potassium is presented. Available phosphorus content in all the soils was very low. The highest value for this nutrient was 0.0064 per cent in Tellicherry soil and the lowest was 0.0004 per cent in West Kallada soil. The level of available potassium was also poor in most of the soils except in the soils from Thottappally, North Parur and Vechoor. The maximum available potassium found was 0.0236 per cent in Thottappally soil and the minimum was 0.0018 per cent in Tellicherry soil.

10. Correlations

High degrees of correlation were found between the following:

(a) Conductivity and the chloride content,
(b) Conductivity and the sulphate content,
(c) Conductivity and the content of silt and clay,
(d) Conductivity and the total sesquioxide content, and
(e) pH and the sulphate content.

The first four were positive correlations and the last one a negative correlation. The correlation coefficients and regression equations are given in Table 12.

Table 11

Available Phosphorus and Potassium in Soils

Sample No.	Locality		Available P %	Available K %
1	West Kallada	..	0.0004	0.0086
2	Thottappaly	..	0.0019	0.0236
3	Vaikom	..	0.0006	0.0060
4	Vechoor	..	0.0018	0.0137
5	Murinjapuzha	..	0.0022	0.0240
6	North Parur	..	0.0048	0.0187
7	Thrippunithura	..	0.0012	0.0025
8	Vyttila	..	0.0008	0.0080
9	Thalikulam	..	0.0012	0.0070
10	Cheruvannur	..	0.0044	0.0015
11	Kattampally	..	0.0036	0.0076
12	Tellicherry	..	0.0064	0.0018
13	Payyanur	..	0.0046	0.0035
14	Irikkur	..	0.0008	0.0260

Table 12

Correlations

Correlation between x and y	Correlation coefficient	Regression equation	Level of significance.
Conductivity and chloride	+ 0.68	y = 0.011x + 0.094	0.01
Conductivity and sulphate	+ 0.82	y = 0.025x + 0.125	0.01
Conductivity and silt + clay	+ 0.77	y = 5.6x - 2.571	0.01
Conductivity and total sesquioxides	+ 0.62	y = 0.99x + 3.712	0.01
pH and sulphate	- 0.56	y = -0.041x +0.513	0.05

II. Mechanical composition

The mechanical composition of the fourteen samples are presented in Table 13. It may be noted that the sand fraction predominated in the samples collected from Payyanur, Tellicherry, Cheruvannur, Vyttila and Murinjapuzha. In the other samples the finer fractions were found in higher proportions. Samples from Vaikom, North Parur, Thottappally, Thalikulam and Kattampally were high in the clay content.

These soils can be classified as follows on the basis of the textural classification suggested by Stephens (1953).

Textural classification of soils

Locality	Textural classification
Thottappaly, Vaikom, North Parur, Kattampally, and Thalikulam.	Clay
Murinjapuzha, and Payyanur.	Sand
Thrippunithura, and Vyttila.	Sandy loam
West Kallada, and Cheruvannur.	Sandy clay loam
Irikkur.	Silty clay loam

Table 13

Mechanical Composition and Colour of Soils

Sample No.	Locality	Mechanical Composition: Coarse sand %	Fine sand %	Silt %	Clay %	Colour	
1	West Kallada	25.84	24.99	4.85	23.62	10 YR 5/2	(Greyish brown)
2	Thottappally	0.63	4.84	31.22	41.99	N 2/-	(Black)
3	Vaikom	0.74	2.83	19.87	52.68	10 YR 3/2	(Very dark grey)
4	Vechoor	1.23	43.39	9.40	34.45	7.5 YR 3/2	(Dark brown)
5	Murinjapuzha	66.88	14.95	7.47	7.32	5 YR 3/3	(Dark reddish brown)
6	North Parur	0.84	11.21	5.25	61.89	10 YR 3/2	(Very dark grey)
7	Thrippunithura	25.09	43.93	14.25	11.25	10 YR 4/2	(Dark greyish brown)
8	Vyttila	32.32	35.16	13.25	16.02	10 YR 3/3	(Very dark greyish brown)
9	Thalikulam	13.22	30.46	14.07	30.43	10 YR 5/3	(Brown)
10	Cheruvannur	29.53	37.69	2.04	21.91	10 YR 5/4	(Yellowish brown)
11	Kattampally	0.97	1.98	44.31	30.14	10 YR 4/1	(Dark grey)
12	Tellicherry	79.15	9.13	1.60	8.60	10 YR 5/2	(Greyish brown)
13	Payyanur	42.89	33.87	9.01	13.65	10 YR 6/2	(Light brownish grey)
14	Irikkur	3.57	7.31	60.22	14.61	10 YR 5/2	(Greyish brown)

D I S C U S S I O N

A. Pot culture studies on conductivity as influenced by different salts and its effect on the growth of paddy.

The results obtained from the pot culture studies indicate that the growth of rice plants is adversely affected by high concentrations of salts in the soil. This adverse effect of salinity on plant growth is partly due to the osmotic effect of the salt solution and partly due to a decrease in the absorption of certain cations due to ion antagonism. Thus Magistad <u>et al</u> (1943) found that the reduction in growth of plants was linear with increase in osmotic concentration. According to Mehta and Desai (1959) high concentrations of calcium chloride in the soil solution inhibited the absorption of sodium, potassium and magnesium by plants.

The extent of salt injury depends also upon the nature of the salts involved. Thus, in the present study, rice seedlings could not survive at concentrations of sodium chloride higher than 4 m.mhos/cm. whereas they tolerated magnesium chloride upto a conductivity of 12 m.mhos/cm. Evidently magnesium chloride is able to exert some protective influence against salt injury. This type of protective action for certain salts has been established by Lipman and Gericke (1919). The tolerence of rice for high concentrations of magnesium chloride may therefore be interpretted as a specific effect of magnesium for rice. Similar ideas have been expressed by Mibasher (1948) and Hussan and Overstreet (1952). According to them the nature of the salt and its specific effect on particular plants are important factors in studying the salt tolerence of crops.

Rice plants could tolerate sodium chloride only upto a conductivity of 4 m.mhos/cm. This shows that sodium chloride, when present alone, is highly injurious for the growth of rice. This is in accordance with the work of Iwaki (1956) who found that 0.5 per cent or more of sodium chloride resulted in the death of rice plants. The inhibiting effect of sodium, even at low concentrations, may be partly due to its influence on the microflora of the soils. According to Lipman (1912) ammonification in soils is considerably reduced by low concentrations of sodium chloride. This and similar effects of sodium on the microbiological processes in the soil would to some extent explain the adverse effects of this element on plant growth.

It was seen from the pot culture experiment that in combination with magnesium chloride rice could tolerate sodium chloride upto a conductivity of 8 m.mhos/cm. This can be explained as due to the protective action exerted by magnesium. According to Elagabaly (1955) the uptake of a given ion by plants is considerably influenced by the nature of the complementary ion.

Kelley (1951) has expressed the view that monovalent bases like sodium are less strongly adsorbed than divalent ions like magnesium. According to him this is especially true in the case of sodium. The proportion of exchangeable sodium in the soil becomes high only when that of magnesium or calcium are low. This would explain the beneficial influence of magnesium over the injurious effects of sodium. In the present experiment too, this view would explain the low tolerence of rice to sodium chloride when present alone and its high tolerence to this salt when present in combination with magnesium chloride.

Adsorption of sodium ions by soil particles is described by Kelley (1951) in terms of the following reversible reaction:

$$\text{Mg clay} + 2\ \text{Na}^{+} \rightleftharpoons \text{Na}_2\ \text{clay} + \text{Mg}^{++}$$

From the above it is obvious that magnesium, when present in combination with sodium, supresses the toxicity of the latter to a considerable degree by effecting its adsorption.

The height of plants decreased with increase in salt concentration in all the treatments (Table 2). This may be considered as a reflection of the general reduction in growth as a result of increase in the level of salinity.

Increase in salt concentration in all the treatments resulted in considerable reduction in the yield of grain and straw. According to Iwaki et al (1958) the nitrogen content of plants was increased and carbohydrate content decreased with increase in salt concentration. This effect of salinity would explain partly the reduction in the yield of grain and straw.

B. Correlation studies between chemical and mechanical properties of salt-affected soils of Kerala in relation to conductivity and soil reaction.

Soil reaction (pH)

From the results presented in Table 9, it can be seen that all the fourteen samples were acidic in reaction. Most of them had pH values lower than that of ordinary cultivated soils. United States salinity laboratory staff (1954) classified saline soils as those which have conductivities more than 4 m.mhos/cm. for their saturation extract at 25°C and exchangeable sodium percentage less than 15. They have also specified that the pH of these soils will be less than 8.5. There it is presumed that the pH values will be near about neutral. (7.0)

Subramoney (1947) studying the Kari soils of Kerala had found high acidity in the soils of Kuttanad area which are also subjected to inundation by salt water. It is worthwhile to see that these soils are similar to Thottappally soils. (Sample No.2). He has stated that the reasons for high aoidity in these soils are not only due to organic acids but also due to strong mineral acids. He detected appreciable amounts of sulphuric acid and other mineral acids in Kari soils. The high organic matter content and high amounts of sulphate also contribute to the high acidity.

There exists a high negative correlation between pH and sulphate content of these soils. (Plate No.12) This strongly suggests that the main cause of acidity may be the mineral acids such as sulphuric acid. Subramoney (1947) has stated indisputedly that sulphuric acid is an oxidation product of sulphur compounds distributed in organic and inorganic forms in Kari soils. His experiments showed that oxidation was aerobic and primarily biological. The organic matter is first decomposed by various heterotrophic organisms and the sulphur bearing fraction is liberated. It is then acted upon by various bacteria and sulphur is finally liberated as hydrogen sulphide. This is oxidised through sulphur to sulphuric acid which combines with the soil bases to form their sulphates.

Conductivity

Conductivity of the fourteen samples were very high and the values were much higher than those for the ordinary cultivated soils of Kerala. It is evident that the source of high conductivity is sea water.

Subramoney (1947) has pointed out that the total soluble salts of Kari soils are very high andthe main salts are sulphates and chlorides. It is observed in the present experiment that a high correlation exists between conductivity on the one hand and sulphates and chlorides on the other. (Plates 8 and 9) Magnesium and sodium percentages are also correlated positively with conductivity. These findings show that the high conductivity in these soils is due to the large amounts of chlorides and sulphates of sodium and magnesium present in them.

It is interesting to note that the soils which contain high conductivity showed higher values for sequioxides also. A strong positive correlation exists between the sequioxide content and soil conductivity. (Plate 11) This shows that sequioxides also contribute their share to raise the conductivity of these soils.

A positive correlation exists between the conductivity and the percentage of silt and clay. (Plate 10) This can be explained on the basis that in soils containing more of the finer fractions the salts are not as freely washed away as in the case of sandy soils. This is in accordance with the work of Lunin and Gallatin (1960) who studied the influence of percentage of clay and sand on the uptake of cations. They found that dilution of clay with an equal volume of sand decreased exchangeable cations in the soil.

<u>Fertility status of the salt-affected soils</u>

Nitrogen status of these soils is generally satisfactory except in few cases (Table 9).Subramoney (1947) has also obtained similar results. The high nitrogen content may be the result of high organic matter accumulation in these soils. There is nothing very remarkable about the distribution of the other nutrient elements.

SUMMARY AND CONCLUSION

A pot culture study was conducted using different salts in different concentrations so as to produce varying conductivities in the soil. The influence of different concentrations of various salts on the growth and yield characteristics of rice were studied. Fourteen typical soil samples from the salt-affected areas in Kerala were also examined for their chemical and mechanical composition.

The pot culture study showed that irrespective of the nature of the salt rice seedlings could not tolerate a salinity level of more than 12 m. mhos/cm. There was considerable variation in the extent of tolerence to salinity from different sources. At conductivities lower than 12 m.mhos/cm. the effect of the type of salt was predominant. Magnesium chloride was tolerated upto a conductivity of 12 m.mhos/cm. while potassium chloride and calcium chloride were tolerated only upto a conductivity of 8 m.mhos/cm. Sodium chloride was highly injurious to rice which could not survive in concentrations of this salt higher than 4 m.mhos/cm. A conductivity of 10 m.mhos/cm. was readily tolerated by rice when sodium chloride was applied in combination with magnesium chloride as well as when sea water was the source of salinity. This is indicative of the fact that conductivity alone cannot be considered as a factor of the injurious effect of salinity in soils. It is seen from the pot culture experiment conducted that the injurious effect of sodium chloride is remedied to an extent by the addition of magnesium chloride. Thus magnesium chloride exerts some protective influence against the salt injury. The tolerence of rice for high concentrations of sea water also can be interpretted in terms of the specific effect of magnesium for this crop, as sea water contains an appreciable amount of magnesium.

Component growth factors such as height of plants, number of tillers, number of ear-heads and the yield of grain and straw were all adversely affected by increasing levels of salinity. The adverse effect of magnesium chloride was generally less than that of the other salts. Formation of earheads was also delayed with increasing levels of salinity.

Laboratory examination of the typical salt-affected soils of Kerala revealed a negative correlation between the pH and the sulphate content which suggested that the high acidity of these soils might be due to the presence of mineral acids such as sulphuric acid. There were high degrees of positive correlation between conductivity on the one hand and the contents of chloride, sulphate, sodium and magnesium on the other. This suggested that the high conductivity of these soils might be due to the chlorides and sulphates of sodium and magnesium. Conductivity was further positively correlated to the content of silt and clay. This indicated that there was less leaching of salts from soils containing a high proportion of finer fractions. The electrical conductivities of all the soil samples examined were high and their pH values were very low (Table 9). The chloride and sulphate contents were high in all samples and the latter predominated. (Table 10) The distribution of nitrogen was generally satisfactory and there was nothing remarkable about the other nutrient elements.

It can be concluded that the concept of saline soils, as commonly understood, is not fully applicable to the salt-affected (saline) soils of Kerala.

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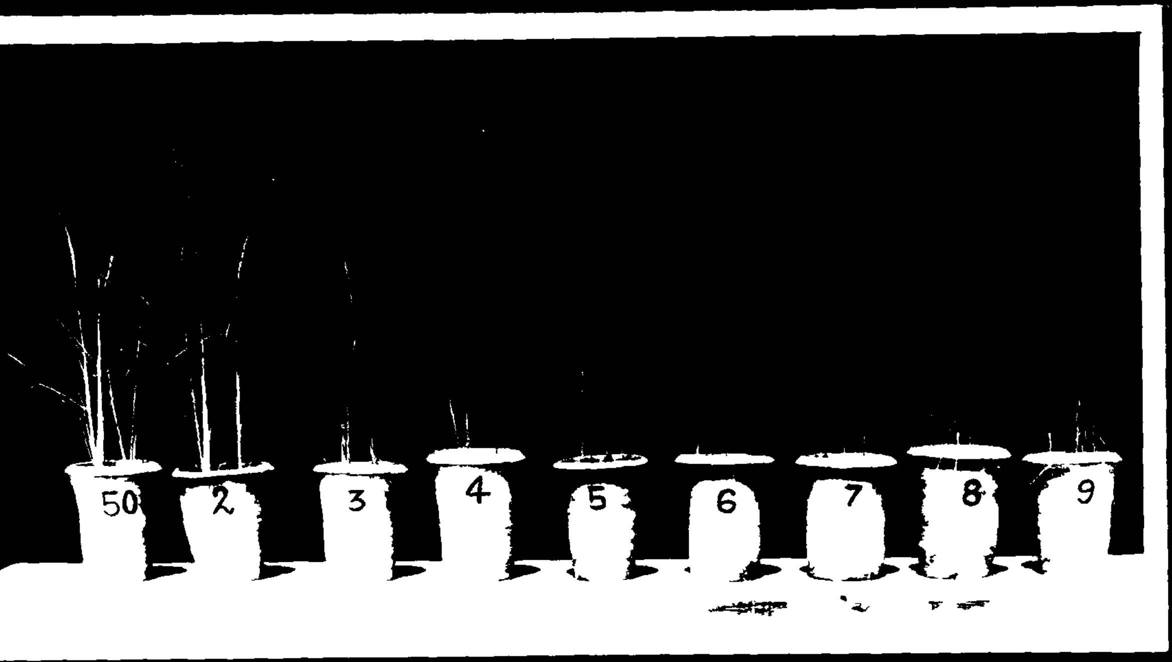
* Original not seen.

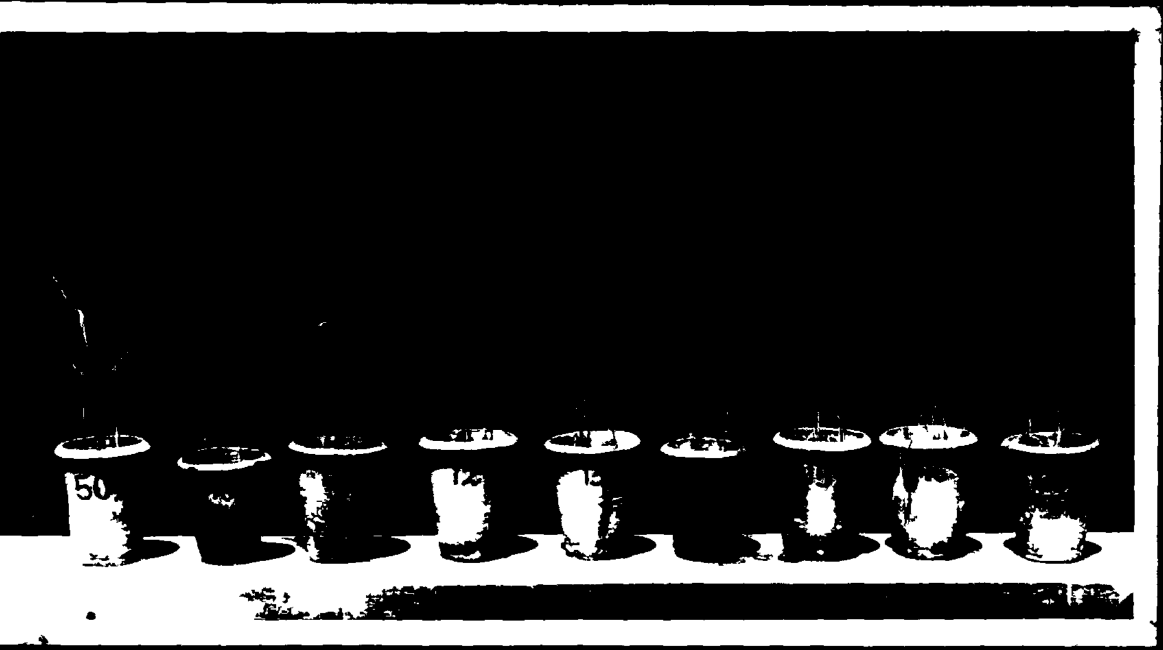
ILLUSTRATIONS

PLATE 1

Appearance of the rice plants during the second week after transplanting.

Pot Nos. 2 - 9	Sodium chloride treatments
Pot Nos. 10-17	Potassium chloride treatments
Pot Nos. 18-25	Magnesium chloride treatments
Pot No. 50	Control


50
2
3
4
5
6
7
8
9

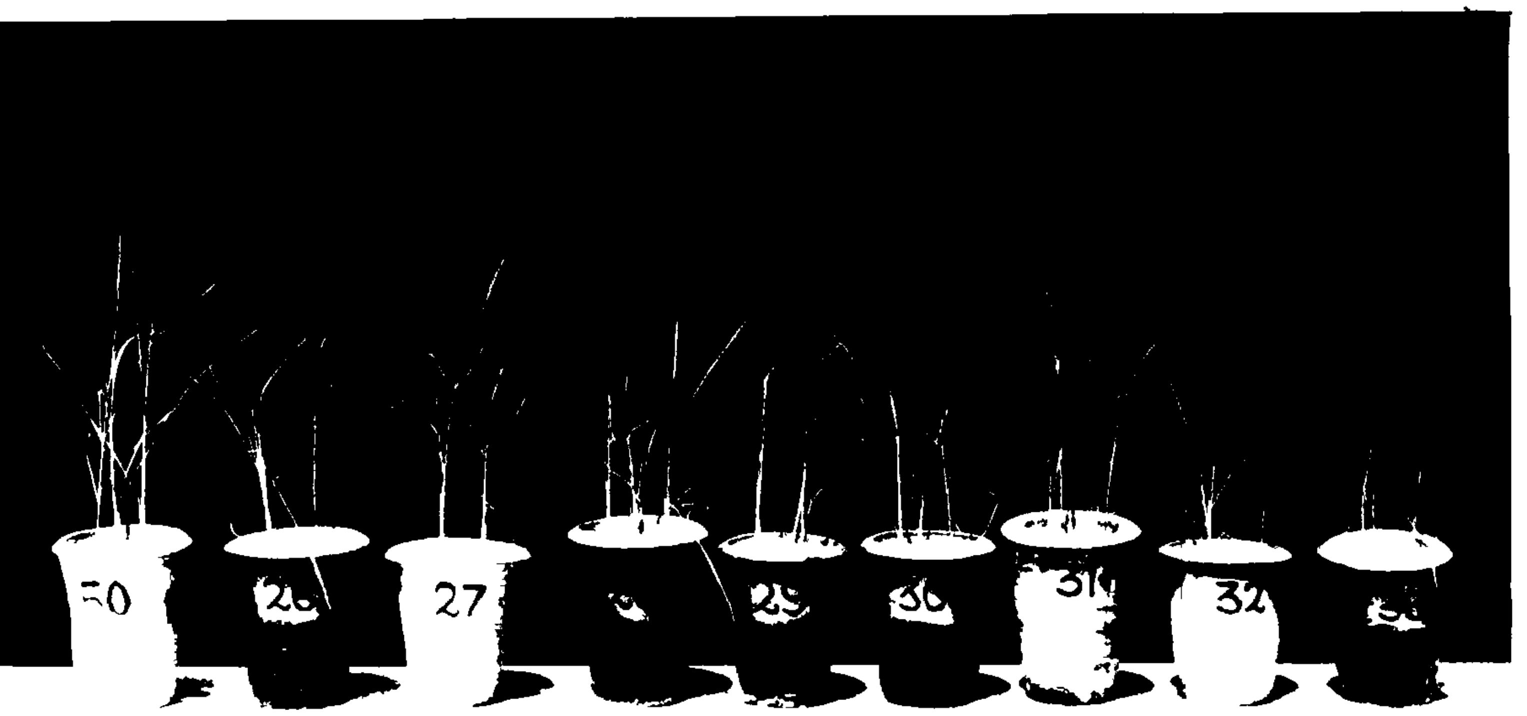

50


8
19
20
21
22
23
24
25

PLATE 2

Appearance of the rice plants during the second week after transplanting.

Pot Nos.	26 - 33	Calcium chloride treatments
Pot Nos.	34 - 41	Sodium chloride + Magnesium chloride treatments
Pot Nos.	42 - 49	Sea water treatments.
Pot No.	50	Control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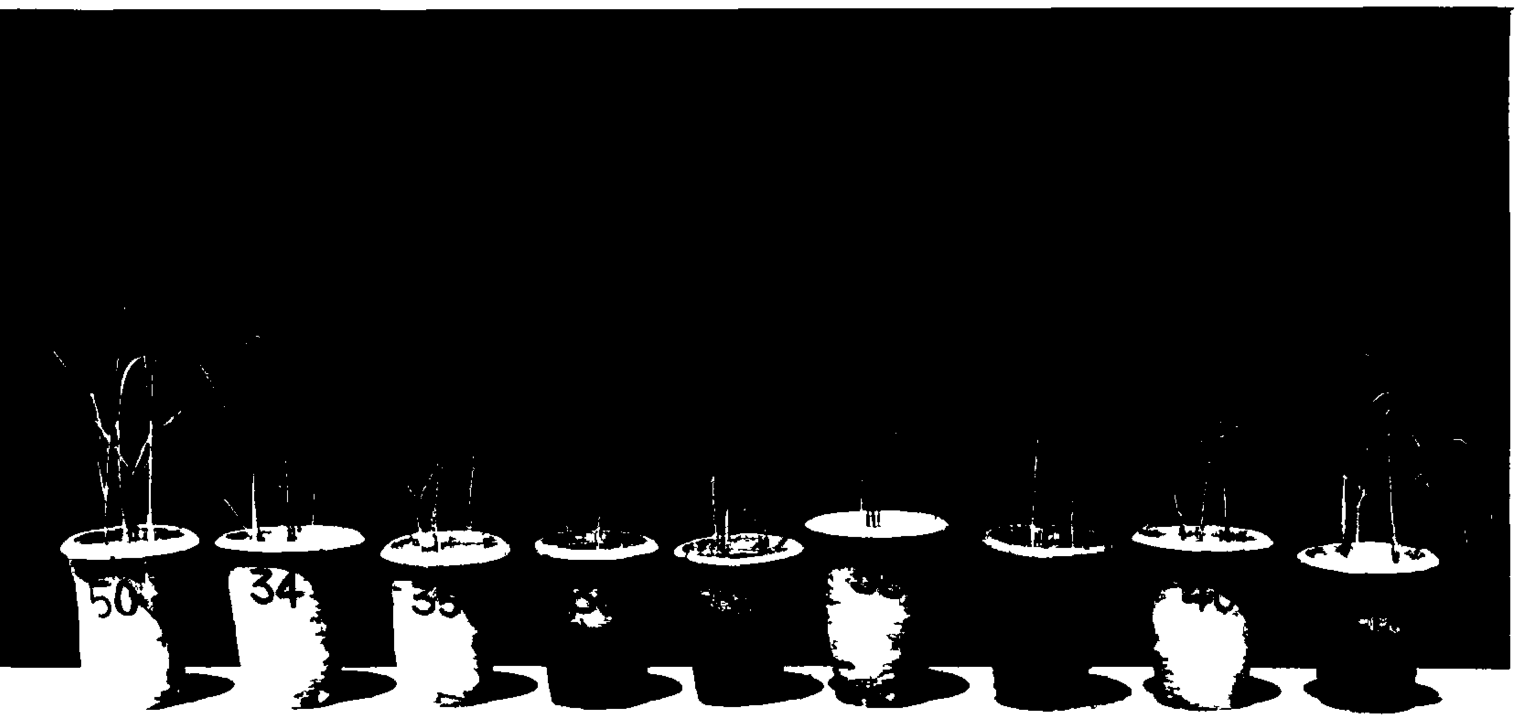
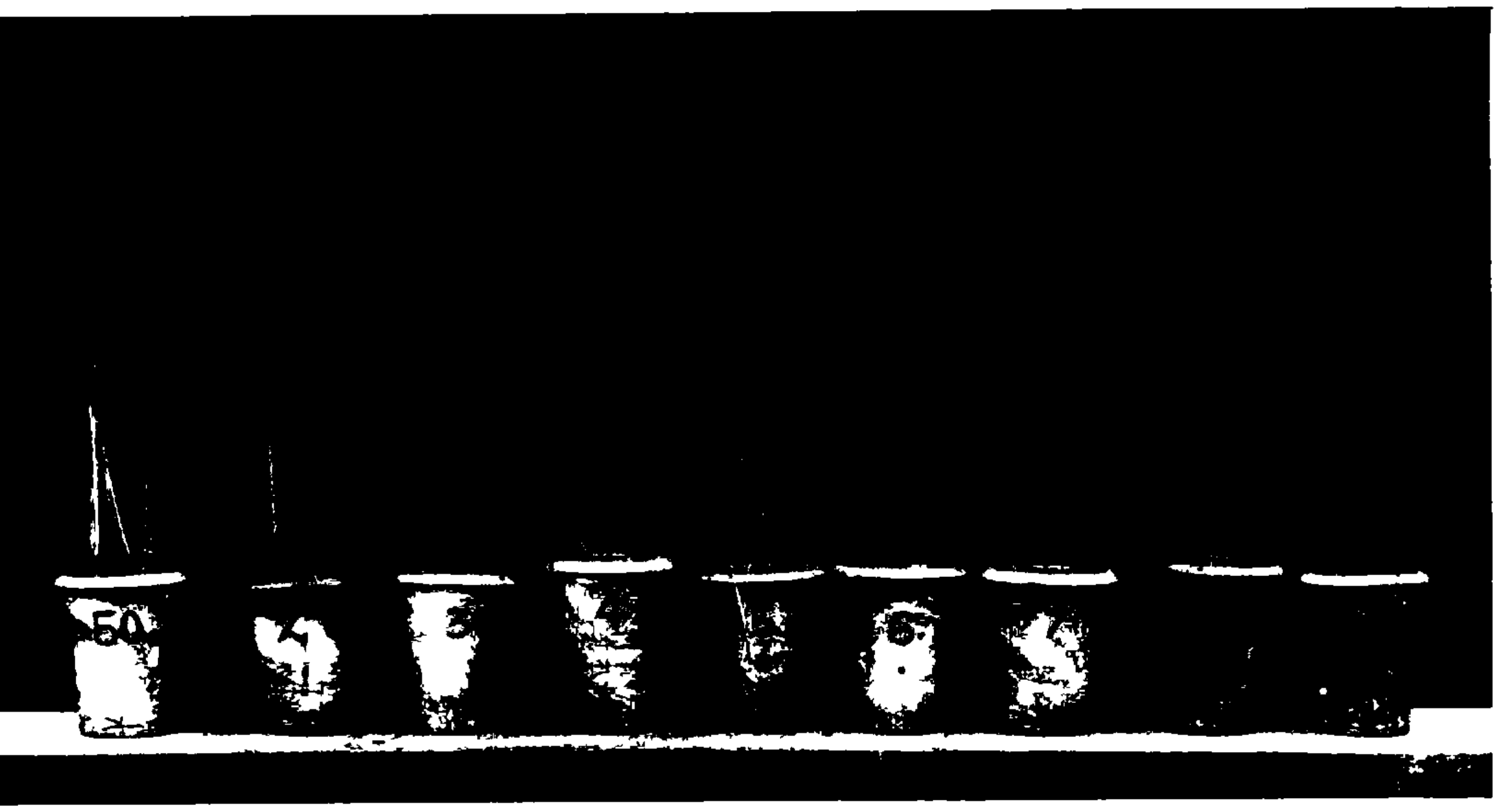

50
34


50
45
48
49

PLATE 3

Appearance of the rice plants at the end of the fourth week after transplanting.

Pot Nos. 2 - 9	Sodium chloride treatments
Pot Nos.10 -17	Potassium chloride treatments
Pot Nos.18 -25	Magnesium chloride treatments
Pot No.50	Control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50

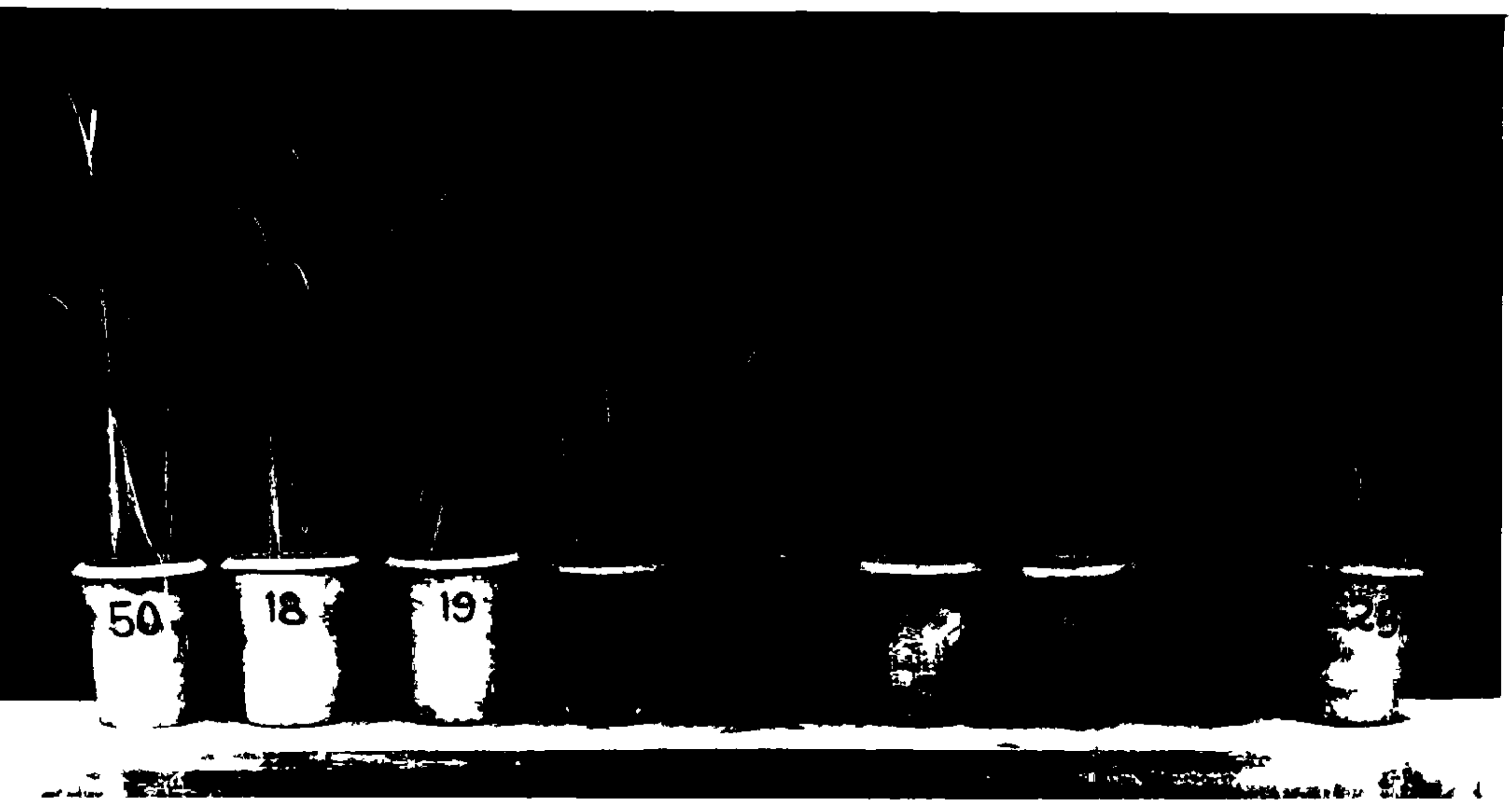
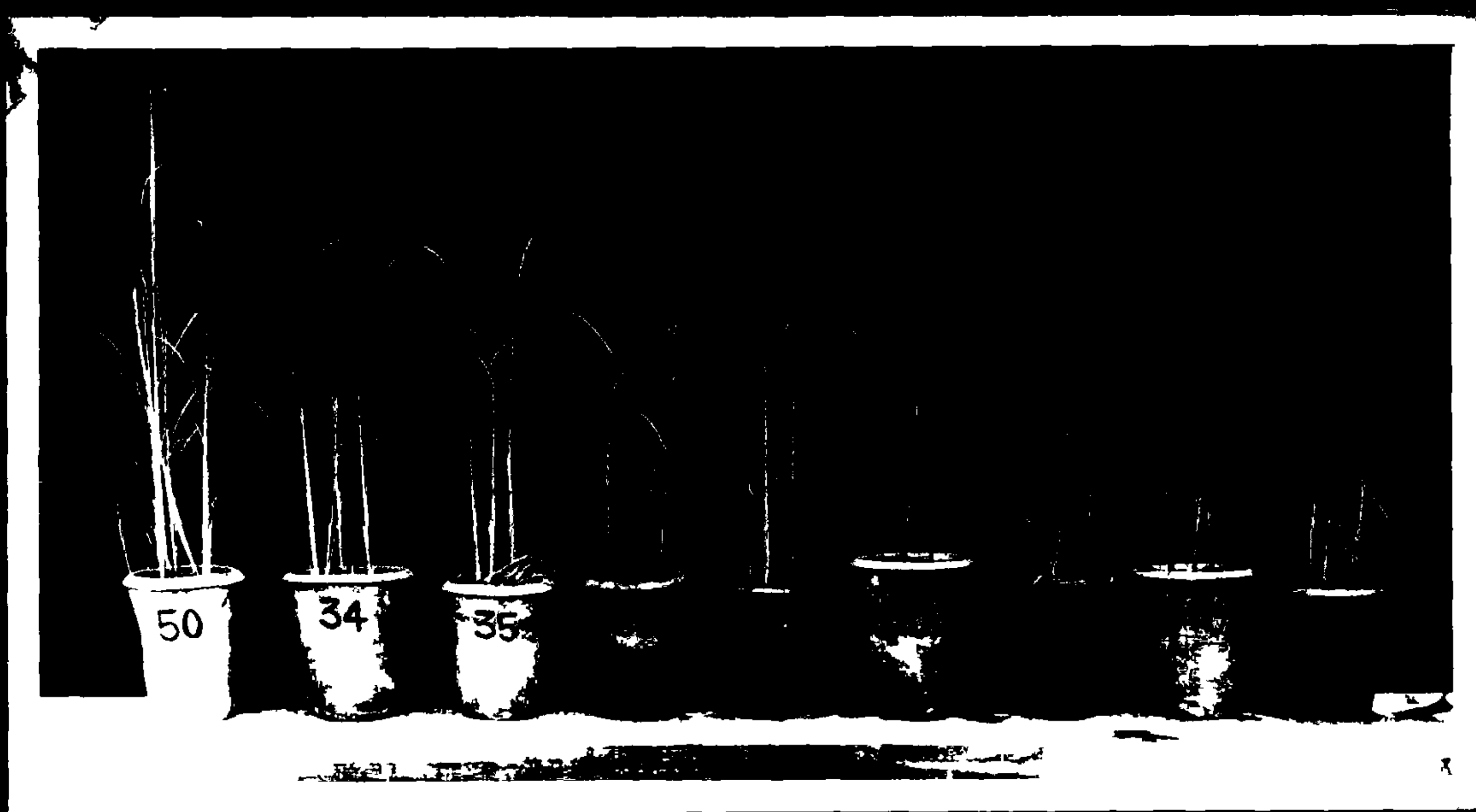

50
18
19

PLATE 4

Appearance of the rice plants at the end of the fourth week after transplanting.

Pot Nos. 26-33	Calcium chloride treatments
Pot Nos. 34-41	Sodium chloride + Magnesium chloride treatments
Pot Nos. 42-49	Sea water treatments
Pot No. 50	Control


50
27


50
34
35


50
42
45
46
47
48
49

PLATE 5

Appearance of the rice plants on the 80th day after transplanting.

Pot Nos. 2- 8	Sodium chloride treatments
Pot Nos. 10-17	Potassium chloride treatments
Pot No. 50	Control

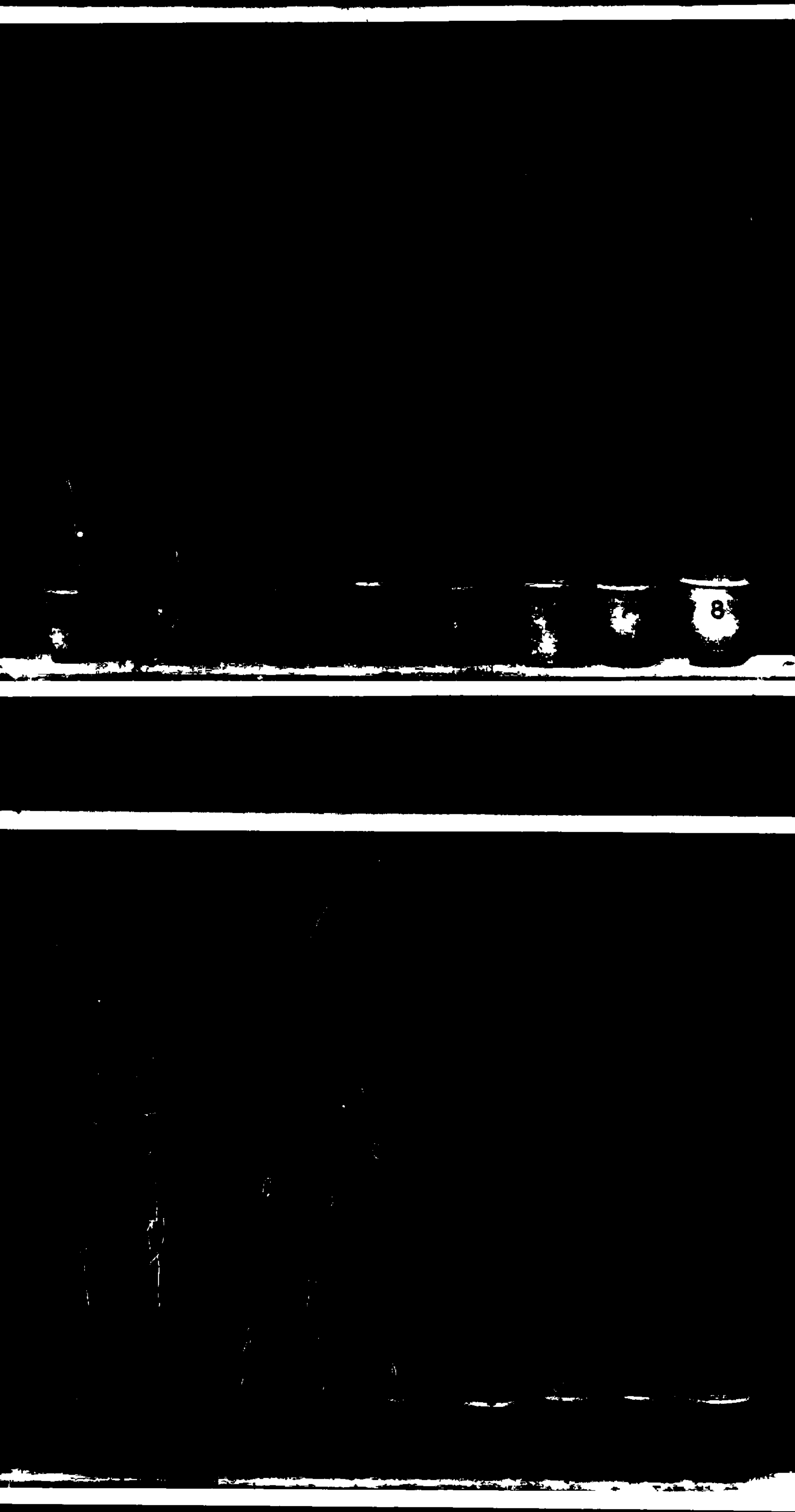

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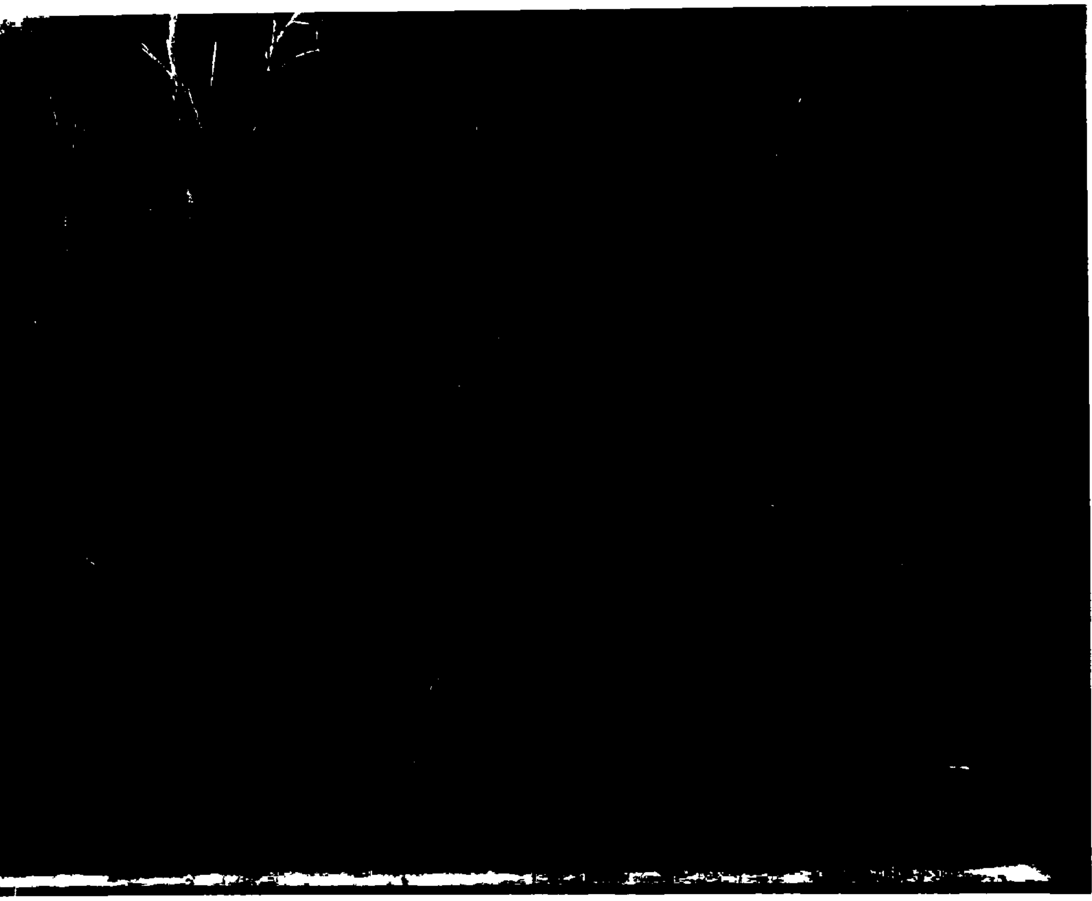
PLATE 6

Appearance of the rice plants on the 80th day after transplanting.

Pot Nos. 18 - 25	Magnesium chloride treatments
Pot Nos. 26 - 33	Calcium chloride treatments
Pot No. 50	Control



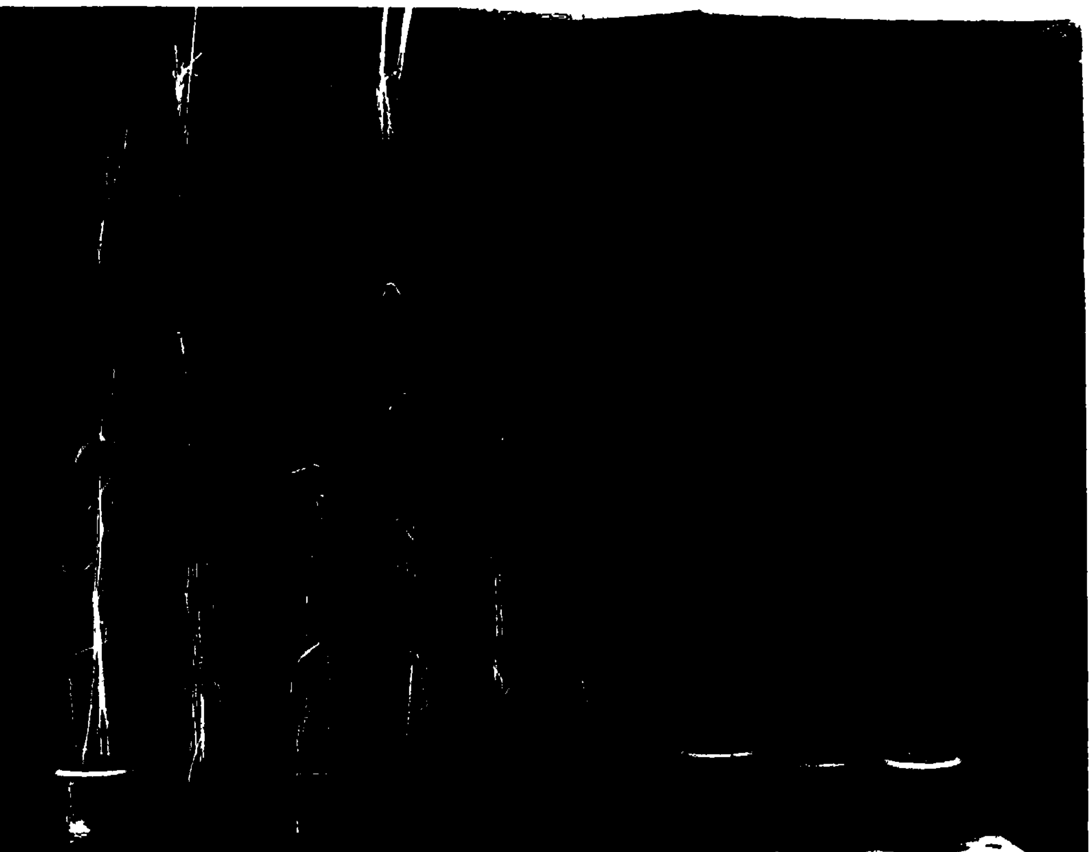
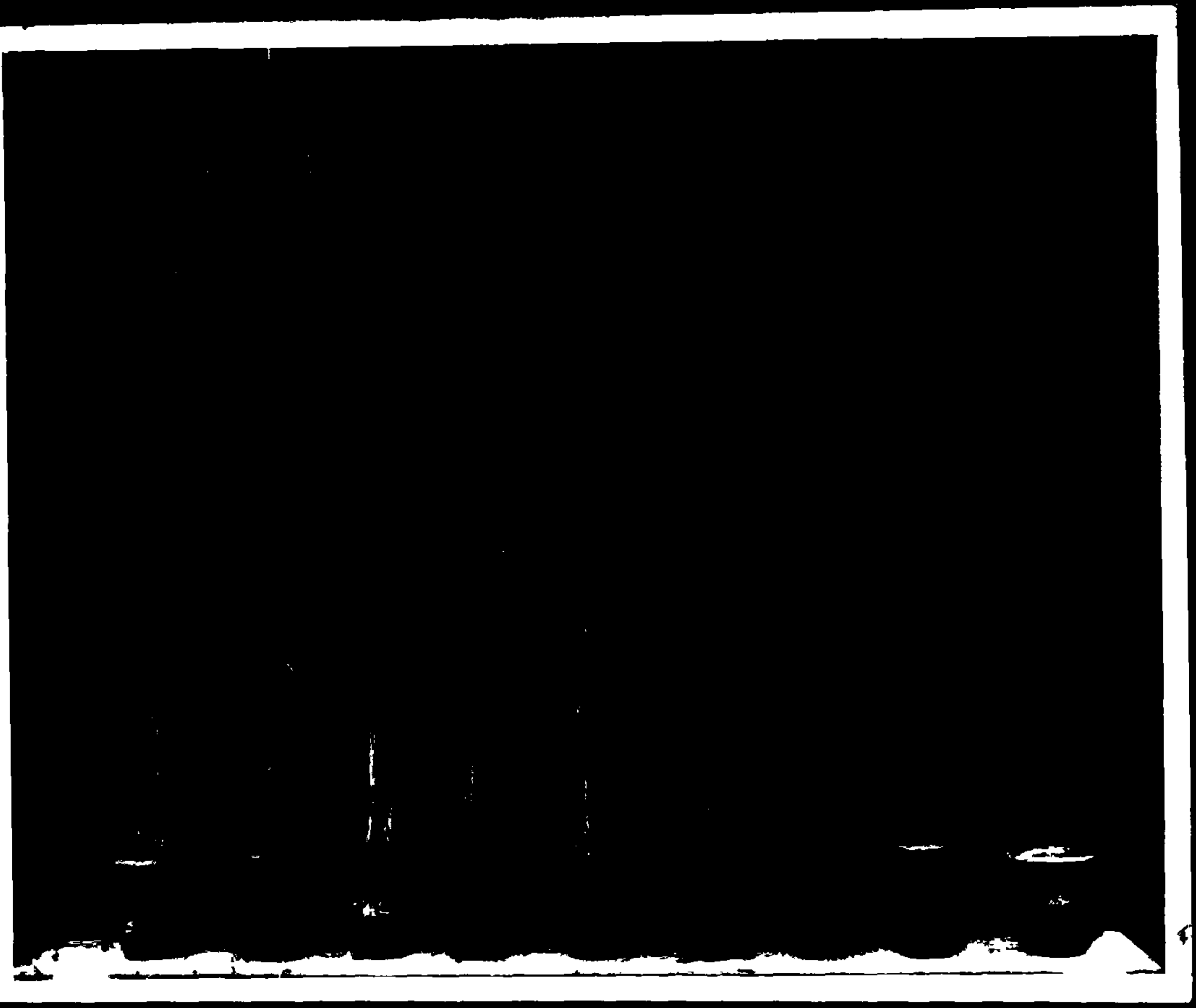


PLATE 7

Appearance of the rice plants on the 80th day after transplanting.

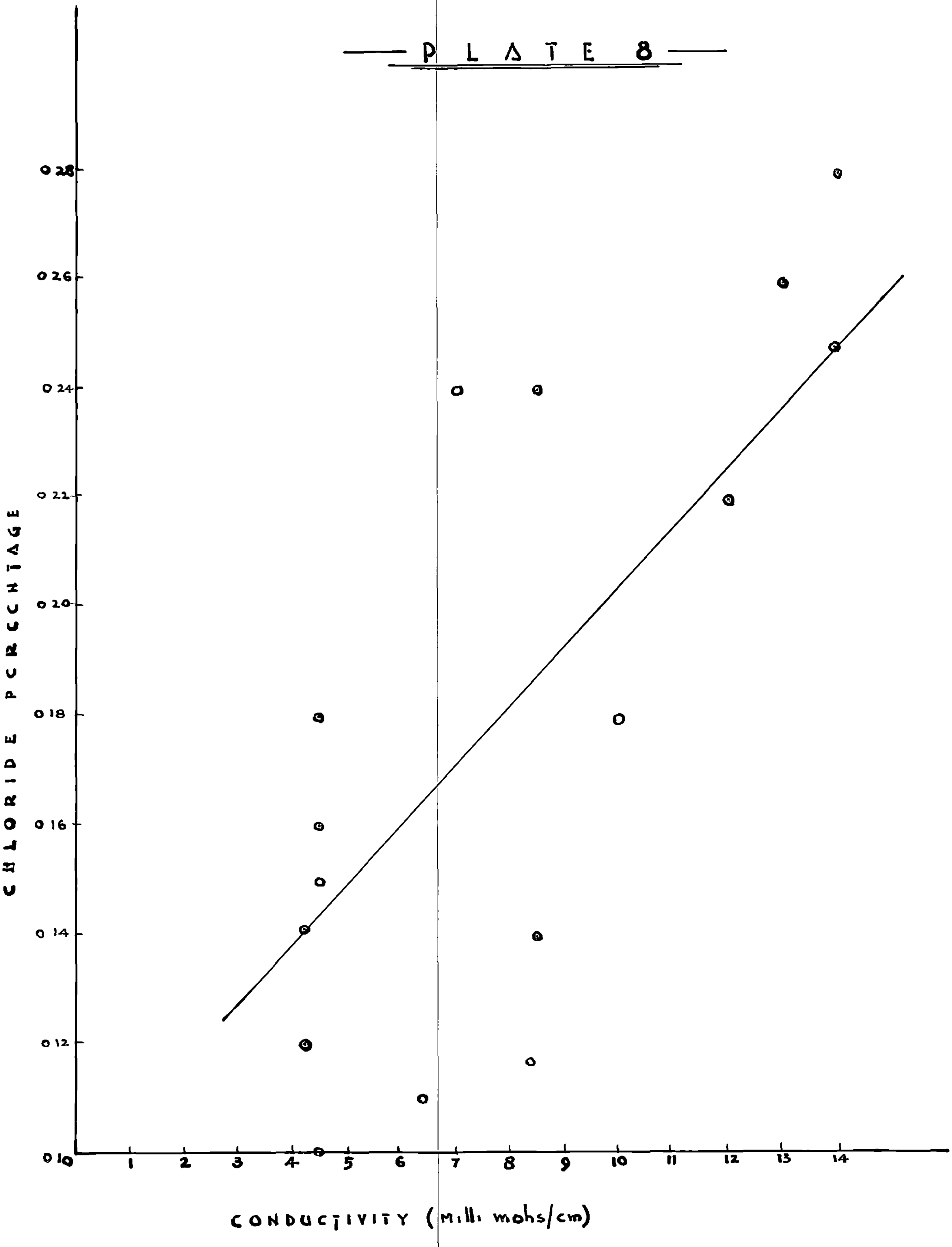
Pot Nos.	34-41	Sodium chloride + Magnesium chloride treatments
Pot Nos.	42-49	Sea water treatments
Pot No.	50	Control



PLATES 8 - 16

LINEAR REGRESSIONS

PLATE 8



0 28
0 26
0 24
0 22
0 20
0 18
0 16
0 14
0 12
0 10
CHLORIDE PERCENTAGE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
CONDUCTIVITY (Milli mohs/cm)

PLATE 9

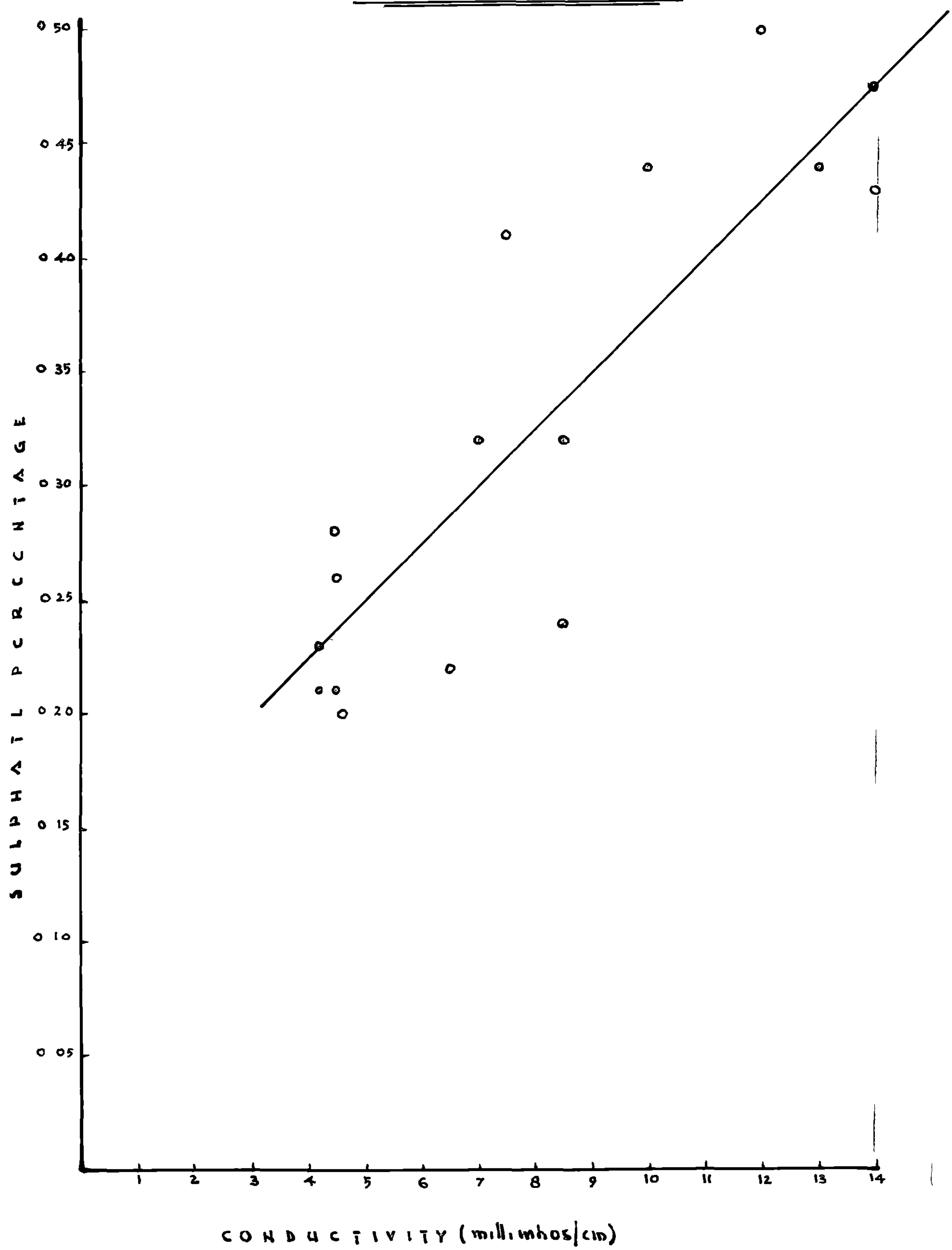
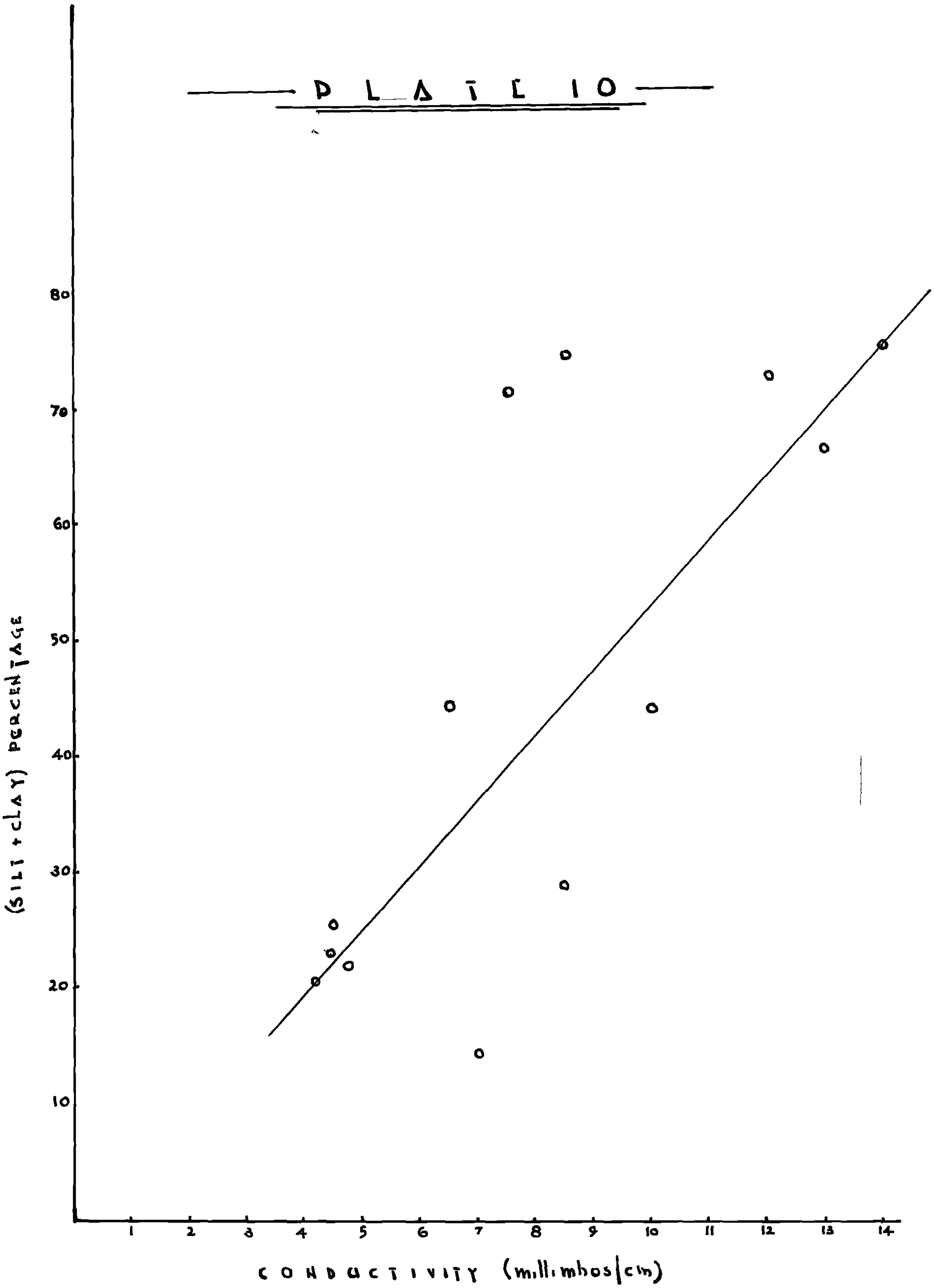

0 50
0 45
0 40
0 35
0 30
0 25
0 20
0 15
0 10
0 05
SULPHATE PERCENTAGE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
CONDUCTIVITY (millimhos/cm)

PLATE 10



(SILT + CLAY) PERCENTAGE
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14
CONDUCTIVITY (millimhos/cm)

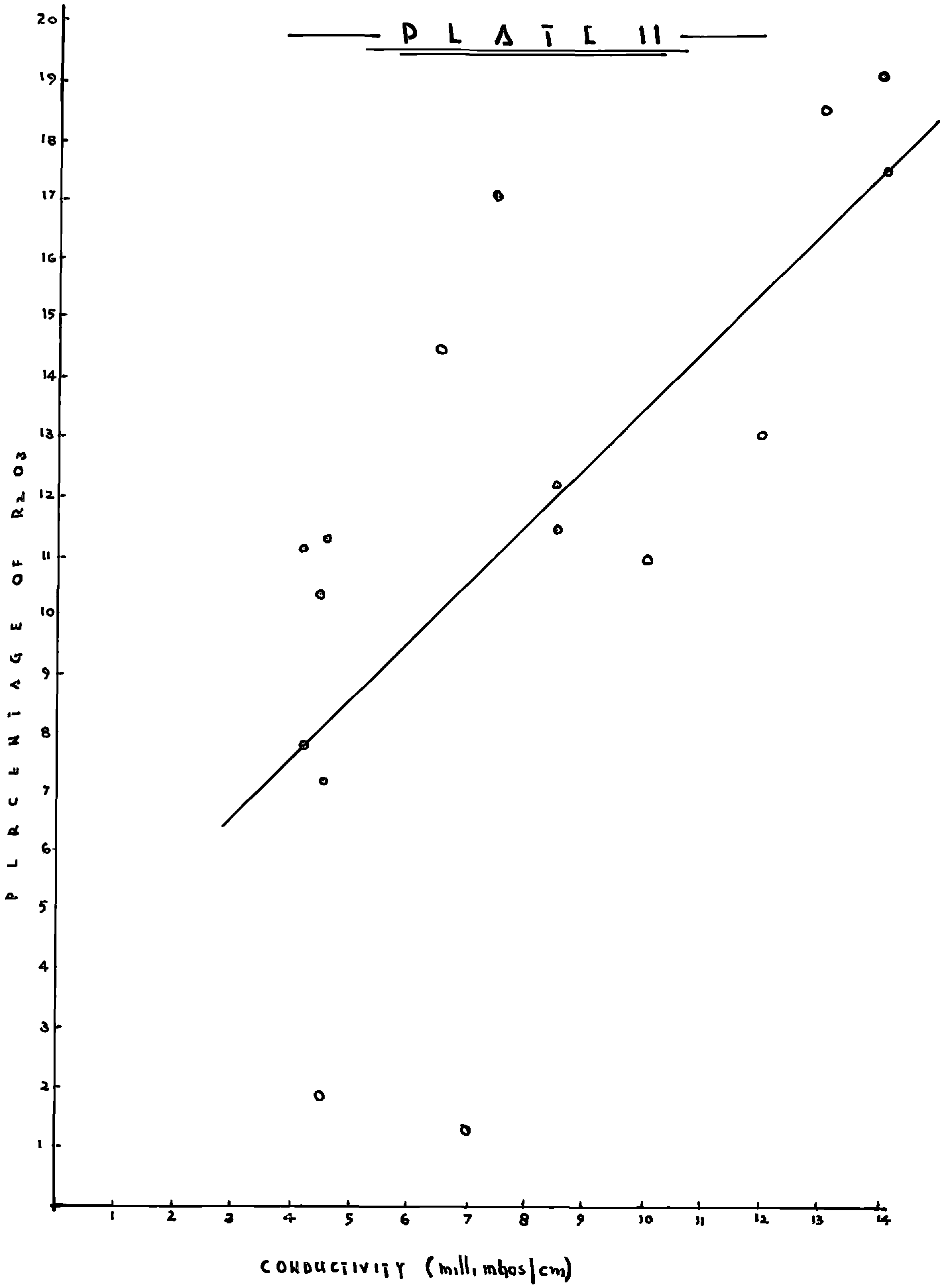


PLATE II
PERCENTAGE OF R_2O_3
CONDUCTIVITY (millimhos/cm)

PLATE 12

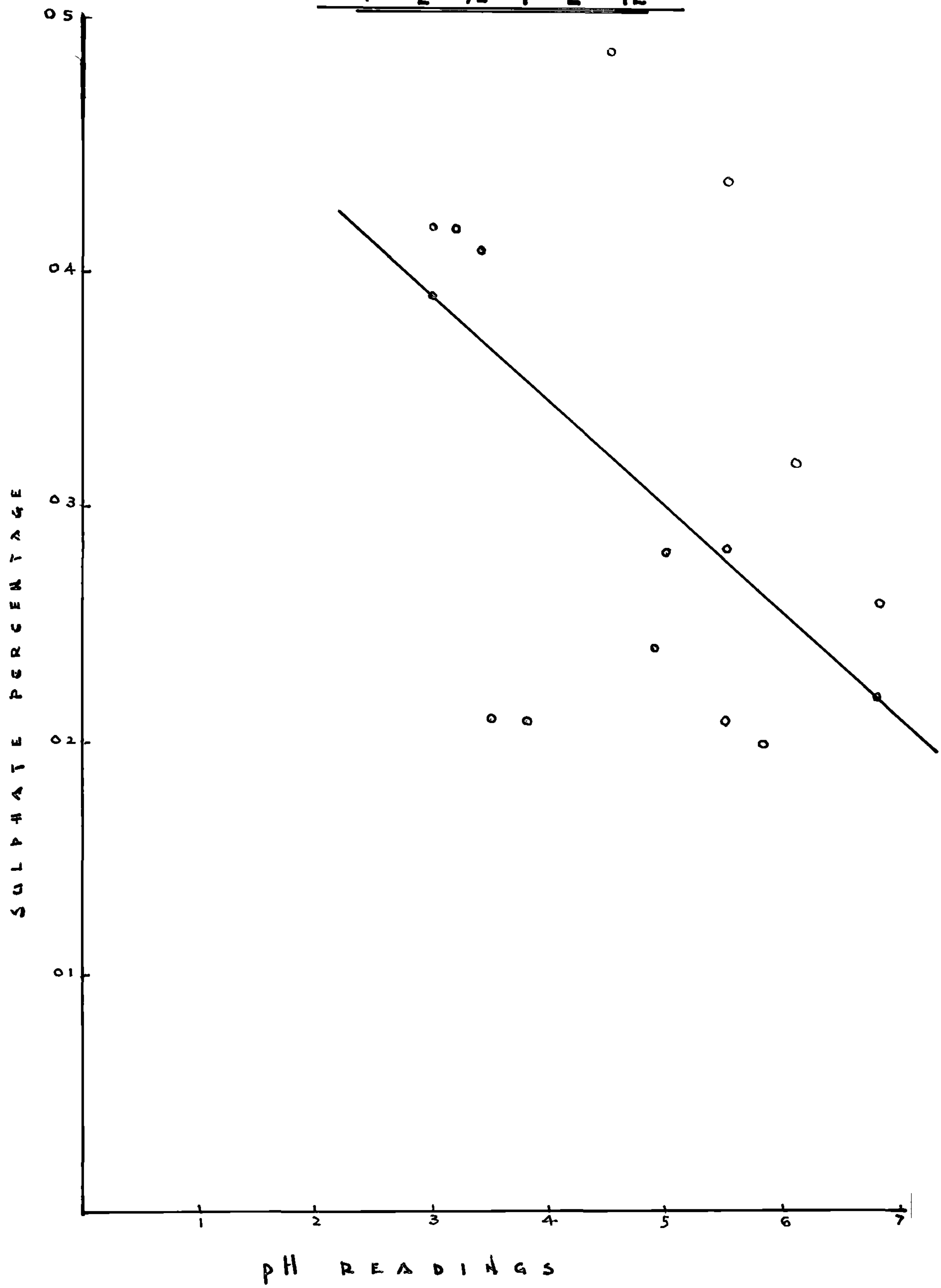
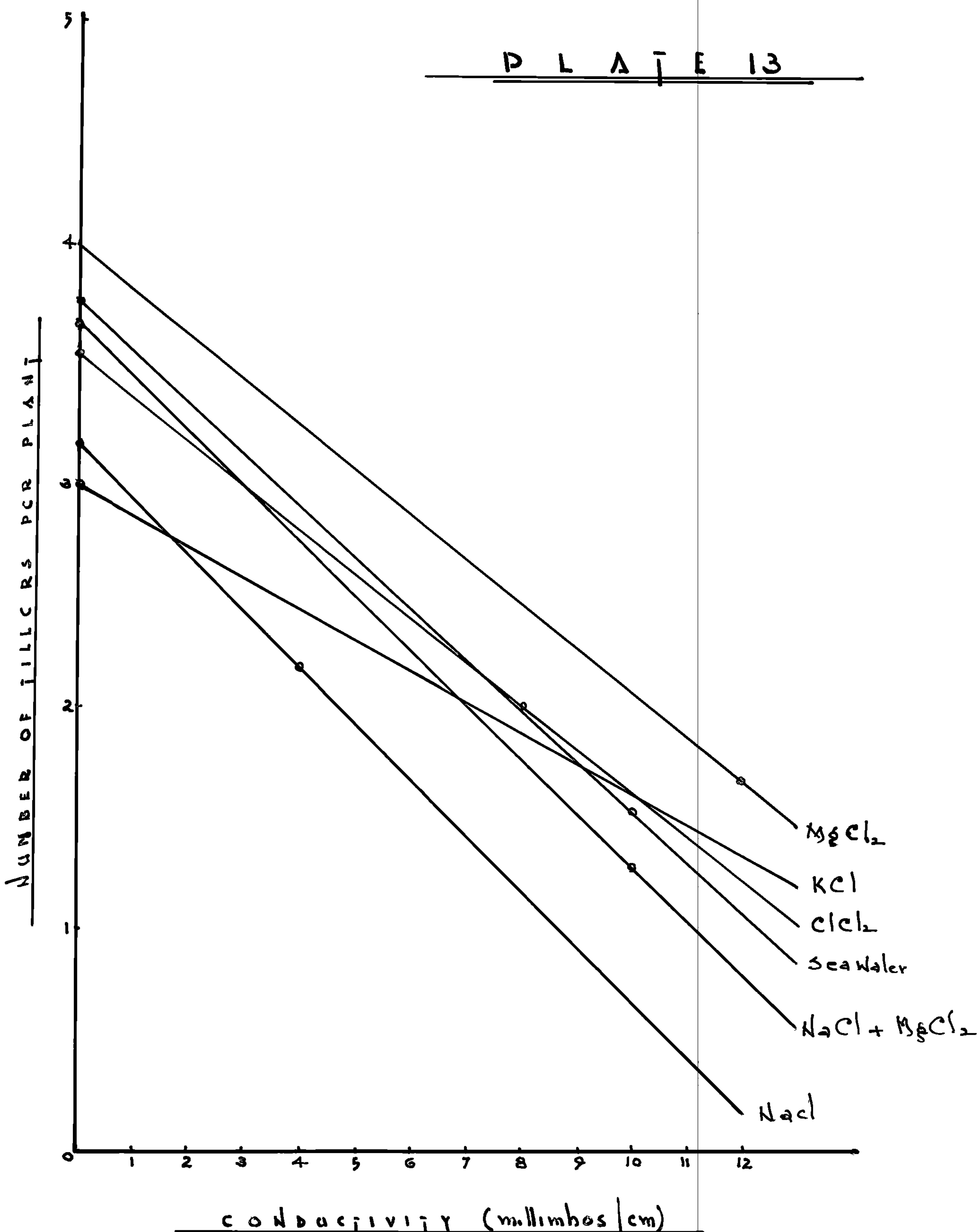
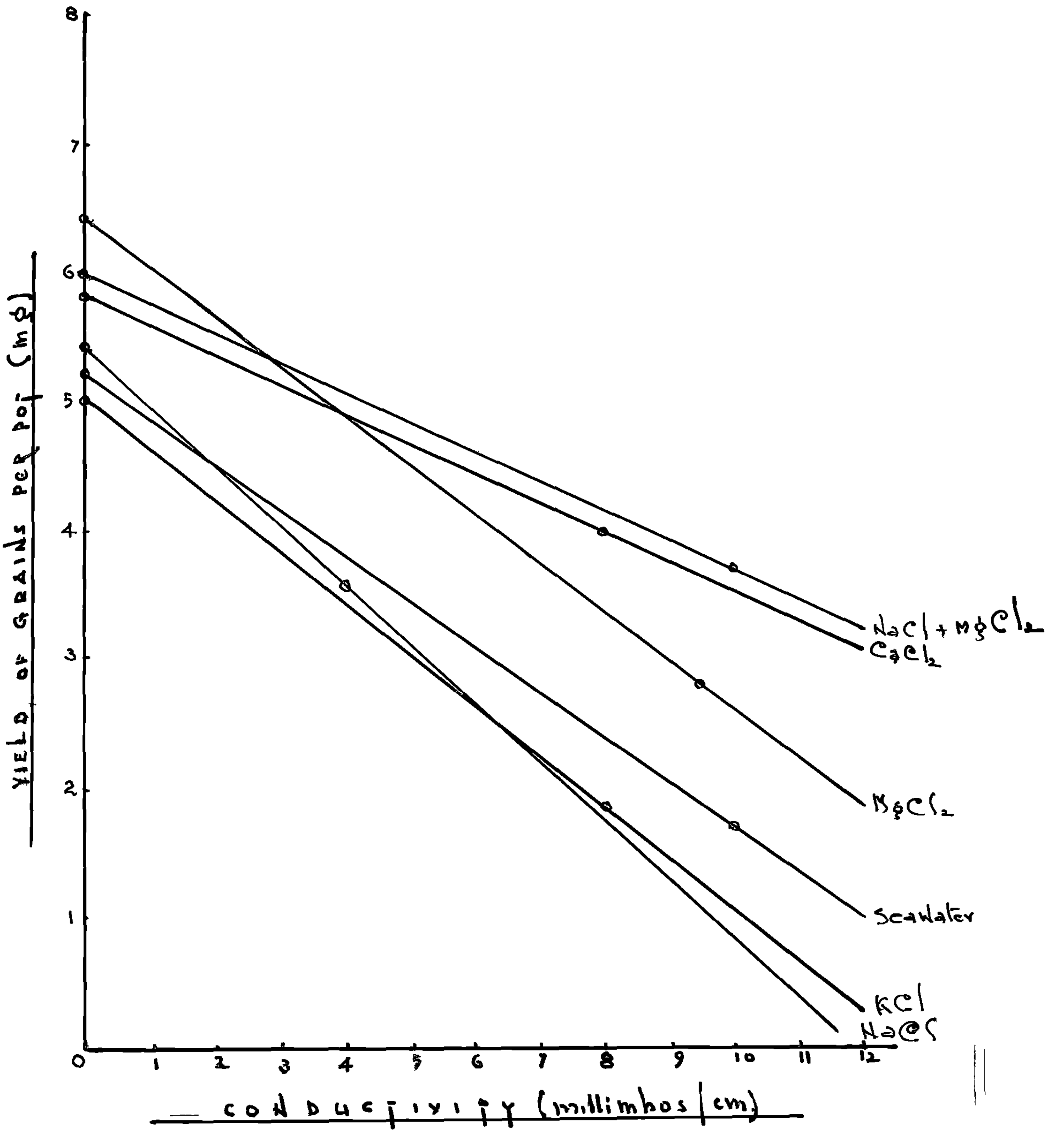


PLATE 13



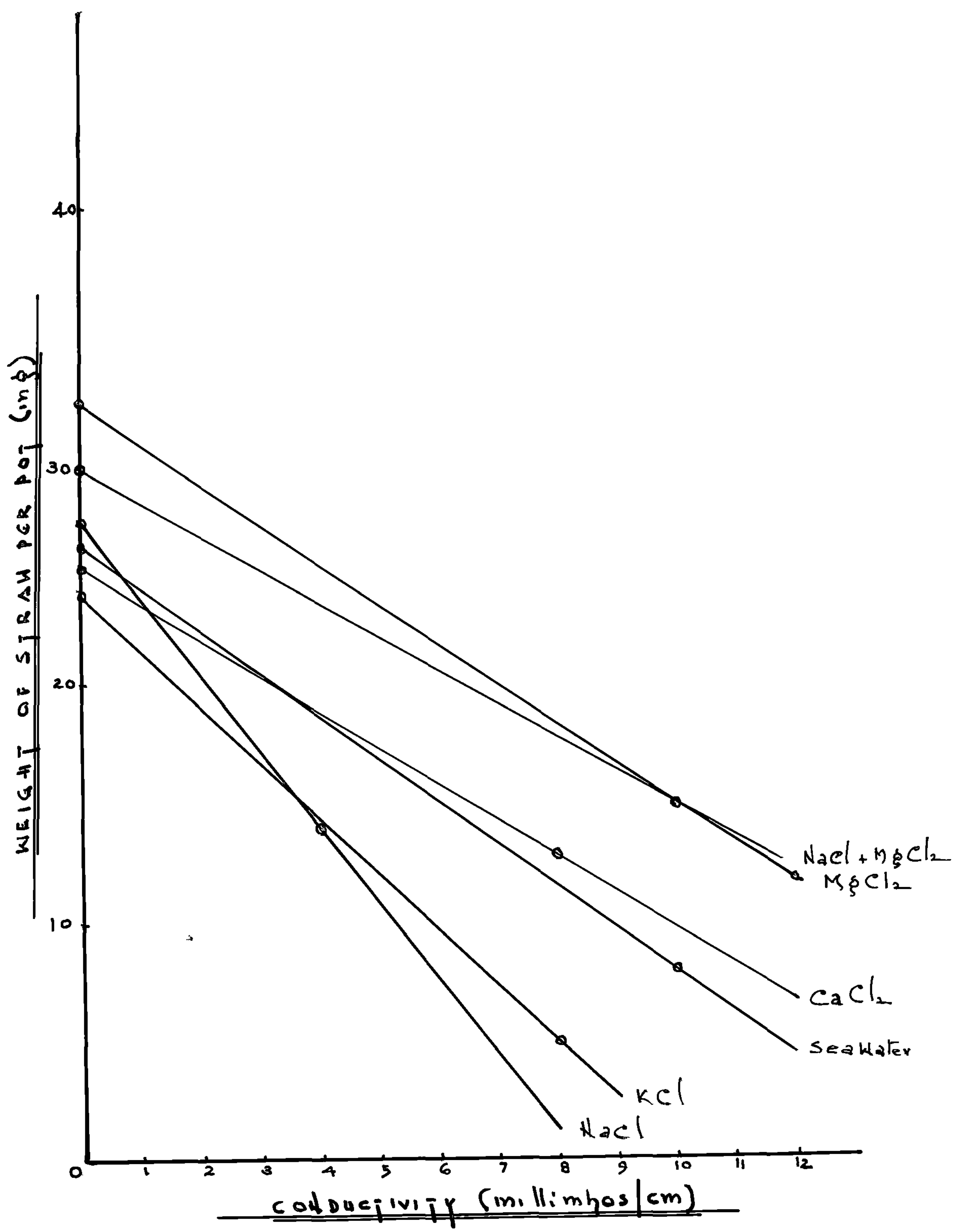
NUMBER OF TILLERS PER PLANT
0
1
2
3
4
5
1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTIVITY (millimhos/cm)
$MgCl_2$
KCl
$ClCl_2$
Sea Water
$NaCl + MgCl_2$
Nacl

PLATE 14



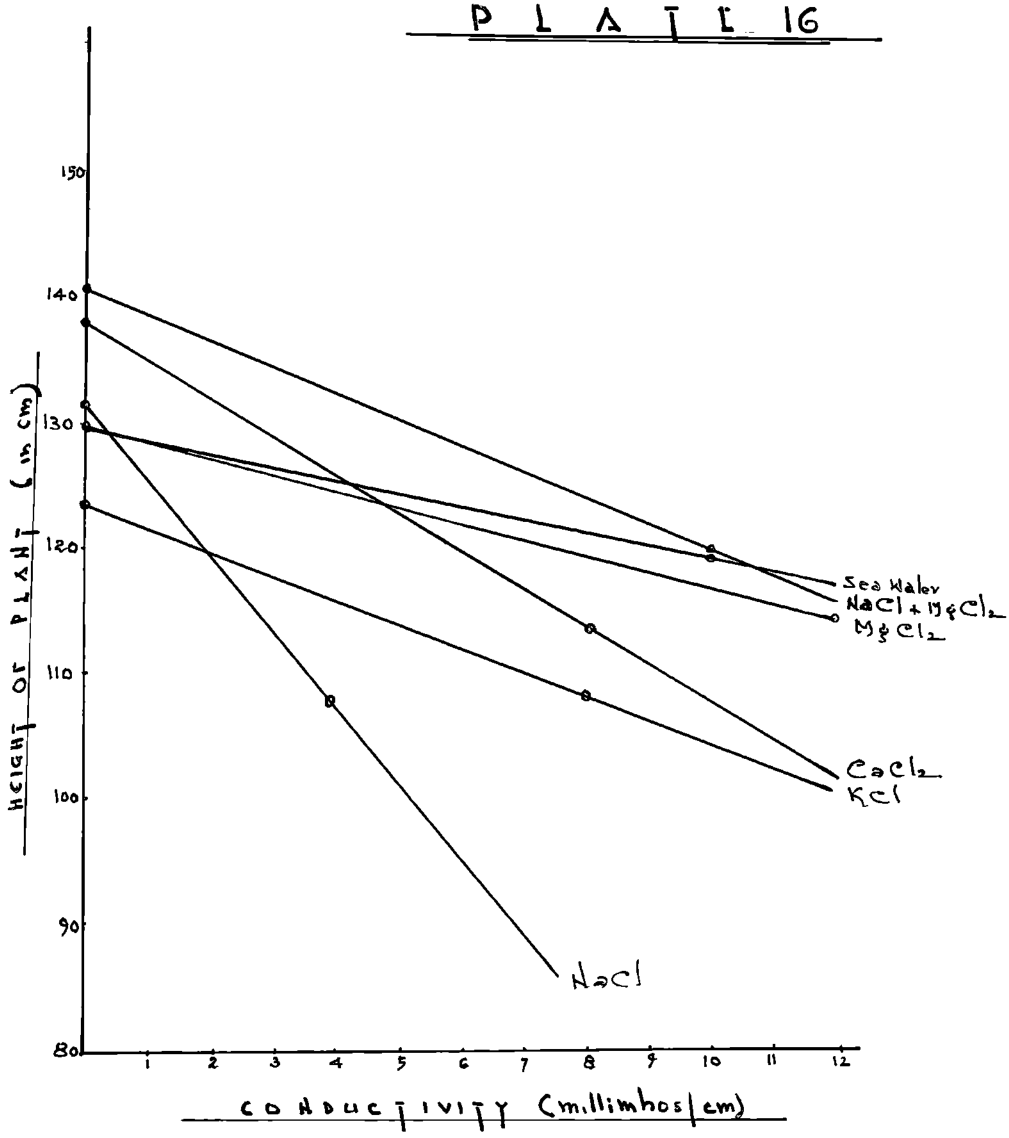
YIELD OF GRAINS PER POT (mg)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
NaCl + MgCl2
CaCl2
MgCl2
Seawater
KCl
NaCl
CONDUCTIVITY (millimhos/cm)

PLATE 15



40
30
20
10
0
WEIGHT OF STRAW PER POT (in g)
1
2
3
4
5
6
7
8
9
10
11
12
CONDUCTIVITY (millimhos/cm)
NaCl + MgCl2
MgCl2
CaCl2
Seawater
KCl
NaCl

PLATE 16



150
140
130
120
110
100
90
80
HEIGHT OF PLANT (in cm)
1
2
3
4
5
6
7
8
9
10
11
12
CONDUCTIVITY (millimhos/cm)
Sea Water
NaCl + MgCl2
MgCl2
CaCl2
KCl
NaCl