EFFECT OF SODIUM CHLORIDE ON SOIL CHARACTERISTICS, YIELD AND QUALITY OF COCONUT GROWN IN A LATERITE SOIL

By

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THESIS

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Faculty of Agriculture
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DECLARATION

I hereby declare that this thesis entitled "Effect of sodium chloride on soil characteristics, yield and quality of coconut grown in a laterite soil" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

Vellanikkara,
28th April, 1987

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CERTIFICATE

Certified that this thesis entitled "Effect of sodium chloride on soil characteristics, yield and quality of coconut grown in a laterite soil" is a record of research work done by Kum. Prema, D. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned, members of the Advisory Committee of Kum. Prema, D., a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agrl. Chemistry, agree that the thesis entitled "Effect of sodium chloride on soil characteristics, yield and quality of coconut grown in a laterite soil" may be submitted by Kum. Prema, D. in partial fulfilment of the requirement for the degree.

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C O N T E N T S

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF APPENDICES

INTRODUCTION

INTRODUCTION

The coconut palm (<u>Cocos nucifera</u> L.) is a crop which is most intimately connected with customs and folklore of the people in Kerala. No where in India, the socio-economic development of a state is so much dependent on a single crop. The importance of coconut palm can not be confined to statistical figures alone as each and every part of the palm is useful to man in one way or another. It provides oil, food, drink, fibre, timber, thatch, mats, fuel, domestic utensils, etc. and it is also of aesthetic importance to Keralites. No wonder it has been called 'Kalpa Vriksha'.

India is the third largest coconut producing country in the world. Coconut occupies about 1.1 million ha in India. Among the major coconut growing states, Kerala ranks first covering an area of 6.89 lakh ha (62.64 per cent of the total area under coconut in India). The total production in Kerala comes to 3395 million nuts which accounts 43.14 per cent of the total production of coconuts in the country. Considering the economy of the state, coconut contributes to 9.29 per cent of the total income and 26.2 per cent of the agricultural income. About 10 million people depend directly or indirectly on coconut culture and industry for their livelihood. Moreover, the agroclimatic conditions of Kerala are much suited for this crop, especially in the coastal belt where there is little scope for replacement of coconut, the major crop of the area. The economy of Kerala farmer is therefore directly dependent on the performance of this crop.

Coconut is widely grown in laterite soil, the major soil type of Kerala. Among the fertilizer elements supplied to the crop, potassium is the one that is applied in largest quantity. From time immemorial, it is the farmers' practice in Kerala to apply sodium chloride to coconut grown in laterite soil. The essentiality of sodium in some halophytes (Atriplex vascicaria) was already reported (Brownell, 1965). It is generally believed that the function of potassium in plant can be substituted to some extent by sodium since potassium and sodium closely resemble in their properties as they are elements of the same group in the periodic table. The response to sodium chloride may also be due to the favourable effect of chlorine. However, the exact effect of application of common salt to coconut is not properly understood. Research attempts to reveal the effect of sodium chloride on coconut are very few, especially in India.

Two field experiments are in progress at the Regional Agricultural Research Station, Pilicode, Kerala, from the year 1976 to evaluate the effect of application of sodium chloride to coconut. The present study was undertaken drawing soil and plant samples from these experiments with the following objectives in view:

1. To study the effect of substituting potassium chloride to various levels by sodium chloride on i) the yield ii) quality of copra and iii) nutrient uptake of coconut palm grown in laterite soil; and

2. To study the effect of application of sodium chloride on the physical and chemical characteristics of the soil.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. Response of crops to application of Na

It was not until twentieth century that the essentiality of elements other than C, H, O, N, P, K, Ca, Mg, S and Fe was demonstrated. Later a few more elements were conclusively proved to be essentials. The presence of Na was found to be beneficial for some crops while it was reported to be essential for halophytes like Atriplex vascicaria (Brownell, 1965). There is a general belief that the function of K in plant can be substituted by Na to certain extent since K and Na resemble in their properties.

Harmer et al. (1953) surveyed investigations on the effects of Na on plant growth and placed crops into two classes with regard to their response to Na.

A. Benefited by Na in a deficiency of K

Group 1. None to slight benefit

Group 2. Slight to medium benefit

B. Benefited by Na even in sufficiency of K

Group 1. Slight to medium benefit

Group 2. Large benefit

Hewitt (1963) concluded that the response to Na was dependent upon the species and the composition of the culture solution.

There were discussions of essentiality of Na for crops (Tisdale and Nelson, 1975) and on the requirement of Na as essential element and partial substitute for the roles of K in plant cells (Hewitt, 1963; Flowers and Lauchli, 1983).

1.1 Coconut

Coconut is one of the most important crops grown in Kerala state. Among the fertilizer elements supplied to this crop, K is the one that is applied in largest amounts. Application of common salt to coconut is a common practice of farmers of the state. Yet scientific reports on the response of Na to coconut are very few.

Briones (1931) reported that moderate amounts of NaCl seemed to invigorate coconut seedlings, giving rapid growth of tops and roots, but a heavier application was found to be harmful.

In the case of Na, in coconut, Ziller and Prevot (1963) fixed a level of 0.4 per cent as the critical level which was not desirable to exceed. This was in the 14th leaf. Smith (1969) reported that Na could replace K in coconut when the foliar concentration of K was less than 0.5 per cent and that of Na was less than 0.4 per cent.

Barrant (1975) observed that Na caused significant increase in yield for one year of three years' yield recorded. There was marked but nonsignificant increase in yield in the other two years. The Na x K interaction also caused significant increase in yield. He concluded that coconut palm should be placed in the category of plants which respond most to Na when available K is high and absorb more of the element at lower levels of K.

Ramanandan (1975) observed that $NaNO_3$ could be used instead of $(NH_4)_2SO_4$ and muriate of potash for coconut on equivalent nutrient basis.

Mathew et al. (1984) reported that replacement of K applied as KCl at the rate of 1000 g K_2O per palm per year, to the extent of 50 per cent or even 75 per cent of Na_2O applied as NaCl for five years did not reduce yield of nuts at the Coconut Research Station, Pilicode.

1.2 Cereals

1.2.1 Rice

Yoshida and Casteneda (1969) observed a promotion of growth in rice in the presence of moderately higher concentrations of NaCl when K was limiting. An increase in yield of rice was obtained in a sandy loam soil at higher ESP in soil (Elghamry et al., 1979). The yield was 26.6 g per pot at 7.98 ESP which was increased to 32.9 g per pot at an ESP of 13.21. Oommen et al. (1979) observed that spraying of 10 per cent NaCl solution on ears could hasten maturity of rice variety Triveni in kayal lands without reducing grain yield significantly. Similar results were obtained earlier by Ramaiha et al. (1974) and Govindaswamy et al. (1976).

Elghamry et al. (1979) reported a decrease in yield of rice with increasing ESP on a clay loam soil. The grain yield of 43.2 g per pot at 15.7 ESP was dropped to 28.2 g at 27.81 ESP.

1.2.2 Wheat

Joshi (1976) found that wheat cv Kharchia 65 was tolerant to high alkalinity and gave highest yields at an ESP value 60. Russell (1978) reported a reduction in yellow rust of wheat, when NaCl solution (8.6 g/l), applied to the soil at 20 ml per plant but not when it was sprayed on to the leaves. The growth and yield of the crop was not affected adversely in the absence of rust. The efficiency of spike dry matter production per cent in wheat was found to be promoted by increasing salinity (El-Sherbieny et al., 1986).

Blevins et al. (1978) found that KNO_3 was better for wheat than $NaNO_3$ as the application of the former showed higher nitrate reductase level in the leaves and less in the roots, accumulated more malate in leaves, accumulated more NO_3 and more of the accompanying cation. El-Sherbieny et al. (1986) obtained a negative response in dry matter yield of shoots and spikes in wheat with increasing levels of salinity.

1.2.3 Maize

Only a slight positive response of corn to Na fertilization was reported by Troug et al. (1953), the increase in yield being less than 10 per cent and the Na content of the crop was less than 0.2 per cent. Nitsos and Evans (1969) reported an absolute requirement of K for particulate starch synthase enzyme in sweet corn for optimum activation, though Na and Li were 21 per cent and 8 per cent as effective as K respectively.

Larson and Pierre (1953) reported that corn plants did not respond to Na under any conditions of K deficiency or K sufficiency. An increase in the Na content of maize was associated with a reduction in the dry matter yield (Poonia and Bhumbla, 1972; K'Drev and Georgieva, 1974, Shukla and [redacted] 1979; Kawasaki and Wallace, 1980) low yields and high mortality at Na concentrations above 25 mM (Yeo et al., 1977).

1.2.4 Sorghum

Gullo et al. (1972) reported that Na could replace K in some functions in sorghum, but not in elongation of stems and sheaths.

1.2.5 Barley

In barley, Na has been shown to replace K to some extent (Mullison and Mullison, 1942; Lehr and Wybenga, 1958; Hiatt, 1969; Kumar and Singh, 1973).

Troug et al. (1953) reported that barley was intermediate in response to Na between crops which showed notably favourable response and slightly favourable response.

1.2.6 Oat

Lehr (1953) obtained a positive effect of Na on grain and straw yield of oat grown on Na free sand dusarit mixture at all K levels. He pointed out the chance of an independent function of Na by itself on yield.

When oats were grown in soil, the positive response in yield was obtained only when K was limiting in soil (Lehr, 1953). Similar results were obtained by Larson and Pierre (1953) and Wehnut and Collins (1953). Troug et al. (1953) found the response of oats to Na fertilization, between crops which showed highly favourable response and slightly favourable response. But the response was more than that of barley.

1.3 Legumes

Truog et al. (1953) reported that alfalfa responded only slightly to Na fertilization. Schultz et al. (1979) reported that the yield increase in white clover and lucerne, which were given different K/Na ratios did not always relate to K/Na ratio. Yield of Medicago sativa was not affected by Na application and Na did not substitute for K in this species (Sherrell, 1983).

Singh et al. (1980) reported that an increase in ESP level decreased cowpea germination and fodder yield in cowpea. In general, the vegetative growth of legumes was adversely affected by increasing the ESP of soil

(Batra and Bharadwaj, 1981). Barbarick (1985) reported that as additional K was applied to the soil, the Na content of *Medicago sativa* and Na level of soil were decreased. The additional K suppressed the Na uptake which possibly resulted in greater N fixation and dry matter accumulation.

1.4 Sugar yielding crops

Sodium was found to be an indespensible element for sugarbeet,approaching K in importance (Lehr, 1941). Sugarbeet responded to Na even in the presence of large amounts of K. The correlation coefficients of total Na + K content versus yield of beets were 0.91 and 0.93 for the two soils compared while the correlation coefficients of K alone versus yield were 0.24 and 0.46.(Larson and Pierre, 1953). Marked increase in yield of sugarbeet was obtained by Na application when K was not limiting (Troug et al., 1953; Draycott et al., 1970; El-Sheikh and Ulrich, 1970; Bonjour, 1971).

The positive response of sugarbeet to Na application was also seen when K was limiting in the soil (Ulrich and Ohki, 1956;Shephered et al., 1959; Warcholowa, 1971; El-Sheikh and Ulrich, 1970; Bonjour, 1971; Draycott and

Durrant, 1976). Sodium and rubidium applied simultaneously to the nutrient solution resulted in synergic effects when the K supply of the soil was low (El-Sheikh and Ulrich, 1970).

Increase in yield of sugarbeet due to Na application was also reported by Kofoed and Fogh (1971) and Holmes <u>et al</u>. (1973). Holmes <u>et al</u>. (1973) found that the most profitable level of common salt for sugar yield as 377 kg/ha and that of muriate of potash as 127 kg K_2O/ha. Draycott and Durrant (1976) found the optimum level of Na + K for maximum yield in sugarbeet as 150 kg Na + 167 kg K per ha.

Application of Na improved the quality of sugarbeet by increasing the sucrose percentage (Troug <u>et al</u>., 1953; Warcholowa, 1971; Werner, 1977).

Draycott and Farley (1971) reported that Na and irrigation increased the leaf area index, total dry matter and sugar yield. Lawlor and Milford (1973) studied the effect of Na on water stressed sugar beet. They reported that Na increased the water content of leaf and storage root, fresh weight of the plant, leaf water potential, turgor and leaf growth rate and decreased the osmotic potential of leaf under stress conditions, but did not affect CO_2 uptake, transpiration, relative growth rate or net assimilation rate. Draycott *et al*. (1974) observed that Na fertilizers increased the yields of sugarbeet grown in a calcareous sandy loam soil irrespective of irrigation treatments but K increased yield only in irrigated crops. Durrant *et al*. (1978) reported that Na increased the leaf area index in the early stage of growth. The water content of leaves, final yield of root dry matter and sugar were increased. Sodium increased the leaf water content and diffusive conductance under conditions of moderate soil moisture deficit and decreased the leaf water potential when there was severe drought. The increase in yield was done by two mechanisms (1) the improved interception of radiation, by the crop by increasing leaf area, early in the season (2) the efficiency of leaves under conditions of moderate stress.

Palladina and Bershtein (1973) reported that the addition of Na, increased the ATP-ase activity two to three fold while the addition of K increased it only by 28 to 66 per cent. Terry and Ulrich (1973) found that with-holding Na as well as K from the culture medium of sugarbeet (28 days after planting) increased the deleterious effect of K deficiency on photosynthesis and stomatal opening.

Durrant *et al*. (1974) re-examined the results of field experiments with sugarbeet (1959-'69) and found instances of near perfect substitution of K and Na fertilizers as a result of chance combination of weather and crop husbandary. Cormuck (1981) reported that application of NaCl and K in autumn and spring gave similar yields in sugarbeet.

Moistening the seeds of sugarbeet with NaCl solution increased root yield in sugarbeet (Genkel and Bakonova, 1974; Yapprov and Iskakov, 1974).

There are reports of negative response of sugarbeet to Na application. The sugar yield and percentage content of dry matter in roots and leaves were decreased with increased application of Na (Shephered et al., 1959; Bonjour, 1971; Kofoed and Fogh, 1971).

In sugarcane, Valdivia (1978) established 15 per cent exchangeable Na as the critical value beyond which yield of sugarcane fell by 15 per cent. With 10 per cent exchangeable Na there was hardly a reduction in yield while 25 to 26 per cent caused a halving of yield.

1.5 Grasses

Lolium multiflorum exhibited good response to Na application (Saalbach et al., 1971; Nowakowski et al., 1974). Lolium perenne and Dactylis glomerata (orchardgrass) also showed good response to Na application (Saalbach <u>et al</u>., 1971). Haster <u>et al</u>. (1974) found that $NaNO_3$ without any K gave maximum yield of pasture in a rotation experiment. Mika and Naxinec (1976) reported that dry matter yield of above ground parts of <u>Dactylis glomerata</u> grass was increased by increase in applied Na upto 2 me/l. The dry weight of <u>Chloris gayana</u> (Rhodes grass) was significantly increased with increasing Na concentration upto 10 mM (Ando <u>et al</u>., 1979). The lower the K concentration in the nutrient solution, the more the Na absorbed by <u>C. gayana</u>. Jarvis and Hopper (1981) reported that there was an increase in the yield of shoots and roots in perennial rye grass, with increasing Na in the solution in a solution culture. It was suggested that, during the early stages of growth, there might have been an inadequate supply of K and that of Na might have substituted for K in some nonspecific roles of K in the plants. Mundy (1983) observed that near maximum yield was obtained when Na was included in the nutrient solution and when K concentration was sub-optimum in pasture species grown in sand culture.

Cope <u>et al</u>. (1953) reported that Sudan grass absorbed very little Na even when the element was applied to the soil. The increase in yield obtained was attributed to increase in K absorption when Na was applied to the soil. Negative response to Na application in grasses was also observed by Gammon (1953), Saalbach et al. (1971), Bhajwa and Bhumbla (1974), Mika and Naxinee (1976), Mika (1979), Smith et al. (1980), and Stark (1984)

Medium response to Na application in grasses was reported by many workers. Gammon (1953) reported that in Pangola grass Na would substitute 2/3 of the requirement without causing any appreciable reduction in growth. The yield of Italyan rye grass receiving 40 ppm N was increased by K but not by Na, whereas yield of the grass receiving 160 ppm N was increased by both K and Na (Nowakowoski et al., 1974). Mika (1979) found that application of 50 kg NaCl per ha produced a moderate increase in above ground dry matter in Dactylis glomerata. Jarvis and Hopper (1981) reported that there was not a complete replacement of Na for K in perennial rye grass which was supplied with different levels of K in solution culture.

1.6 Oil yielding crops

Aslam (1975) reported that both growth and alkali cation content of safflower plants were affected by K and Na treatments. Sodium increased growth of plants about

40 to 50 per cent at all K treatments. Visual K deficiency symptoms were less severe when Na was included in the treatment solution.

Yield was reduced in Sesamum indicum at an ESP more than 15.5 and seed oil content decreased slightly at an ESP of 25 (Yousif et al., 1972). A reduction in seed yield of soybean, seed oil content and 1000 seed weight was reported when the plants were irrigated with saline water. The more the Na concentration of the water supplied, the more the decrease (Slama and Bonaziz, 1978). Lauchli and Wieneka (1979) reported that dry weight of all plant parts of soybean variety Jackson was significantly reduced by 10 mM NaCl, but higher concentrations did not cause further reduction. Chhabra et al. (1979) found that an ESP more than 16 delayed germination, decreased plant height and stem to leaves ratio in sunflower. Emergence of flower heads was delayed but the maturity was enhanced at high ESP.

In Brassica juncea, ESP values more than 23 delayed germination and emergence of flowers and pods. The grain and oil yields were found to be reduced but there was enhancement in maturity (Singh et al., 1979).

1.7 Fibre crops

Significant increase in yield in seed cotton was obtained by addition of Na as fertilizer with relatively low rate of K fertilization (Cooper et al., 1953; Lancaster et al., 1953; Balaguru and Khanna, 1982). Lancaster et al. (1953) observed largest increase in yield of cotton, when Na was applied in most K deficient soil. Application of Na to this soil not only increased the growth and vigour of the crop but also reduced potash deficiency symptoms. Partial substitution of Na for part of the K in growth of cotton was observed when the latter was deficient in soil (Lancaster et al., 1953; Marshall and Sturgis, 1953; Balaguru and Khanna, 1982).

Robinson (1971) reported that highest cotton yields were obtained in soils with ESP values 8 to 16 and lower yields in the ESP range of 0 to 5 in Vertisols. [redacted] et al. (1980) reported that Na was not inferior to K in increasing yield when applied at a certain level of K content of soil.

Sodium was found to have effect on the quality of fibre. Favourable response on the quality of cotton fibre was found to be optimum with six per cent Na, whereas it gradually decreased and was negligible at a level of 18 per cent (Wybenga and Treggi, 1958). Treggi (1961) reported that the development of fibrous zone in hemp was favourably affected at moderate Na supply. Sodium was supposed to have an indirect effect on the formation of fibrovascular tissue, by conferring greater mobility and therefore greater availability upon P. Balaguru and Khanna (1982) found that the succulence of plant was increased in cotton, by addition of both Na and K.

Little or no response of Na on cotton was observed when Na was added with ample K fertilization (Cooper et al., 1953; Lancaster et al., 1953). Adverse effects of Na on cotton at high ESP in soil were reported by Shabassy et al. (1971) and Longenecher (1974).

1.8 Halophytes

Williams (1960) reported that Hologeton spp which received no added Na in its nutrition exhibited poor growth and vigour. Sodium as NaCl increased the growth, succulence and oxalate content of the leaves. Though there was no complete substitution of K by Na, Na was found essential for vigorous growth of this plant. Brownell (1965) concluded that small amount of Na was essential for growth and development of *Atriplex vascicaria*. Only Na of the group I elements affected the recovery of Na deficiency symptoms. Brownell and Jackman (1966) observed that respiratory response in *Atriplex vascicaria* to Na was specific to Na, as different salts of Na caused similar responses and no other univalent cation substituted for Na. Sodium was found to be the most effective ion in stimulating leaf succulence in *Atriplex hortensis* var. *cupreata* irrespective of whether the anion was chloride, bromide or sulphate (Handley and Jennings, 1977).

Match *et al*. (1986) observed that optimum level of NaCl concentration for obtaining maximum dry weight yield was 50 mM, in *Atriplex gmelini*.

1.9 Vegetables

Effmert (1960) reported that application of Na fertilizer in the presence of equivalent K markedly increased the root yield of carrot. When tomato plants were grown in sand culture with four levels of KNO_3 in combination with two levels of $NaNO_3$, the K deficiency symptoms occurred more frequently with the lower level of $NaNO_3$ (Besford, 1978a). Besford (1978b) in another experiment with tomato plants grown in a series of nutrient solutions in which K was replaced by Na in different proportions, found that plants selectively absorbed and transported K to the shoots in preference to Na. Percira and Westerman (1978) found that lettuce yield was increased over that of control by application of Na and partial substitution of K by Na was taken place. But a greater yield was obtained with K. No difference in response was found in lettuce to NaCl and Na_2SO_4 on growth.

Sanches-Conde (1971) reported that growth of radish in solution culture was better with K_2SO_4 than with Na_2SO_4 but highest yield was obtained when both K_2SO_4 and Na_2SO_4 were present in the solution. Sodium reduced tobacco mosaic virus infection in tomato though it could not replace K as a plant nutrient. In experiments conducted with intact chloroplasts of spinach and *Vicia faba*, the addition of K or Na ions to the medium increased the rates of CO_2 fixation. Potassium was more effective than Na in this respect (Pfluger and Cassier, 1977). Sugiyama *et al*. (1981) reported that in soil culture where cabbage and snap bean were grown at various replacements of K and Na, a particular level of K in soil gave optimum growth irrespective of the level of Na.

Tal *et al.* (1976) found that Na substituted K in its functions in stomatal movement under conditions of high salinity in the case of *Capsicum*.

Hara *et al.* (1977) found that cabbage grown in cultures devoid of Na halides had the highest dry weight, highest yield and showed no deficiency symptoms. Gurrier *et al.* (1985) found that tomato plants infected with *Verticellium alboeatrum* increased the content of Na and decreased the content of K of the plants. The extent of K/Na substitution varied with the fungal strain. Singh and Abrol (1985) found a significant negative correlation between ESP and bulb yield of onion and garlic. Onion was found to be more sensitive to sodic condition than garlic. Burns and Hutsby (1986) reported a pronounced delay in the uptake of additional amounts of Na and in its translocation within the K deficient lettuce plants.

1.10 **Fruit crops**

Khanduja *et al.* (1980) reported that vine growth was depressed with increasing levels of ESP in the grape vine cv. Thompson Seedless. Spiers (1983) found that high Na levels (120 mg/l) resulted in increased leaf N and reduced plant growth in blue berry.

1.11 C-4 Plants

Brownell and Crossland (1972) found that six species having characters of plants with C4 photosynthetic pathway, Echinochloa utilis, Cynodon dactylon, Kyllinga brevifolia, Amaranthus tricolor, Kochia childsii and Portulaca grandiflora responded decisively to NaCl (0.1 me/1) supplied to the culture solutions. These plants developed chlorosis and necrosis in the absence of Na. Under similar conditions, Poa pratensis, having characteristics of C3 photosynthetic pathway made normal growth and did not respond to the addition of Na. Boag and Brownell (1979) reported that the response of C4 plants to Na deficiency did not involve changes in the pathway of photosynthetic carbon assimilation. Johnston et al. (1984) reported that the chlorophyll a/b ratio of Amaranthus tricolor, Kochia childsii and Chloris gayana was significantly lower in Na deficient plants compared with normal C4 plants. Of the Group I element, only Na, irrespective of the salt supplied to deficient cultures, restored the chlorophyll a/b ratios to the values observed in normal plants.

2. Interaction of Na with other nutrient elements in plants

Sodium was found to have interactions with other nutrients in the plants in regulating their uptake and translocation in the plant tissues.

2.1 Potassium

Inverse relationship between Na and K content of plant was reported by many workers in different crops. An increase in the applied Na decreased the K uptake. Similarly, increased application of K fertilizers depressed the Na uptake. This trend was reported by Barrant (1975) in coconut; Devitt et al. (1981) in wheat, Yeo et al. (1977) in maize, Elzam (1971) in barley, Lessani and Marschner (1978) in Phaseolus vulgaris, Schultz et al. (1979) in lucerne and white clover, Sherrell (1984) in lucerne, Warcholowa (1971) and Marschner et al. (1981) in sugarbeet, Shabassy et al. (1971) in cotton, Mika and Naxinec (1976) in cocksfoot grass, Ando et al. (1979) in Chloris gayana, Kolota and Sciazko (1979) in cabbage.

High Na treatment did not affect K content of fodder cowpea (Singh et al., 1980). Mengel and Naneth (1971) reported that though high K concentration in soil solution depressed the Na content of the herbage, the antagonistic effect was weak when concentration of Na in soil solution was high.

2.2 Calcium

An increase in the Na content of tissue was associated with a decrease in Ca. Such antagonism was observed in wheat (Mehrotra and Das, 1973; Ray et al., 1977; Singh and Singh, 1982), in maize (Poonia and Bhumbla, 1972; K'Drev and Georgiva, 1974; Shukla and Mukhi, 1979; Kawasaki and Wallace, 1980), in barley (Elzam, 1971), in *Phaseolus vulgaris* (Lessani and Marschner, 1978), in cowpea (Singh et al., 1980), in sugarbeet (Warcholowa, 1971), in para grass (Bhajwa and Bhumbla, 1974), in cocksfoot grass (Mika and Naxinec, 1976), in *Brassica juncea* (Singh et al., 1979) and in cotton (Johansson and Joham, 1971; Shabassy et al., 1971).

There were reports that Na had no effect on the Ca content of plant tissues (Uziac, 1973 in lettuce, Aslam, 1975 in safflower).

2.3 Magnesium

Generally inverse relationship was found between Na and Mg. The increase in the Na content of the plant causes a decrease in Mg content and vice versa. Reports on this aspect include those of Ray et al. (1977), Singh and Singh (1982) in wheat, Schultz et al. (1979) in lucerne, Singh et al. (1980) in cowpea, Bhajwa and Bhumbla (1974) in paragrass, Mika and Naxinec (1976) in cocksfoot grass and Shabassy et al. (1971) in cotton. Aslam (1975) reported that Na concentration in all above ground plant parts was significantly increased by addition of Na.

Singh et al. (1979) reported that an increase in the exchangeable Na percentage had no effect on the content of Mg in the plant.

2.4 Nitrogen

Sodium treatments increased the uptake of N by K deficient carrots (Effmert, 1960).

Sodium in the nutrient medium did not affect the percentage content of N in plant parts (Uzaic, 1973, in lettuce; Mika and Naxinec, 1976 in cocksfoot grass).

When NO_3 was supplied as the $NaNO_3$ or KNO_3 wheat cv Arthur seedlings were found to absorb and accumulate more NO_3 from KNO_3 than from $NaNO_3$ (Blevins et al., 1978).

2.5 Phosphorus

Effmert (1960) found that treatment with Na increased P uptake in K deficient carrots. Sodium was found to decrease the content of P in plant parts in cocksfoot grass (Mika and Naxinec, 1976), cabbage and beet root (Kolota and Sciazko, 1979).

Sodium was found to have no effect on the P content in plant parts. This was shown by Uziac (1973) in lettuce, Singh *et al*. (1979) in *Brassica juncea*, Mohamed and Abd-El-Hadi (1985) in *Phaseolus vulgaris*.

2.6 Micronutrients

Singh *et al*. (1979) reported that increasing values of ESP had no effect on the content of Fe, Mn, Zn and Ca in *Brassica juncea*. Singh *et al*. (1980) found that an increase in the ESP increased the content of Fe in the forage of cowpea and decreased the content of Mn. Copper and Zn contents remained unaffected.

3. Interaction of Na with other nutrients in soil

Kawasaki *et al*. (1972) reported that the exchangeable fractions of Rb and Na in barley roots were decreased by the presence of Ca in the nutrient solution, while the nonexchangeable fraction increased irrespective of the type of Ca salt.

Burkart and Amberger (1977) reported that Na content decreased with increasing K applied to soil in field trials using wheat. Buyoumi et al. (1978) reported that increasing ESP decreased the uptake of N, P and K and increased Na uptake in a sandy loam and clay loam.

Barbarick (1985) reported that application of K fertilizer consistently decreased the Na level of the soils.

4. Influence of Na as a fertilizer on physico-chemical characteristics of soil

Pillai et al. (1959) observed that no moisture conservation effect was found in a sandy soil as a result of adding 900 kg NaCl and 765 kg KCl to coconut per ha.

Sodium chloride caused crust formation on the soil surface and inhibited growth at seedling emergence but did not decrease yield (Kofoed and Fogh, 1971).

Singh et al. (1971) reported that there was significant correlation between pH of the soil and its ESP and the ESP could be reasonably estimated from pH.

Tinker (1971) reported that the uptake and release of Na by sugarbbet caused rapid annual fluctuations in the Na content of the top soil following the addition of Na fertilizers. During the second year the sub soil contained more Na than top soil. A small residue was present in the third year, but none was present in the subsequent years.

Dixit and Lal (1972) reported that increasing exchangeable Na decreased the hydraulic conductivity in an experiment using soil of six textural classes.

Totev (1975) observed that large amounts of Na_2SO_4 (2280 to 6100 kg/ha) did not cause harmful salinization in a chernozem soil. He reported no adverse effect on the growth of sugarbeet and lucerne and no soda was formed in the soil due to the above treatment. The concentration of $NaHCO_3$ did not rise and $\frac{Ca^{2+} + Mg^{2+}}{Na^{+}}$ ratio decreased markedly resulting in a more favourable balance and concentration level of ions. This favourably affected plant growth and humus solubility.

Draycott *et al.* (1976) found that application of several times the recommended amounts of Na would not damage soil structure when sugarbeet was grown in soils of loamy very fine sand, very fine sand, very fine sandy loam, sandy clay loam and clay loam textures.

Abrol et al. (1978) reported that on a predominantly illitic, alluvial sandy loam soil, moisture retention increased at soil water suctions greater than about 0.2 atm with increasing ESP.

Knyazeva (1978) found that the activity and dissociation of Na ions in soil increased with increasing soil dispersion. The presence of NaCl suppressed the dissociation of adsorbed Na ions.

Grieson (1979) reported that water stable aggregation was increased with higher organic matter and low ESP.

Sharma and Agrawal (1979) reported that the crust strength of sandy loam, loam and clay loam soils increased with increasing ESP and a dispersion percentage of silt and clay.

Draycott and Bugg (1982) concluded that Na fertilizers for sugarbeet should always be applied before ploughing to avoid soil compaction but on sands these might be advantageous for post-ploughing application.

Kazman *et al.* (1983) found that the infiltration rate of soil can be very sensitive to low levels of ESP.

Mathew *et al.* (1984) observed that application of NaCl to coconut at the rate of 750 g Na_2O and 500 g Na_2O per palm per year for 5 years to the laterite soil of Pilicode, Kerala did not alter the pH, EC and aggregate stability of the soil.

5. Mechanism of sodium absorption and tolerance to Na in plants

El-Sheikh and Ulrich (1971) reported that two mechanisms are involved on the uptake of Na, at low and high Na and K concentration (0-8 me/l). The operation of the first mechanism was at the lower concentration of Na (less than 1 me/l) and it was blocked by the presence of K. The second mechanism functioned at higher concentration of Na (more than 1 me/l) transporting Na as well as K.

The uptake of Na in wheat was found to increase at higher ESP in soil (Mehrotra and Das, 1973). It was found that the salt resistant varieties of different crops accumulate more Na than salt sensitive varieties. This was shown by Kannan (1975) in rice and Buyoumi *et al.* (1978) in wheat.

Balasubramanian and Rao (1977) found that salt tolerance in rice was associated with the regulation of the accumulation of Na and K at the tillering stage, thus reducing the adverse effects of salt stress on tiller potential.

Lessani and Marschner (1978) found that chlorine content increased more than the Na content in the shoots of Phaseolus vulgaris with an increasing supply of NaCl.

Abrol and Bhumbla (1979) found that the reduction in soil ESP was quickest and extended to the greatest depths when rice (Oryza sativa) was grown and rice was highly tolerant to exchangeable Na. They also reported that wheat (Triticum aestivum) was only moderately tolerant to exchangeable Na.

West and Taylor (1980) reported that the rates of uptake of Na and Cl were much higher in Phaseolus vulgaris when it was grown in stagnant waterlogged conditions than in aerobic conditions. However, the pattern of distribution of Na and Cl and final concentration of Na and Cl in plants were similar in both conditions.

Flowers and Yeo (1981) found that within cultivars of rice which were not homozygous lines, there was high variability in Na uptake and in survival under saline conditions by individual plants. This was in contrast to the relative uniformity in the uptake. There was negative correlation between Na and Cl accumulation by individual plants and their survival under saline concentration.

Field and green house trials in sorghum conducted by Morard (1981) concluded that after absorption Na was rapidly translocated in the conductive tissues, particularly in the roots leaving a low Na content in the leaf laminae. It was suggested that absorption of Na was not selective. Its translocation was passive and accumulation of Na in the roots might prevent Na absorption in toxic amounts.

Eggers and Jeschke (1983) showed that Triticum was capable of accumulating Na^+ in root vacuoles. It resembled barley in showing efficient influx and exchange selectivity at the plasmalemma.

Johanson and Cheesman (1983) observed that Na but not K accumulated in the mesocotyl of maize seedlings grown in solution culture containing NaCl. Johanson et al. (1983) reported that at equal levels, uptake of Na by the stele of the mesocotyl of maize seedlings in solution culture was more rapid than that of K, and Na was preferentially retained in the stele. Transport of Na to the cortex halted when the supply of ions in the transpiration stream was interrupted. Potassium did not substitute for Na in restoring the transport and did not compete with Na for transport to the cortex.

Drew and Dikumwin (1985) concluded that at higher NaCl concentration, the ability of maize roots to exclude Na ions was saturated by the inward Na diffusion. The ratio of Na/K transported to the shoot increased by a factor of 600 when the concentration of NaCl was increased from 2.4 to 40 moles per m^3 and roots suffered due to anoxia.

Weil and Khalil (1986) reported that tissue content of N in winged bean increased significantly with increasing salinity, suggesting that dry matter accumulation in winged bean was more sensitive to salinity than N fixation.

6. Response of coconut to chlorine

The essentiality of chlorine in the nutrition of coconut was well established through foliar diagnosis. The supply of cations, K or Na is mainly in the form of their chloride. The favourable effect of NaCl on growth of coconut may also be due to the effect of Cl. So the importance of chlorine nutrition in coconut is reviewed.

It was Ollagnier and Ochs (1971) who first recognised the importance of chlorine for coconut and oil palm. He remarked that K is not always necessary and that the response of these palms to muriate of potash (KCl) which was attributed to K should infact have been credited to chlorine.

Apacible (1974) showed that with application of KCl the Cl content of the leaf markedly changed. The Cl content of the leaf was also highly correlated with yield. Thus he assumed that the response to KCl was actually due to Cl and not due to K.

Magat *et al*. (1975) reported that the correlation between the yield and the chlorine content of the leaf was higher than the correlation between yield and K content of the leaf. Prudente and Mendoza (1976) found that the Cl content of the leaf was highly correlated with nut/tree, weight per nut and copra/tree. Manicot *et al*. (1980) remarked that K, N and Cl predominated in the mineral requirements of coconut. Because of the relative abundance in nature, deficiency of chlorine was generally limited to specific situations.

Teffin and Quencez (1980) made a detailed study of the importance of chlorine for coconut. The response to KCl application was classified into two: (1) Only Cl was assimilated in large quantities giving positive effect on yield. Very little K was assimilated or the level of K was even slightly depressed; (2) Both K and Cl perfectly assimilated having positive correlation with yield.

Eschbach et al. (1982) reported that Cl deficiency affected the growth of young palms and the yield of mature ones. They said that levels of Cl below 0.1 per cent in leaves showed deficiency.

Nair and Sreedharan (1983) stressed the importance of Cl in coconut and oil palm and reported that the effect of Cl content of leaf tissue on morphological characters and yield was greater than that of K.

MATERIALS AND METHODS

MATERIALS AND METHODS

The coconut palms of the sodium chloride trial conducted at the Regional Agricultural Research Station (KAU), Pilicode, Hosdurg taluk of Kasaragod district were made use for the present study. The station is located at a longitude 70° E, latitude 13° N and at an altitude of 15 m from the mean sea level.

1. Details of field experiments

At the Regional Agricultural Research Station, Pilicode, there are two field experiments laid out in 1976, in order to evaluate the effect of NaCl on coconut palms. The soil type of the experiment site is laterite (Oxisol). The meteorological parameters of the experiment site are given in Appendix 1. The details of the experiment are given in Fig.1 and 2. The design, layout and treatments were the same for both the experiments and they were as follows:

Design	:	RBD
No.of treatments	:	6
No.of replications	:	4
No.of palms/plot	:	6

FIG. 1. LAY-OUT OF EXPERIMENT No. 1

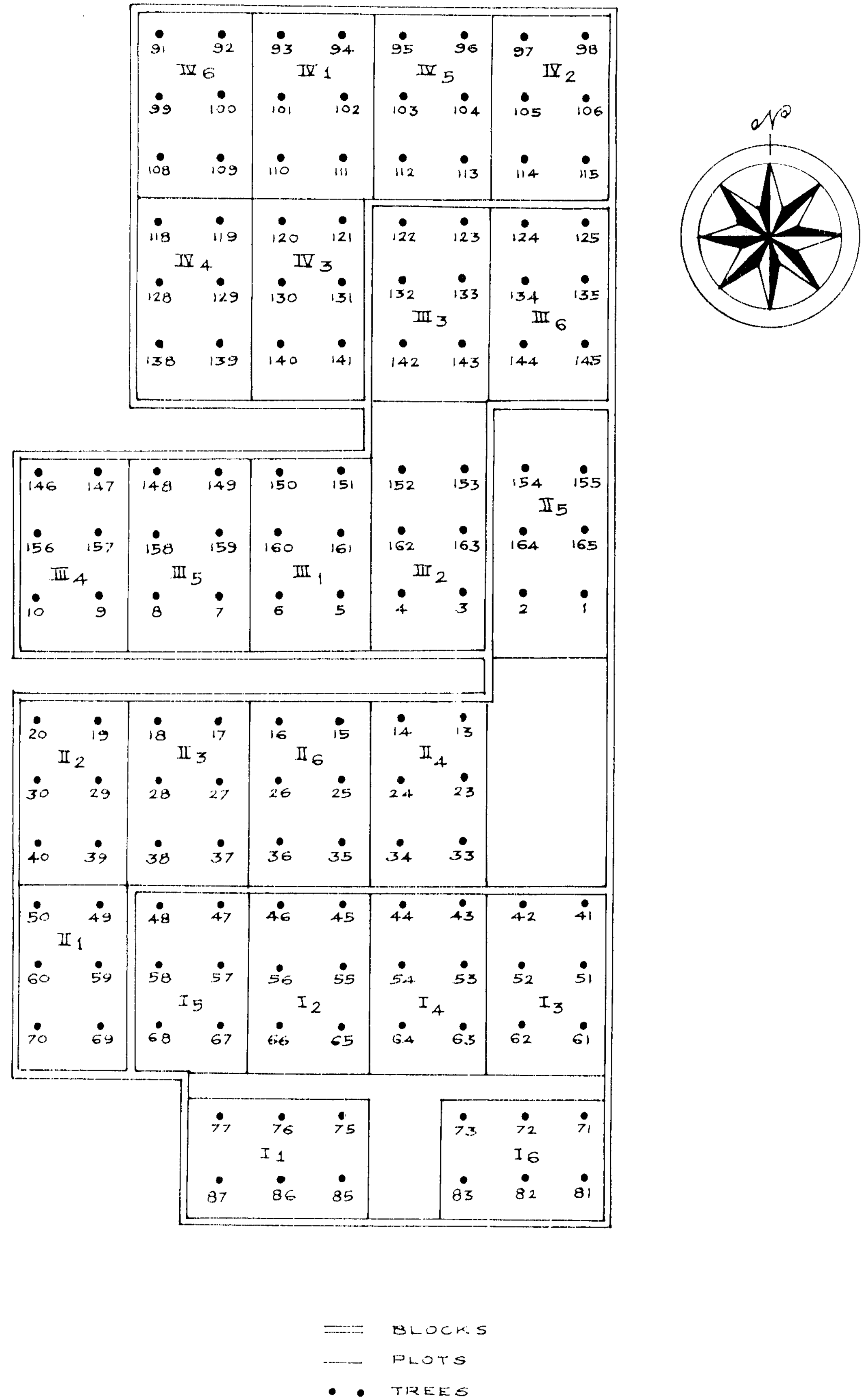
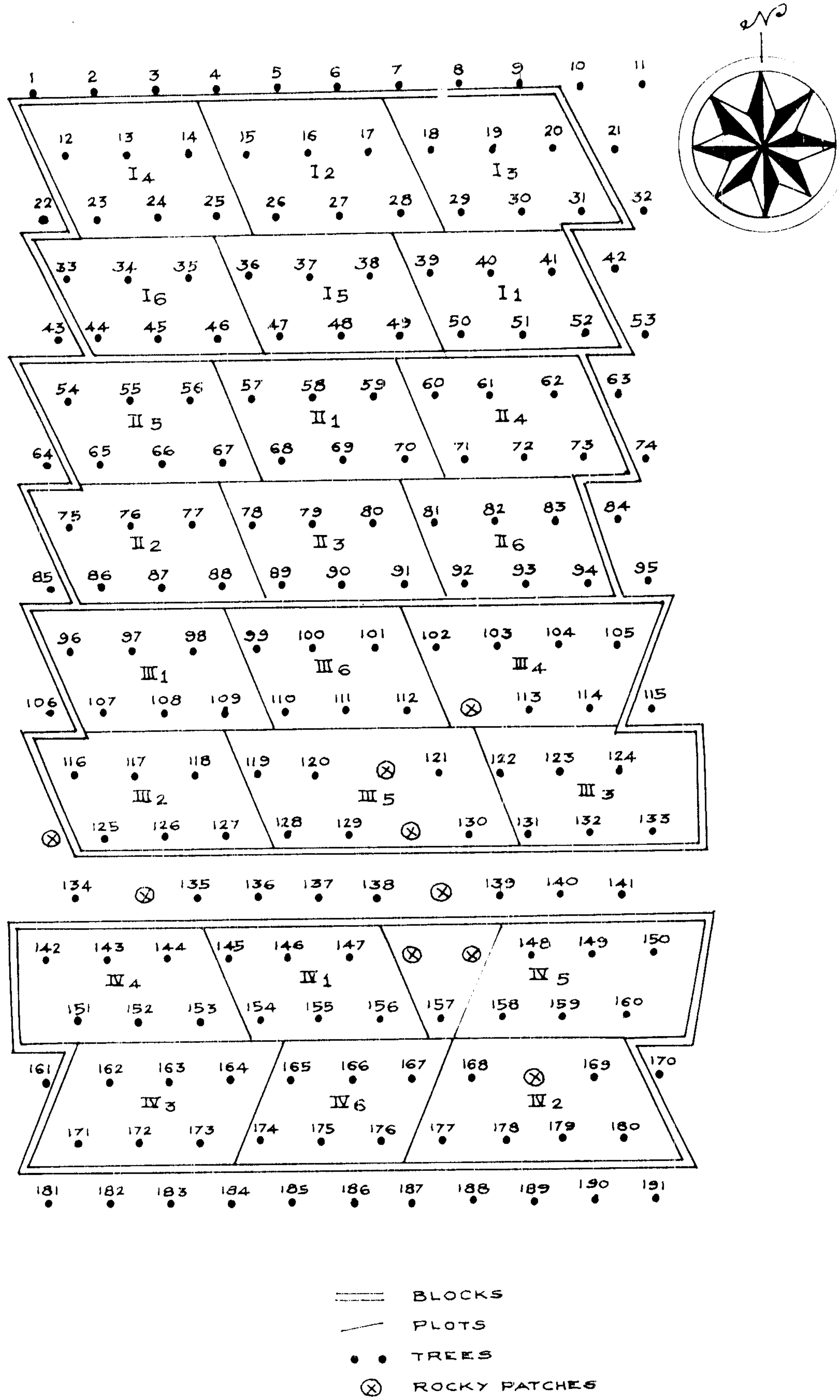


FIG. 2. LAY-OUT OF EXPERIMENT NO. 2.



Treatments

T_1	control
T_2	1000 g K_2O/palm/year
T_3	750 g K_2O + 250 g Na_2O/palm/year
T_4	500 g K_2O + 500 g Na_2O/palm/year
T_5	250 g K_2O + 750 g Na_2O/palm/year
T_6	1000 g Na_2O/palm/year

Potassium was applied as potassium chloride and sodium as sodium chloride in two split doses. These palms also received 500 g N (urea), 320 g P_2O_5 (superphosphate), 300 g CaO (lime) and 170 g MgO (magnesium sulphate). The fertilizers were applied in two doses, one third at the time of early south-west monsoon showers and two-third in September-October. The crop was rainfed and all cultural and management operations were done as per the package of practices recommended by the Kerala Agricultural University (Anon, 1976).

1.1 Experiment No.1

The first experiment was conducted with 24 year old stock of hybrid palms (TxD) which received N, P and K as per the recommended dose (500 g N, 320 g P_2O_5, 1200 g

K_2O per palm per year) till 1976, after which the above treatments were superimposed. Thus the palms have received the fertilizer treatments only for the last 10 years i.e., from 1976 to till the time of sampling for this study (January, 1986). The observations on growth, morphological characteristics and yield of the experimental palms, recorded at the Regional Agricultural Research Station, Pilicode were made use for the study. The number of leaves retained at the crown per year, number of leaves produced per year, number of female flowers produced per palm per year and annual nut production per palm for the last eight years (1978-'85) and during the pretreatment period were used for the statistical analysis of the data.

1.2 Experiment No.2

The second experiment was laid out with newly planted coconut seedlings (DxT) and therefore the treatments were given from planting till the date of sampling. Since the palms were only of 10 year old, they have not yet reached the stage of stabilized yield. Therefore, the yield of the palms was not considered. Similarly they were not subjected to analysis for the yield and quality of copra.

The observations on growth and morphological characteristics of the young experimental palms, recorded at the Regional Agricultural Research Station, Pilicode were made use of. The mean values of number of functioning leaves at the crown (1984 and 1985), total number of leaves produced so far (upto 1985) and the early flowering nature of the palmswere made use for the statistical analysis of these characters. A scoring technique was developed to analyse the effect of treatments on earliness of flowering. The palms which were not flowered upto 1985 were given a score of zero. The following scores were given in the increasing order, according to the earliness of flowering.

Year of flowering	Score
1985	1
1984	2
1983	3
1982	4
1981	5

2. Collection of samples

The soil, leaf and nut samples were collected during the period from 18th to 25th January 1986.

Soil samples were collected from the base of all the six palms per plot, from six different spots within a radius of 2 m. Samples thus drawn were pooled and one composite sample represented a plot.

Leaf samples were collected from two palms selected at random from each plot. The last fully opened leaf at the centre of the crown was referred to as the first leaf and the leaves were numbered in the order of their increasing age. In the first experiment, the 14th leaf was sampled by cutting two leaflets from the middle portion of the leaf from either side of the rachis with the help of a hook knife. In the case of the second experiment, samples from the 10th leaf were drawn in a similar way. (The total number of leaves in some of these palms was less than 14). Leaf samples from the two palms of the same treatment plot were pooled to get a composite sample.

Nut samples were collected at the rate of two nuts per palm from the two palms selected for leaf collection. For chemical analysis, the copra of these four nuts of the two palms of a plot were pooled into a composite sample.

3. Laboratory studies

3.1 Soil

3.1.1 Preparation of the sample

A part each of the soil sample was kept in its natural undisturbed condition for aggregate analysis. The rest of the soil sample was air dried, powdered gently and passed through a 2 mm sieve. The prepared samples were kept in labelled plastic containers for further studies.

3.1.2 Aggregate analysis

The analysis was based on the technique developed by Tiulin (1928) and Yoder (1936). One hundred gram of the sample pre-sieved through 8 mm sieve was placed in the top sieve of a set of sieves having openings of 4.75, 2.00, 1.18, 0.50, 0.25 mm diameter and saturated by spraying a small quantity of water with a hand atomiser, allowing a wetting time of 10 minutes. The fraction retained on each sieve was transferred and dried to constant weight at 105°C. These were pooled together, dispersed with 10 ml of 4 per cent $NaOH$ and passed through the same set of sieves, washed with water and the sand fraction of above 0.25 mm diameter was oven dried and weighed. From the results mean weight diameter, structural co-efficient and percentage aggregate stability were worked out.

3.1.3 Mechanical analysis

Mechanical analysis of the 2 mm sieved soil was done by the hydrometer method (Piper, 1942) and the data have been furnished in Appendix 2 and Appendix 3.

3.1.4 Soil physical constants

Apparent density, absolute specific gravity, maximum water holding capacity, pore space and volume expansion of soil were determined by the method of Keen and Raczkowski (1921) using Keen-Raczkowski boxes.

3.1.5 Moisture retention characteristics

Moisture retention studies on soil samples passed through the 2 mm sieve were made at 0.3 and 15 bar pressure using a pressure plate apparatus. The plates used for soil water retention at 0.3 and 15 bar were 1 bar and 15 bar ceramic plates respectively (Richards, 1954).

3.1.6 Chemical properties

The organic carbon content of soil was determined by Walkly and Black method as described by Piper (1942). The total N was determined by Kjeldahl digestion distillation procedure described by Jackson (1958). Available phosphorus was extracted by Bray No.1 extractant (0.025 N HCl + 0.03 N NH_4F; soil/solution ratio 1:10; period of extraction 5 min) and the P content was determined colorimetrically by the chlorostannous reduced molybdo-phosphoric blue colour method in HCl system (Jackson, 1958).

Available K was extracted with 1N neutral ammonium acetate (soil solution ratio 1:5; period of extraction 5 min) and the K content was determined using a flame photometer (Jackson, 1958). Available Na was extracted with neutral 1N ammonium acetate as in the case of K and the Na content was determined flame photometrically (Jackson, 1958). Available chloride was extracted with water (soil water ratio 1:5; period of extraction 5 min) and Cl content was determined by Mohr's titration (Jackson, 1958).

CEC was determined using 1N neutral ammonium acetate. A known weight of soil was saturated overnight with neutral 1N ammonium acetate to displace the cations. Excess ammonium acetate was washed with alcohol. The NH_4^+ ions were then displaced using 1N KCl solution. A known aliquot of the KCl leachate was distilled with excess NaOH in a microkjeldahl distillation apparatus. The liberated NH_3 was absorbed in boric acid and titrated against standard HCl using methyl red-methylene blue mixed indicator and CEC was expressed as me/100 g of soil.

The ammonium acetate leachate obtained at the time of determination of CEC was made use for the determination of exchangeable cations (Piper, 1942). Exchangeable Ca and Mg were determined by the versenate titration method (Hesse, 1972).

Exchangeable K and Na of the leachate were read in a flame photometer and expressed as me/100 g of soil. Exchangeable sodium percentage was then calculated using the formula,

$$ESP = \frac{\text{Exchangeable Na}}{\text{CEC}} \times 100$$

The pH of the soil in water was determined using a soil : water ratio of 1: 2.5 by a pH meter (Jackson, 1958). Electrical conductivity of the supernatant liquid of the soil water suspension used for the determination of pH was read with the help of a conductivity bridge (Jackson,1958).

3.2 Leaf

First the midrib of the leaflet was separated and the marginal threads of the lamina were removed. The lamina samples were then taken by cutting 10-20 cm long strips from the middle of the laminae. The samples were cleaned and sundried. The laminae were dried at 80°C and processed for chemical analysis.

Total N in the leaf was determined by the microkjeldahl digestion - distillation method (Jackson, 1958). A known weight of the sample was digested in a mixture of HNO_3, $HClO_4$ and H_2SO_4 (10:4:1). The P content was determined colorimetrically by the vanado-molybdo phosphoric yellow colour method in HNO_3 medium (Jackson, 1958). The contents of K and Na in the extract were read in a flame photometer (Jackson, 1958).

For the determination of chloride in the plant sample, organic matter in the sample was destroyed by digestion with HNO_3 and permanganate in the presence of excess of $AgNO_3$. Chloride was precipitated as AgCl, the excess Ag being titrated with thio-cyanate in the presence of acetone using ferric iron as indicator (Anon, 1972).

3.3 Coconut water

Fresh coconut water was analysed for soluble K and Na. The K and Na were read in a flame photometer.

3.4 Copra

3.4.1 Preparation of the sample

Husked nuts were cut into two halves and were sundried. Partially dried kernels were separated from the shell and again kept for further drying. Drying was continued till the cut surface of dried copra showed pearl white edges. The copra was cut into thin flakes, labelled and stored for chemical analysis.

3.4.2 Chemical analysis

The total N, P, K, Na, Ca, Mg and Cl content of copra were analysed as in the case of leaf samples.

3.5 Oil

3.5.1 Determination of oil content of copra

The oil content of copra was determined by soxhlet extraction procedure using petroleum benzene as the extractant at 40-60°C.

3.5.2 Oil quality analysis

Bulk extraction of oil was carried out using petroleum benzene as solvent, at room temperature, with mechanical agitation.

The specific gravity of the oil was determined using a specific gravity bottle. Refractive index of the oil was measured using an Abbe Refractometer. The iodine number and saponification value of oil were determined as per standard analytical procedures (Sankaram, 1966).

4. Statistical analysis

The data on the average annual nut production per palm, number of functioning leaves, female flower production, number of leaves produced per year during the experimental period were analysed using the analysis of covariance technique (Snedecor and Cochran, 1967). The data on other observations were analysed by the analysis of variance method for RBD (Panse and Sukhatme, 1985). Coefficients of simple linear correlation and regression between various factors were worked out, as described by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

As already described under "Materials and Methods" two field experiments laid out at the Regional Agricultural Research Station, Pilicode, Kasaragod district, Kerala in order to evaluate the effect of NaCl on coconut, are made use of, for the present study. The soil of the experiment site is laterite (Oxisol) and the area enjoys an average annual rainfall of about 3200 mm. In the first experiment, the fertilizer treatments were superimposed on 24 year old coconut palms in 1976 which were receiving N, P and K as per the recommended dose till that year. The second experiment was laid out in 1976 with newly planted coconut seedlings and therefore the treatments were given from the very start of the field experiment. In both experiments, the crop is rainfed. The soil and leaf samples for this study were collected in January 1986.

A. Experiment No.1

1. Effect of fertilizer treatments on the morphological and growth characteristics of the palm

The data on the number of functioning leaves are presented in Table 1. A scrutiny of the data on number of functioning leaves of the individual palms recorded for the

Table 1 Effect of fertiliser treatments on the number of leaves retained by the palms

Treatment No.	R_1	R_2	R_3	R_4	Mean	Adjusted treatment mean
1	27.04 (30.60)	30.49 (33.06)	29.09 (27.42)	29.17 (27.53)	28.95 (29.65)	28.50
2	30.33 (31.11)	29.98 (31.39)	29.63 (28.25)	25.48 (24.97)	28.86 (28.93)	28.80
3	31.35 (36.00)	28.08 (29.11)	29.60 (23.61)	28.35 (26.92)	29.35 (28.91)	29.30
4	29.79 (30.75)	31.31 (31.86)	30.75 (27.47)	30.10 (29.25)	30.49 (29.84)	29.94
5	29.29 (28.89)	29.00 (26.56)	29.88 (29.14)	22.73 (21.40)	27.73 (26.50)	29.00
6	30.67 (30.81)	29.04 (29.89)	27.73 (27.50)	31.87 (28.53)	29.83 (29.18)	29.64
SEM						0.816
CD (0.05)						2.474

The values in parenthesis are pretreatment values
The treatment values are the mean of the period 1978–1985 (8 years) and the pre-treatment values are the mean of the period 1971–1976 (6 years)

last eight years (1978-1985) revealed that the number of functioning leaves retained by the palm varied from 8 to 42. Such a marked variation was mainly due to the heterogeneity of the experimental palms. When the data were analysed employing the technique of analysis of covariance taking the pretreatment values as covariate, the results indicated that the fertilizer treatments could not influence this character significantly. The adjusted treatment means for the six fertilizer treatments ranged from 28.50 to 29.94, the maximum being recorded by T_4 (50% substitution of K_2O by Na_2O) and the minimum by T_1 (control). The coefficients of correlation between various characteristics studied are presented in Table 53. It was seen that the number of functioning leaves was significantly correlated with yield ($r = 0.6722^{**}$) and the total number of leaves produced per year ($r = 0.7401^{**}$). The relationship between yield and the number of leaves retained by the palm has been graphically represented in Fig.3. The simple linear regression equation of yield on number of leaves showed that the minimum number of leaves required for the very expression of yield is 13.570 and that unit increase in number of leaf will correspond to a yield increase of 5.045 nuts per palm per year. This relationship is quite understandable since palms with higher number of leaves can

FIG. 3. RELATIONSHIP BETWEEN NUMBER OF FUNCTIONING LEAVES AND YIELD.

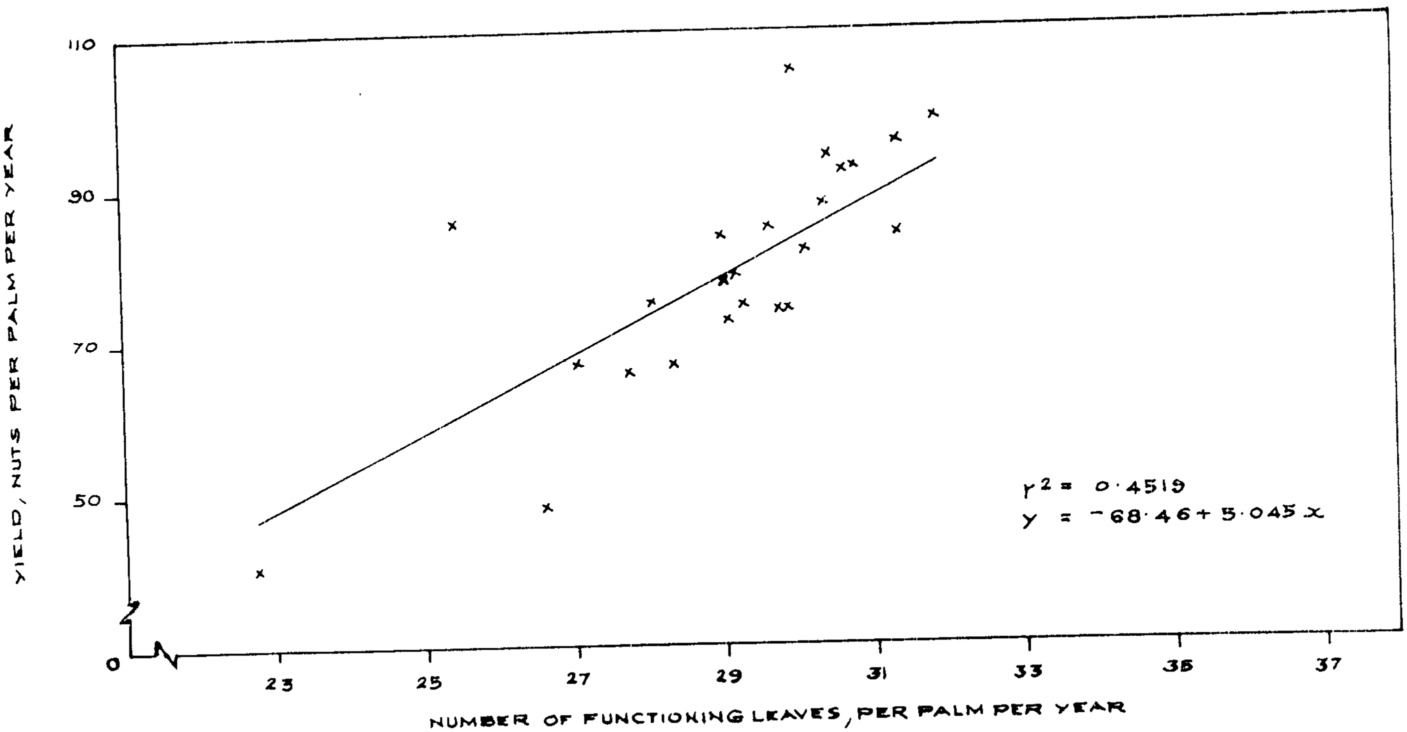
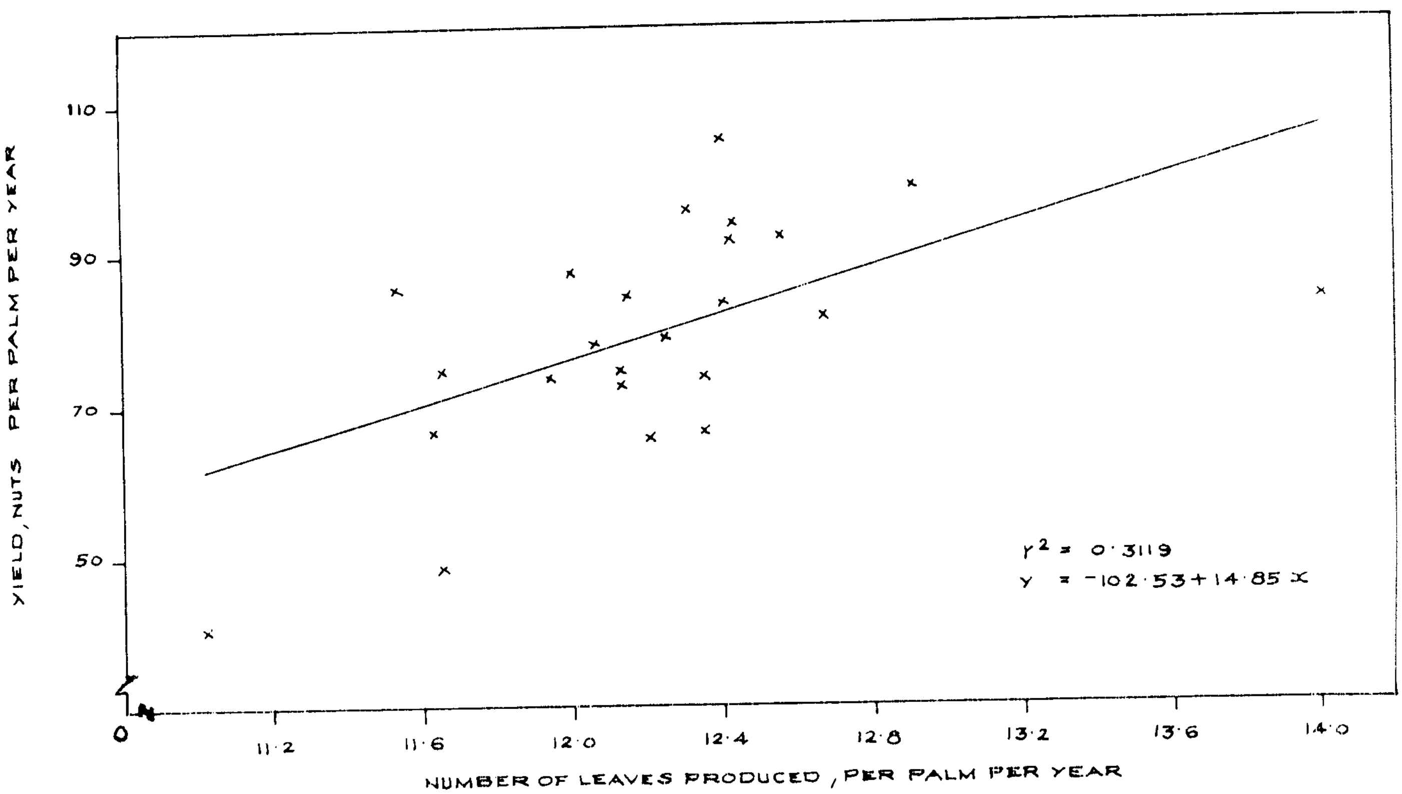


FIG. 4. RELATIONSHIP BETWEEN NUMBER OF LEAVES PRODUCED PER PALM PER-YEAR AND YIELD.



synthesise more dry matter and give increased yield as compared to a palm with less number of leaves retained. Similar observations have been made by Gopi (1981) and Krishnakumar (1983). A palm which produces leaves at a faster rate will normally retain more number of leaves at its crown at any period of time and therefore the relationship between total number of leaves produced and the number of leaves retained by the palm is quite anticipated.

The number of leaves produced per palm per year, recorded for the last eight years (1978-1985), showed a variation from 6 to 17. Statistical analysis of the data using analysis of covariance revealed that the treatments did not differ in their influence on this character (Table 2). The adjusted treatment means for the six treatments varied from 11.94 to 12.59, the maximum being recorded by T_4 (50% substitution of K_2O by Na_2O) and the minimum by T_2 (1000 g K_2O). As in the case of number of leaves retained by the palm, the total number of leaves produced also varied between individual palms markedly, mainly due to the high heterogeneity of the experimental palms. Probably, this high degree of variation within a treatment would have nullified the possible differences in effects of treatments. The number of leaves produced per year was significantly

Table 2 Effect of treatments on the number of leaves produced per palm per year

Treatment No.	R_1	R_2	R_3	R_4	Mean	Adjusted treatment mean
1	11.63 (12.50)	12.43 (13.28)	12.13 (11.50)	12.25 (11.72)	12.11 (12.25)	11.95
2	12.00 (12.78)	12.40 (12.89)	12.15 (11.44)	11.53 (11.33)	12.02 (12.11)	11.94
3	12.31 (13.06)	11.65 (12.06)	11.65 (11.03)	12.35 (11.69)	11.99 (11.96)	12.01
4	11.94 (12.36)	14.00 (12.78)	12.56 (11.86)	12.67 (12.31)	12.79 (12.33)	12.59
5	12.13 (11.89)	12.40 (11.28)	12.35 (11.81)	11.02 (10.06)	11.98 (11.26)	12.43
6	12.42 (12.14)	12.06 (12.31)	12.21 (11.86)	12.91 (11.94)	12.40 (12.06)	12.36
SEM						0.245
CD (0.05)						0.744

The values in parenthesis are pretreatment values
The treatment values are the mean of period 1978-1985 (8 years) and
the pretreatment values are the mean of period 1971-1976 (6 years)

correlated with the number of leaves retained at the crown ($r = 0.7401^{**}$) and yield ($r = 0.5585^{**}$). The relationship between the number of leaves produced per palm per year and yield has been graphically represented in Fig.4. As already explained increased production of leaves results in increase in yield due to higher photosynthetic activity.

The data on the number of female flowers produced per palm per year are presented in Table 3. The number of female flowers produced by individual palms per year ranged from 4 to 749, for the last eight years from 1978 to 1985. As the regression test for analysis of covariance was not significant, only the analysis of variance technique was employed for the statistical treatment of the data. No significant difference between the six fertilizer treatments was seen as the treatments could not influence this character decisively. The mean values of the six treatments varied from 219.95 to 262.65, the maximum being recorded by T_2 (1000 g K_2O) and the minimum by T_3 (25% substitution of K_2O by Na_2O). The number of female flowers produced was found to be significantly correlated with yield ($r = 0.4964^{*}$) and negatively correlated with copra weight per nut ($r = -0.4215^{*}$). The great variability in the number of

Table 3 Effect of treatments on the number of female flowers produced per palm per year

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	211.79	274.00	221.07	240.15	236.75
2	292.90	285.46	241.78	230.46	262.15
3	270.79	229.13	163.86	216.00	219.95
4	225.58	233.88	241.85	232.28	233.40
5	250.69	228.65	225.17	272.96	244.37
6	246.63	230.42	205.58	225.17	226.95
SEM					12.52
CD (0.05)					37.72

The treatment values are the mean of the period 1978–1985 (8 years)

Table 4 Difference between treatment yield and pre-treatment yield of the palms, nuts per palm per year

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	4.99	4.57	23.86	31.68	13.99
2	9.63	18.77	27.54	52.36	27.08
3	11.35	6.05	24.32	31.80	18.38
4	14.32	17.82	39.82	42.26	28.56
5	13.24	38.17	28.28	25.35	26.26
6	7.14	2.96	30.14	43.94	21.05
SEM					4.52
CD (0.05)					13.63

The treatment values are the mean of the period 1978–1985 (8 years) and the pre-treatment values are the mean of period 1971–1976 (6 years) female flowers produced per year between individual palms is attributed to the high degree of heterogeneity of the experimental palms as well as the varying climatic conditions, experienced in different years during the period of experimentation. The relationship between the number of female flowers produced and yield of nuts per palm per year is self explanatory. Increased flower production results in increased yield which will in turn tend to reduce the size of nuts thereby resulting in decreased copra weight per nut. This would explain the negative correlation established between copra weight per nut and the number of female flowers produced.

2. Effect of fertilizer treatments on yield

The data on the effect of fertilizer treatments are presented in Table 4 and Table 5. The yield of nuts of individual palms per year recorded for the last eight years (1978 to 1985) ranged from 1 to 262 nuts. For studying the effect of treatments, the difference between the pretreatment yield and post-treatment yield of the plots was worked out (Table 4). For this purpose, the pretreatment yield was considered as the average yield per palm per year for the period 1971-1976 (6 years) and the post-treatment yield as the average yield of palm per year for the period 1978-1985 (8 years). Observations revealed that the yield of palms increased continuously with the progressing period of time and the maximum increase in yield (28.56 nuts per palm per year) took place in plots receiving treatment No.4 (50% substitution of K_2O by Na_2O). The increasesin mean yield for T_2, T_5, T_6 and T_3 were 27.08, 26.26, 21.05 and 18.38 nuts per palm per year which showed the differences between T_4, T_5 and T_2 were quite marginal. The increase in yield under T_1 was only 13.99 nuts per palm per year. Even though there was 104.15 per cent increase in yield in T_4 as compared to that of T_1, the difference was not found statistically significant, the significance being lost by marginal difference. However, when the data were rearranged, taking post-treatment values as the average yield of palm per year for the last six years (1980-1985) and the pretreatment value as the mean yield of the last four years prior to the application of the treatments (1973-1976) it was seen that the treatments differed significantly when subjected to the analysis of covariance. The adjusted mean values of the six treatments varied from 69.70to 86.84, the maximum being recorded by T_2 (1000 g K_2O) and the minimum by T_1 (control). Treatment T_2

Table 5 Effect of treatments on the yield of palm, nuts per palm per year

Treatment No.	R_1	R_2	R_3	R_4	Mean	Adjusted treatment mean
1	62.94 (66.58)	85.63 (99.67)	73.15 (54.13)	79.77 (54.96)	75.37 (68.84)	69.72
2	86.53 (85.58)	108.56 (90.21)	85.56 (58.38)	87.62 (39.05)	92.07 (68.31)	86.84
3	91.69 (89.54)	74.31 (75.00)	49.09 (27.29)	70.20 (42.86)	71.32 (58.67)	73.82
4	70.92 (63.75)	83.52 (74.54)	94.67 (56.92)	84.09 (44.43)	83.30 (59.91)	84.81
5	74.75 (69.43)	85.59 (47.70)	77.64 (51.33)	43.64 (15.81)	70.41 (46.07)	83.02
6	86.08 (92.42)	73.55 (81.63)	66.29 (41.25)	98.61 (60.54)	81.13 (68.96)	75.38
SEM						5.11
CD (0.05)						15.49

The values in parenthesis are pretreatment values
The treatment values are the mean of period 1980–1985 (6 years)
and the pretreatment values are the mean of period 1973–1976 (4 years)

was closely followed by T_4 and the differences between T_2, T_4, T_5, T_6 and T_3 were not significant.

As in the case of the morphological characters already discussed, the high degree of variation in the yield of individual palms can be attributed to the high genetic variability of the experimental palms and variation in climatic factors during the post-treatment period of eight years. The continuous increase in yield with progressing period of time indicates that the experimental palms have not yet reached their full bearing capacity. However, the increase in yield has been markedly influenced by the application of the treatment, the performance of the palms in treatment receiving full dose of K and 50% K substituted by Na being comparable. The fact that 50 per cent substitution of K by Na did not reduce the yield, is of high practical significance since the cost of NaCl is cheaper as compared to KCl. It is believed that Na may partially substitute the role of K in plants and hence maintain the same level of yield at this rate of substitution. It is also possible that the requirement of K assessed in terms of KCl may be the combined requirement of K and Cl and the requirement of K would have been over estimated to cover the requirement of Cl also. When KCl is substituted by NaCl only K is substituted without affecting the supply of Cl to any significant extent. Since in the present experiment both Na and K are supplied as chlorides it is not possible to partition the effect of Cl from that of K or Na. However, it can be confirmed that the present recommendation of K can be substituted by Na to the extent of 50 per cent without reduction in the amount of Cl supplied. Barrant (1975) observed that Na caused significant increase in yield of Malayan Dwarf coconuts grown in Jamaica and he concluded that coconut palm should be placed in the category of plants which responded to Na when available K is high.

The yield was found significantly correlated with number of female flowers produced ($r = 0.4964^*$), number of functioning leaves retained by the palm ($r = 0.6722^{**}$) and total number of leaves produced per year ($r = 0.5585^{**}$). As already explained, the increased production of leaves results in increased photosynthetic efficiency of the palm resulting in increased yield. The yield was significantly correlated with the Cl content of the leaf ($r = 0.4900^*$). The importance of Cl in nutrition of coconut palm is well established. This also shows that the response of coconut palm to application of KCl or NaCl will definitely also be due to the beneficial effect of Cl. Ollagnier and Ochs (1971) expressed similar views on the effect of KCl or NaCl on coconut palms.

3. Effect of fertiliser treatments on copra weight per nut

The copra weight per nut (Table 6) ranged from 80.25 to 185.75 g per nut. The treatments could not influence this character significantly. The copra weight per nut was significantly correlated with percentage clay content ($r = 0.5614^{**}$), organic carbon in soil ($r = 0.4189^{*}$) and wilting coefficient ($r = 0.5802^{**}$). As the clay percentage and organic matter increase, the wilting coefficient of soil increases and the soil will retain more water at a soil moisture tension of 15 bar. This better moisture conservation of soil may be responsible for the increased copra weight per nut. As already indicated the copra weight per nut was negatively correlated with number of female flowers produced ($r = -0.4215^{*}$).

4. Effect of fertilizer treatments on percentage oil recovery

The data on percentage oil recovery of copra are presented in Table 7. The results indicated that substitution of K by Na has no influence on the recovery of oil. In fact, the maximum oil recovery was recorded in T_4 (50% substitution of K_2O by Na_2O). The mean values for treatments varied from 52.99 to 60.47 per cent.

Table 6 Effect of fertiliser treatments on the copra weight per nut, g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	83.25	140.00	157.50	112.50	123.31
2	99.75	104.50	139.00	93.50	109.19
3	87.75	87.50	178.00	185.75	134.75
4	77.00	148.50	151.50	150.50	131.88
5	109.25	100.50	111.00	105.00	106.44
6	80.25	121.50	145.00	156.50	125.81
SEM					12.74
CD (0.05)					38.41

Table 7 Effect of fertiliser treatments on oil recovery, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	58.40	61.89	59.14	46.43	56.47
2	57.16	53.43	57.94	60.95	57.37
3	55.04	54.01	55.88	47.03	52.99
4	55.43	58.51	59.85	68.08	60.47
5	58.06	58.57	52.66	47.52	54.20
6	72.77	59.88	45.91	55.36	58.48
SEM					3.315
CD (0.05)					9.989

5. Effect of fertiliser treatments on the content of nutrient elements in leaf

5.1 Nitrogen

The data on N per cent in leaf (Table 8) revealed that this nutrient element in leaf varied from 1.444 to 2.269 per cent. The application of fertiliser treatments could not influence the N content of leaf significantly indicating that the uptake and utilisation of N by palm are not determined by the relative proportion of Na and K applied to the soil. The mean values of the treatments varied from 1.672 to 2.111 per cent, the maximum being recorded by T_6 (1000 g Na_2O).

5.2 Phosphorus

The data on the P content in leaf are presented in Table 9. It revealed that this nutrient element in leaf varied from 0.095 to 0.148 per cent. In comparison with N and K the content of P in leaf, in general, was relatively low. The mean content of P in leaf was 0.118 per cent while that of N and K were 1.872 and 0.831 per cent respectively. This indicates the relatively low requirement of P for this crop in comparison with the other two major plant nutrients. Application of fertiliser treatments had no significant influence on the content of P in leaves

Table 8 Effect of fertilizer treatment on content of nitrogen in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.524	1.602	1.482	2.080	1.672
2	2.019	2.053	2.008	1.444	1.881
3	2.060	1.444	1.847	2.102	1.863
4	1.491	1.838	1.473	1.953	1.689
5	1.732	2.218	1.999	2.119	2.017
6	2.186	2.064	1.924	2.269	2.111
SEM					0.129
CD (0.05)					0.388

Table 9 Effect of fertilizer treatments on content of phosphorus in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.096	0.121	0.121	0.095	0.108
2	0.121	0.123	0.121	0.122	0.122
3	0.096	0.122	0.121	0.134	0.118
4	0.097	0.123	0.121	0.135	0.119
5	0.096	0.098	0.120	0.148	0.116
6	0.122	0.124	0.121	0.124	0.123
SEM					0.006
CD (0.05)					0.019

which showed that the uptake of P was not influenced by the relative proportion of Na or K applied to the soil. The maximum content of P (0.123%) was recorded in T_6 (1000 g Na_2O). The content of P in leaf was found correlated with clay per cent (r = 0.5150**) and organic carbon in soil (r = 0.5233**). The inorganic form of P in soil is mainly represented by clay fraction and the organic form of P is embedded in soil organic matter. Relationship between the P content in leaf and the clay as well as soil organic matter is therefore understandable. The P content of leaf was also found correlated with percentage pore space (r = 0.5773**), exchangeable Ca (r = 0.4651*) and exchangeable Mg (r = 0.5109*). This may be attributed to the indirect effect through organic matter and clay in soil.

5.3 Potassium

Table 10 shows the K content in leaf as influenced by the treatments. Statistical analysis of the data revealed that K content in leaf was significantly influenced by the application of treatments. The values corresponding to T_2, T_3, T_4, T_5 and T_6 were 1.116, 0.944, 0.865, 0.843 and 0.604 per cent respectively. This gradation of K content in leaf clearly reflects the influence of the treatments. The treatments T_2, T_3, T_4, T_5 and T_6 received 100, 75, 50, 25 and 0 per cent of the recommended dose of K_2O. A corresponding decline in the K content of leaf was registered. The treatments T_2 and T_3 retained significantly higher amount of K as compared to T_1 and T_6. However T_2, T_3, T_4 and T_5 were statistically on par. The treatment T_1 received no application of K or Na while treatment T_6 received 100 per cent Na_2O in the complete absence of K_2O. While the K content in leaf of palms in T_6 was 0.604 per cent, that of T_1 was 0.616 per cent. This marginal increase in the content of K in T_1 over T_6 can be attributed to the antagonism between K and Na. In the presence of a high level of Na the absorption of K from soil would have been affected marginally. However, T_1 and T_6 were statistically on par. The antagonism between Na and K is also evident from the significant negative correlation between K and Na content of leaf ($r = -0.5914^{**}$). This has been graphically illustrated in Fig.5. The K content of leaf was also negatively correlated with Na content of coconut water ($r = -0.5670^{**}$) and Na content of copra ($r = -0.4679^{*}$). Antagonism between Na and K in coconut palm has also been reported by Barrant (1975). However, in the present study, the negative correlations between levels of K and Na in soil or leaf is partly due to the effect of treatments since in treatments except T_1 (control) the rate of application

FIG. 5. RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND SODIUM CONTENT OF LEAF.

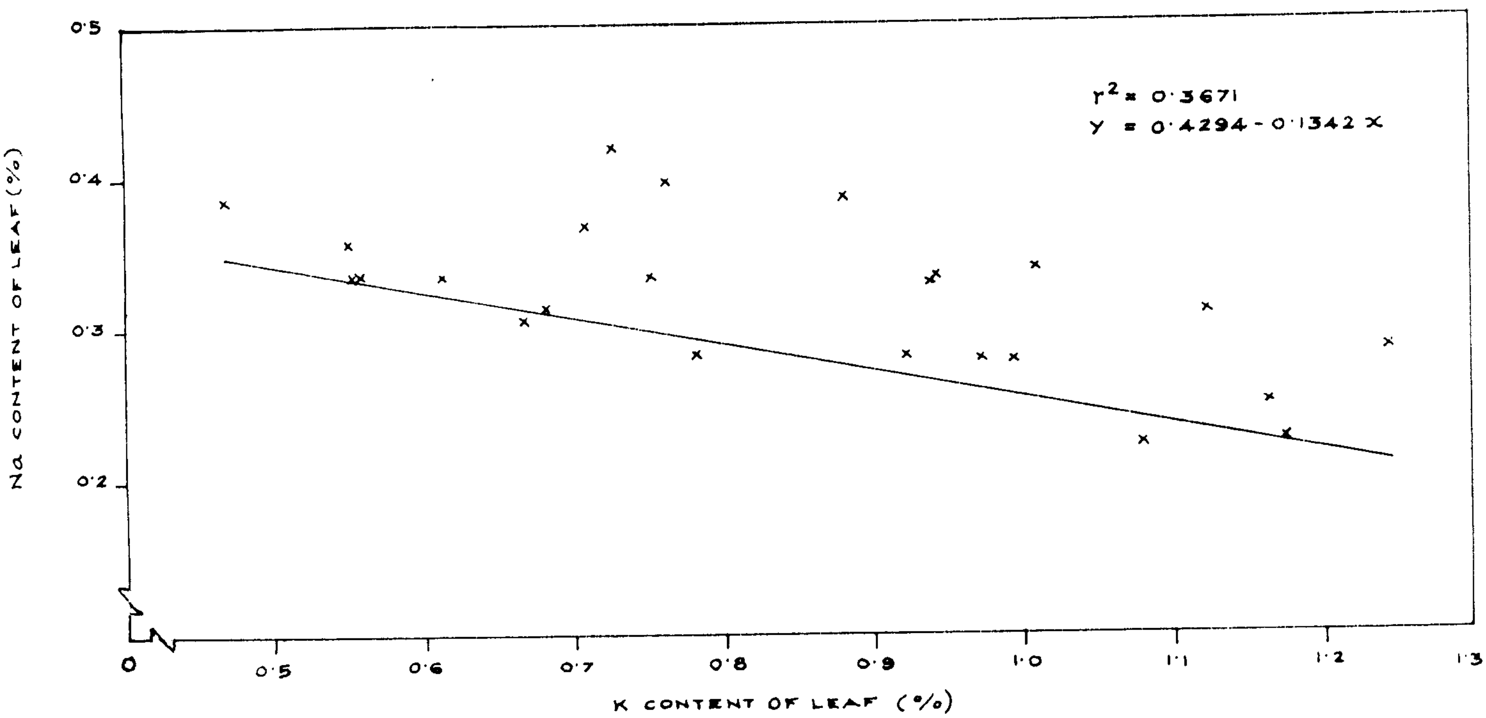


FIG. 6. RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND SODIUM CONTENT OF COCONUT WATER.

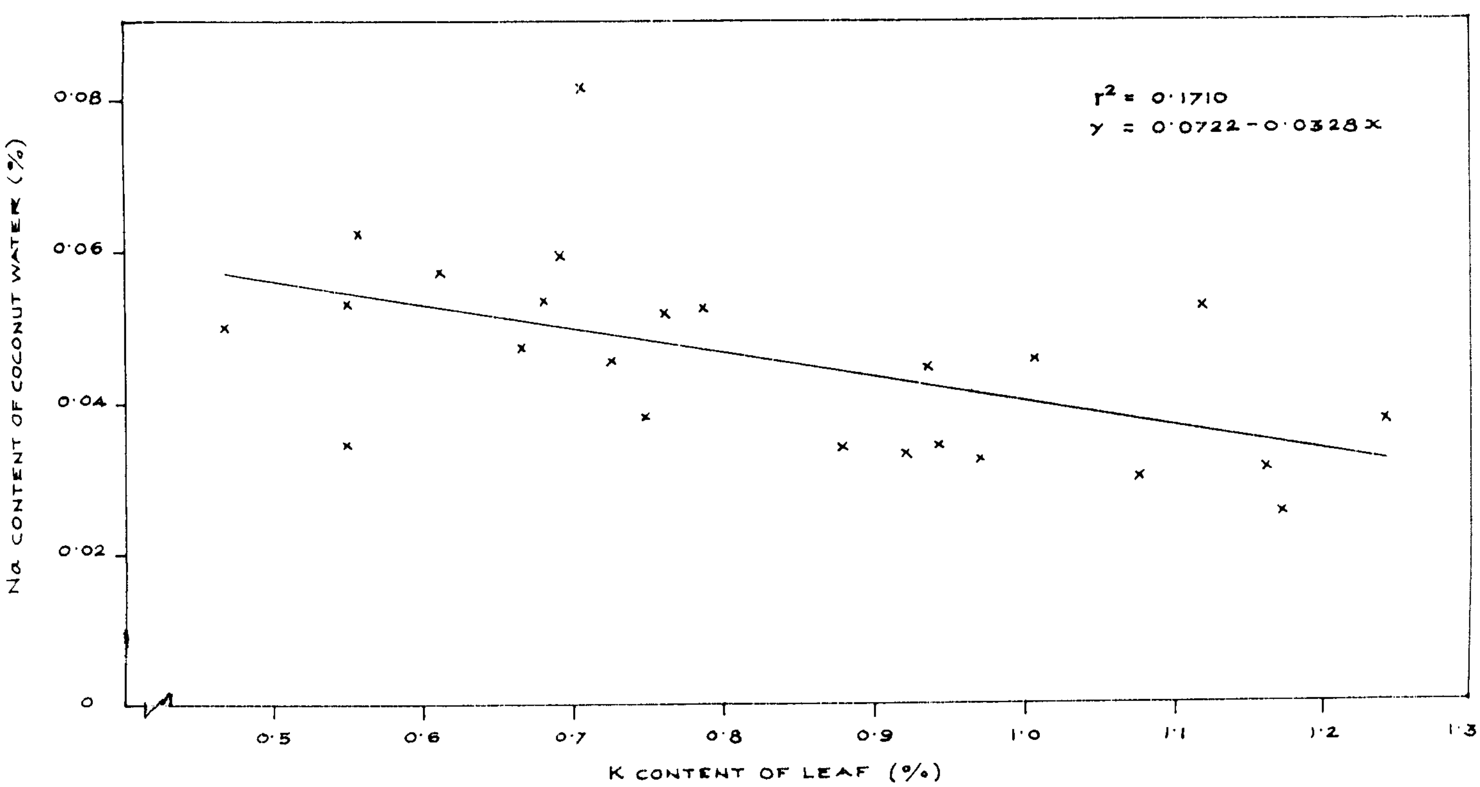


Table 10 Effect of fertilizer treatments on content of potassium in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.555	0.692	0.666	0.550	0.616
2	0.972	1.242	1.077	1.173	1.116
3	0.944	0.922	1.162	0.750	0.944
4	0.726	0.788	0.937	1.008	0.865
5	0.611	0.761	0.880	1.120	0.843
6	0.559	0.681	0.469	0.708	0.604
SEM					0.068
CD (0.05)					0.206

Table 11 Effect of fertilizer treatments on content of sodium in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.333	0.277	0.305	0.357	0.318
2	0.278	0.282	0.221	0.224	0.251
3	0.333	0.279	0.249	0.333	0.299
4	0.419	0.282	0.331	0.336	0.342
5	0.333	0.395	0.385	0.308	0.355
6	0.335	0.312	0.386	0.368	0.350
SEM					0.021
CD (0.05)					0.063

of K_2O increases while that of Na_2O decreases or the vice versa. Fig.6 represents the relationship between K content of leaf and Na content of coconut water.

As expected, uptake of K was found positively correlated with exchangeable K in soil ($r = 0.8220^{**}$). This relationship has been graphically represented in Fig.7. A significant positive correlation was also seen between K content in leaf and available water in soil, probably the uptake of this nutrient would have been significantly influenced by soil moisture. Potassium content of leaf was also found correlated with P content of leaf ($r = 0.4226^{*}$). The increased uptake and utilisation of K would have resulted in efficient uptake and utilisation of P by the palms.

5.4 Sodium

The data on the Na per cent in leaf are presented in Table 11. The values ranged from 0.221 to 0.419 per cent. The influence of fertilizer treatments on the content of Na in leaf was found to be significant. In general, palms receiving higher levels of Na retained relatively higher amount of Na in their leaves. However T_6, T_5, T_4 and T_3 were statistically on par. The treatment T_2 which received no application of Na recorded significantly less amount of

FIG. 7. RELATIONSHIP BETWEEN EXCHANGEABLE POTASSIUM IN SOIL AND POTASSIUM CONTENT OF LEAF

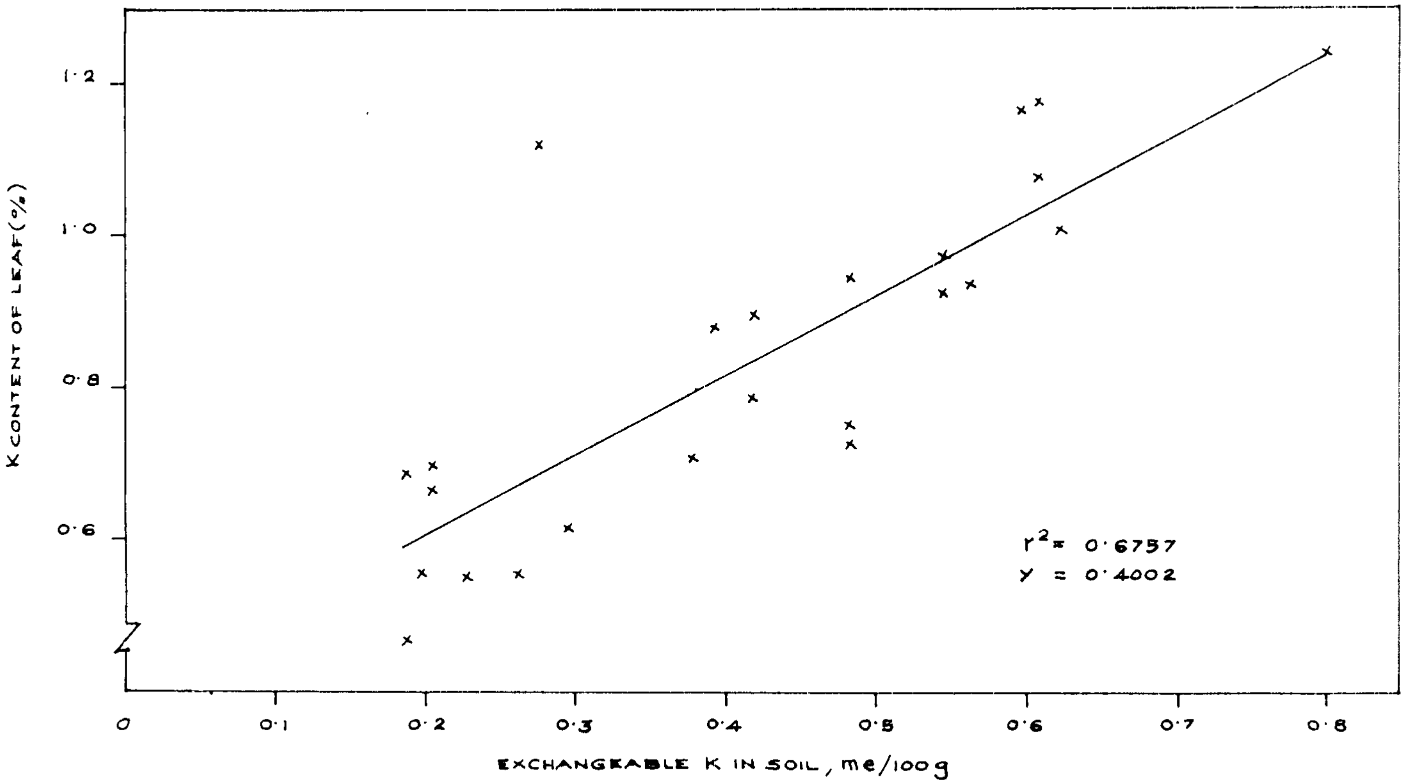
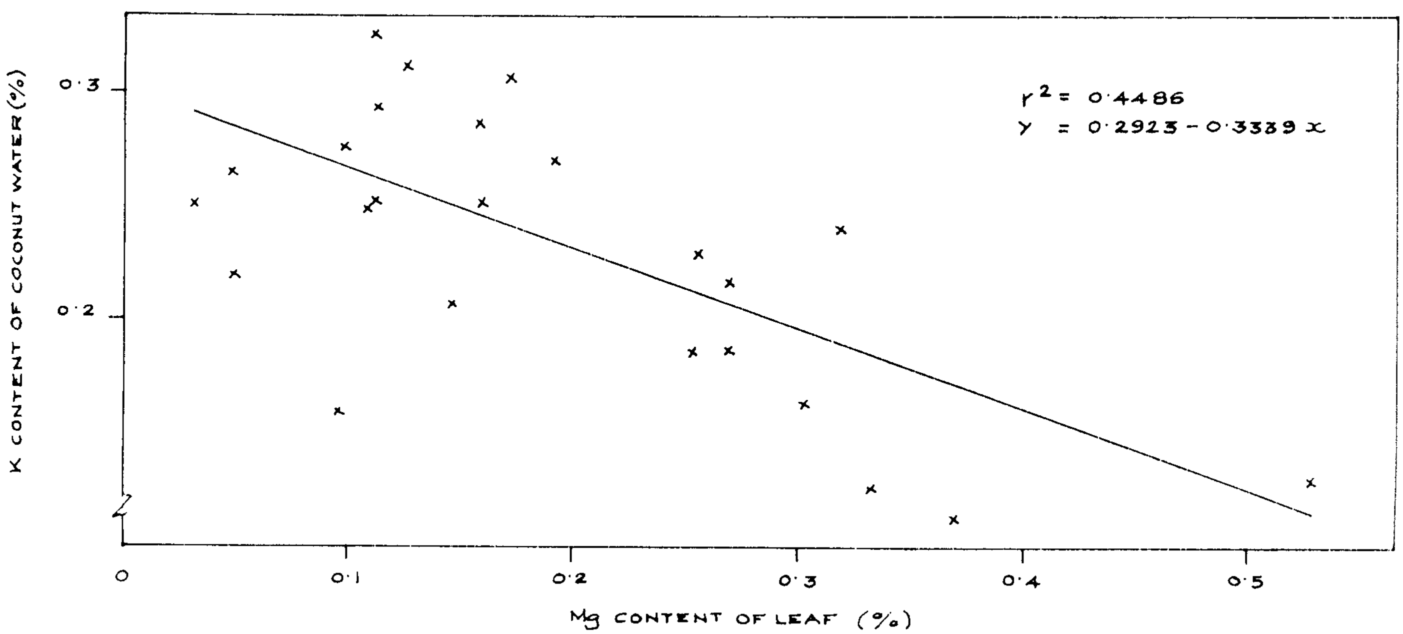


FIG. 8. RELATIONSHIP BETWEEN MAGNESIUM CONTENT OF LEAF AND POTASSIUM CONTENT OF COCONUT WATER.



Na in leaf as compared to other treatments. However, palms of treatment T_1 (control) contained relatively higher amount of Na as compared to T_2. This can be attributed to the antagonism between Na and K. Application of K in the absence of Na would have been adversely affected the uptake of Na from the soil in T_2 while such an antagonistic effect of K is not encountered in T_1 (control). The Na content of leaf was significantly correlated with Na content of coconut water ($r = 0.4135^*$) and Na content of copra ($r = 0.4212^*$). The increased uptake of elements by the palm would have resulted in accumulation of these elements in leaf, coconut water and copra. The Na content in leaf was negatively correlated with K content in leaf ($r = -0.5914^{**}$) and available K in soil ($r = -0.4230^*$). The antagonism between Na and K has already been discussed. In the presence of larger amounts of K in soil, the retention of Na in exchangeable sites of the soil and its absorption by the plant are correspondingly decreased. The possible influence of treatments in attaining negative correlations between Na and K levels in leaf or soil has already been pointed out.

5.5 Calcium

Data presented in Table 12 show that the content of Ca in leaf vary from 0.498 to 1.012 per cent. The

Table 12 Effect of fertilizer treatments on the content of calcium in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.629	0.627	0.838	1.012	0.777
2	0.708	0.720	0.834	0.791	0.763
3	0.498	0.501	0.966	0.996	0.740
4	0.606	0.532	0.937	0.793	0.717
5	0.682	0.719	0.856	0.872	0.782
6	0.554	0.884	0.937	0.909	0.821
SEM					0.053
CD (0.05)					1.593

Table 13 Effect of fertilizer treatments on the content of magnesium in leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.346	0.267	0.157	0.047	0.204
2	0.252	0.256	0.110	0.048	0.166
3	0.094	0.190	0.172	0.110	0.142
4	0.527	0.319	0.125	0.111	0.271
5	0.268	0.096	0.031	0.159	0.138
6	0.301	0.145	0.109	0.369	0.231
SEM					0.052
CD (0.05)					0.157

fertiliser treatments could not affect the Ca content of leaf significantly. The Ca content of leaf was negatively correlated with Mg content of leaf (r = -0.4809*). The antagonism between these two divalent cations is reflected in the negative correlation established between the content of these elements in leaves.

5.6 Magnesium

Data presented in Table 13 show that Mg per cent in leaf ranged from 0.031 to 0.527. However, there was no significant difference in the content of this nutrient in leaf when the values were compared treatment-wise. The mean values for the treatment ranged from 0.138 to 0.231 per cent, the maximum being recorded by T_6 (1000 g Na_2O). This shows that application of Na in place of K has no antagonistic effect on the uptake of Mg by the palms. Magnesium level in leaf was found to be negatively correlated with the Ca content of leaf (r = -0.4809*). This antagonism between Ca and Mg has already been discussed.

5.7 Chlorine

Data on the Cl content of leaf was presented in Table 14. The values ranged from 0.685 to 0.931 per cent. The treatments did not differ in the content of this

Table 14 Effect of fertilizer treatments on chlorine content of leaf, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.718	0.810	0.708	0.767	0.751
2	0.728	0.855	0.742	0.875	0.800
3	0.737	0.741	0.819	0.794	0.773
4	0.931	0.814	0.741	0.781	0.817
5	0.860	0.787	0.697	0.724	0.767
6	0.685	0.850	0.732	0.858	0.781
SEM					0.034
CD (0.05)					0.103

Table 15 Effect of fertilizer treatments on soluble potassium content of coconut water, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.125	0.184	0.284	0.218	0.203
2	0.183	0.228	0.250	0.263	0.231
3	0.159	0.269	0.304	0.324	0.264
4	0.128	0.239	0.311	0.291	0.242
5	0.216	0.273	0.250	0.250	0.247
6	0.160	0.206	0.248	0.113	0.182
SEM					0.020
CD (0.05)					0.061

element retained by the palm probably due to the fact that the amount of Cl applied to the palm remained almost the same under all the treatments irrespective of the proportion of K_2O and Na_2O except T_1 (control). The treatment values ranged from 0.751 to 0.817 per cent and as expected the minimum was recorded by T_1 (control). The Cl content of leaf was significantly correlated with yield ($r = 0.4900^*$). This indicates the decisive role of Cl in the nutrition of coconut palms. The importance of Cl in coconut nutrition has also been stressed by Ollagnier and Ochs (1971) who attributed the effect of KCl or NaCl to Cl rather than K or Na.

6. Effect of fertiliser treatments on soluble K and Na content of coconut water

6.1 Potassium

The soluble K content of coconut water ranged from 0.113 to 0.324 per cent (Table 15). Statistical treatment of the data revealed that the treatment could not decisively influence the soluble K content of coconut water. The fact that the K content of coconut water did not vary with the levels of K supplied to the palm while the leaf content of K varied significantly, indicates that coconut water is not suitable for finding out the K level of the palm. The K content of coconut water was correlated with copra weight per nut (0.5388**). This would show the role of K in the proper development of the nuts. The K content of coconut water was found to be negatively correlated with the Mg content of leaf (-0.6698**) which can be attributed to the low uptake of Mg at higher levels of K application. Tisdale and Nelson (1975) discussed the mechanism of low Mg uptake by plants at higher levels of K application. Fig.8 illustrates the relationship between Mg content of leaf and K content of coconut water.

6.2 Sodium

Sodium content of coconut water ranged from 0.025 to 0.081 per cent (Table 16). Statistical analysis of the data employing the analysis of variance technique showed that the treatment influenced this character significantly. The level of Na in coconut water increased with the increasing application of NaCl and the mean values for T_6, T_5, T_4, T_3 and T_2 were 0.062, 0.048, 0.047, 0.034 and 0.031 per cent respectively. The treatment T_6 differed significantly from T_3 and T_2. However, the treatments T_6, T_5 and T_4 were statistically on par. It is

Table 16 Effect of fertilizer treatments on soluble sodium content of coconut water, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.053	0.059	0.047	0.034	0.048
2	0.032	0.039	0.030	0.025	0.031
3	0.034	0.033	0.031	0.038	0.034
4	0.045	0.052	0.044	0.045	0.047
5	0.057	0.051	0.034	0.052	0.048
6	0.962	0.053	0.050	0.081	0.062
SEM					0.004
CD (0.05)					0.013

Table 17 Effect of fertilizer treatments on nitrogen content in copra, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.820	1.495	1.569	1.407	1.573
2	1.869	1.349	1.611	1.634	1.616
3	1.387	1.608	1.507	1.102	1.401
4	1.303	1.296	1.514	1.659	1.443
5	1.543	1.482	1.414	1.537	1.494
6	1.621	1.393	1.436	1.359	1.452
SEM					0.085
CD (0.05)					0.255

interesting to note that the Na content of coconut water in T_1 (control) was relatively higher (0.048 per cent) as compared to that of T_2. This can be attributed to the antagonism between Na and K. In T_2, the high level of K employed would have considerably reduced the uptake of Na while such an antagonism cannot be anticipated in T_1, thereby registering a relatively higher value for Na. As expected, the Na content of coconut water was significantly correlated with the Na content of leaf (r = 0.4135*), Na content of copra (r = 0.6985**) and available Na in soil (r = 0.5022*). The antagonism between Na and K is further evidenced by the negative significant correlation of Na content of coconut water with K content of leaf (r =-0.5670**), available K in soil (r = -0.6244**) and exchangeable K in soil (r = -0.5788**). The relationship between available K in soil and Na content of coconut water has been graphically represented in Fig.9. Similarly Fig.10 shows the relationship of exchangeable K in soil and Na content of coconut water.

7. Effect of fertiliser treatment on the nutrient content of copra

7.1 Nitrogen

The data on N percentage in copra are presented in Table 17. It ranged from 1.296 to 1.869 per cent. However,

FIG. 9. RELATIONSHIP BETWEEN AVAILABLE POTASSIUM IN SOIL AND SODIUM CONTENT OF COCONUT WATER.

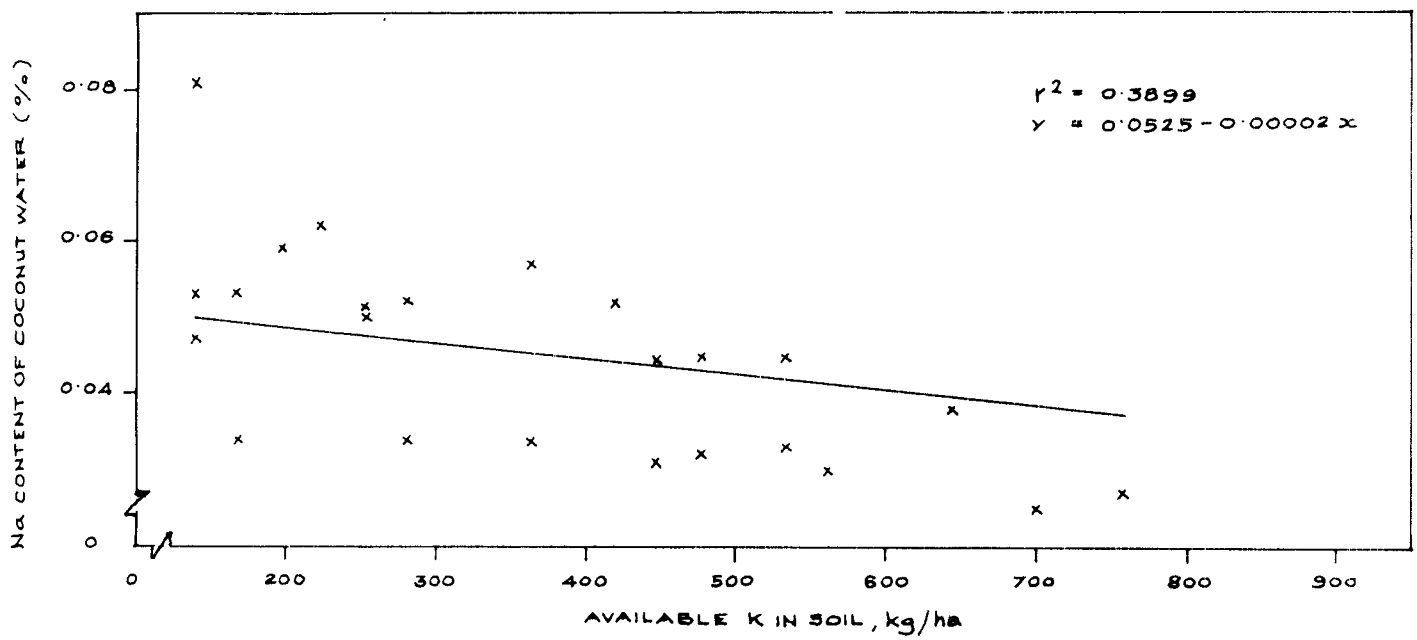
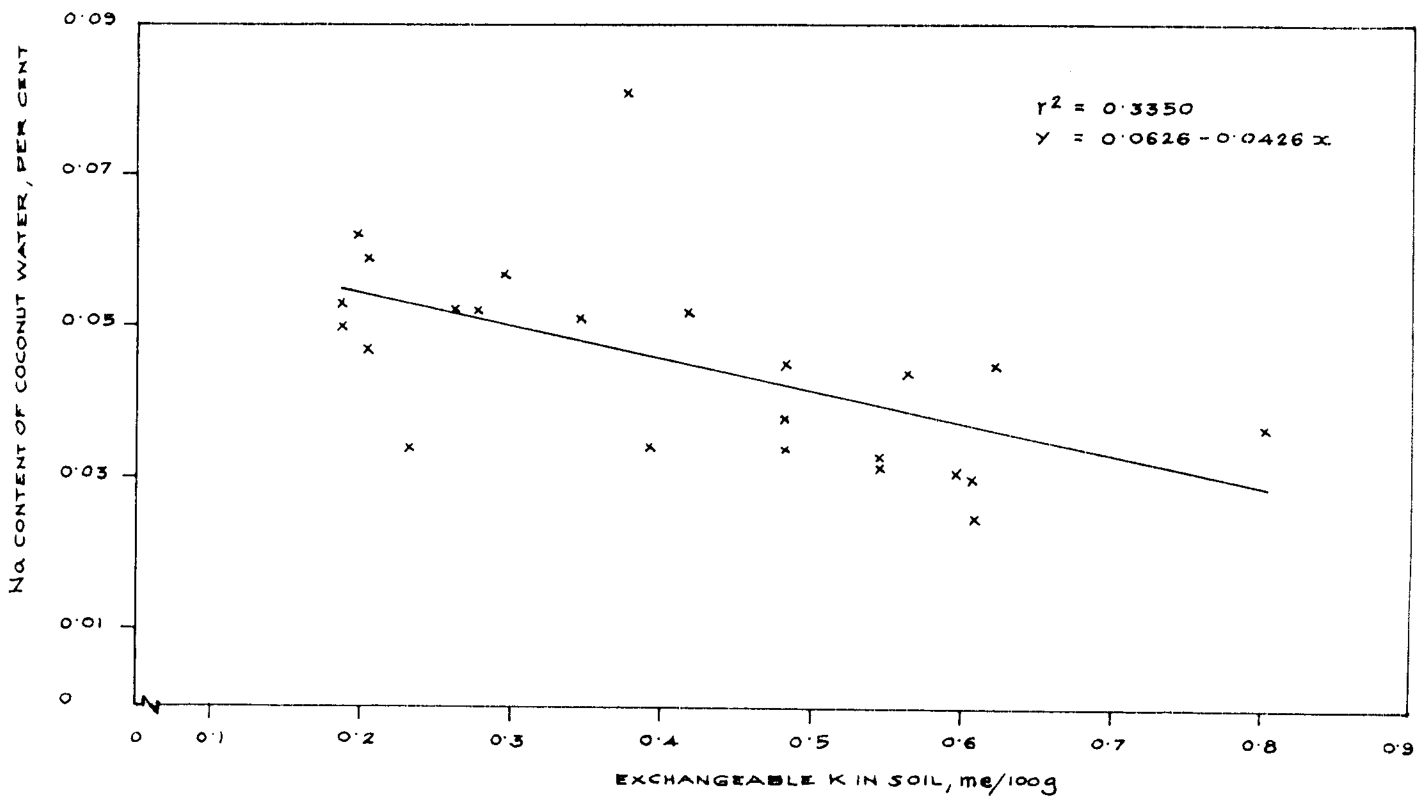


FIG. 10. RELATIONSHIP BETWEEN EXCHANGEABLE POTASSIUM IN SOIL AND SODIUM-CONTENT OF COCONUT WATER.



the treatment means did not differ significantly. The overall mean value for N per cent in copra (1.497) was slightly lower than the overall mean value for N per cent in leaf (1.872).

7.2 Phosphorus

Data on the P content of copra are presented in Table 18. The values ranged from 0.167 to 0.258 per cent. Statistical analysis of the data showed that as in the case of N, the P content of copra was not influenced by the application of different levels of Na or K.

7.3 Potassium

Data on the content of K in copra are given in Table 19. The values ranged from 0.521 to 1.120 per cent. The treatment mean values varied from 0.606 to 0.776 per cent and the variations between the treatment means were not statistically significant. Though different levels of K supplied could induce significant variation in the level of this nutrient in leaf, such a marked variation was not seen reflected in the K content of copra.

7.4 Sodium

Table 20 furnishes the Na content of copra as influenced by the treatments. The values ranged from

Table 18 Effect of fertilizer treatments on phosphorus content in copra, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.232	0.214	0.243	0.207	0.224
2	0.219	0.177	0.237	0.210	0.211
3	0.204	0.202	0.167	0.189	0.190
4	0.195	0.209	0.210	0.208	0.205
5	0.190	0.205	0.231	0.258	0.221
6	0.209	0.219	0.211	0.235	0.219
SEM					0.010
CD (0.05)					0.030

Table 19 Effect of fertilizer treatments on potassium content in copra, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.686	0.663	0.945	0.808	0.776
2	0.579	0.661	0.587	0.595	0.606
3	0.522	0.625	0.845	0.655	0.662
4	0.875	0.618	0.820	0.757	0.768
5	0.521	0.692	0.626	1.120	0.740
6	0.534	0.580	0.939	0.637	0.673
SEM					0.073
CD (0.05)					0.219

0.008 to 0.056 per cent. A comparison of the treatment mean values revealed that the application of treatments significantly influenced the Na content of copra. Increasing rate of application of Na resulted in a corresponding increase in the Na content of copra. Thus the mean values were 0.041, 0.027, 0.024, 0.019 and 0.018 per cent respectively for T_6, T_5, T_4, T_3 and T_2. The treatment T_6 significantly differed from all other treatments. However, T_5, T_4, T_3 and T_2 were statistically on par. As expected, the level of Na in copra was significantly correlated with Na content of leaf ($r = 0.4212^*$) and Na content of coconut water ($r = 0.6985^{**}$). The antagonism between Na and K was again expressed in the negative correlation of Na content of copra with K content of leaf ($r = -0.4679^*$), available K in soil ($r = -0.5159^{**}$) and exchangeable K in soil ($r = -0.4162^*$).

7.5 Calcium

Data on the Ca content of copra are presented in Table 21. The values ranged from 0.077 to 0.155 per cent. Comparison of the treatment means showed that they did not differ significantly. This indicates that the uptake and utilisation of Ca are not influenced by the levels of Na or K applied.

7.6 Magnesium

As in the case of Ca, the Mg content of copra was not found influenced by the application of treatments (Table 22). The mean values of the treatments ranged from 0.054 to 0.074 per cent. A significant negative correlation was seen between the Mg and Ca content of copra (r = -0.6354*) probably due to the negative interaction between these two elements. This relationship has been graphically represented in Fig.11.

7.7 Chlorine

Data on the Cl content of copra presented in Table 23 showed that the values ranged from 0.140 to 0.252 per cent. However, the treatment mean values did not differ significantly. This is because, all the treatments supplied contained almost the same quantity of Cl irrespective of their proportion of Na and K.

8. Effect of fertiliser treatments on the quality of coconut oil

8.1 Specific gravity of oil

The data on the specific gravity of the oil are given in Table 24. The values ranged from 0.9008 to 0.9248.

FIG. 11. RELATIONSHIP BETWEEN CALCIUM CONTENT OF COPRA AND MAGNESIUM CONTENT OF COPRA.

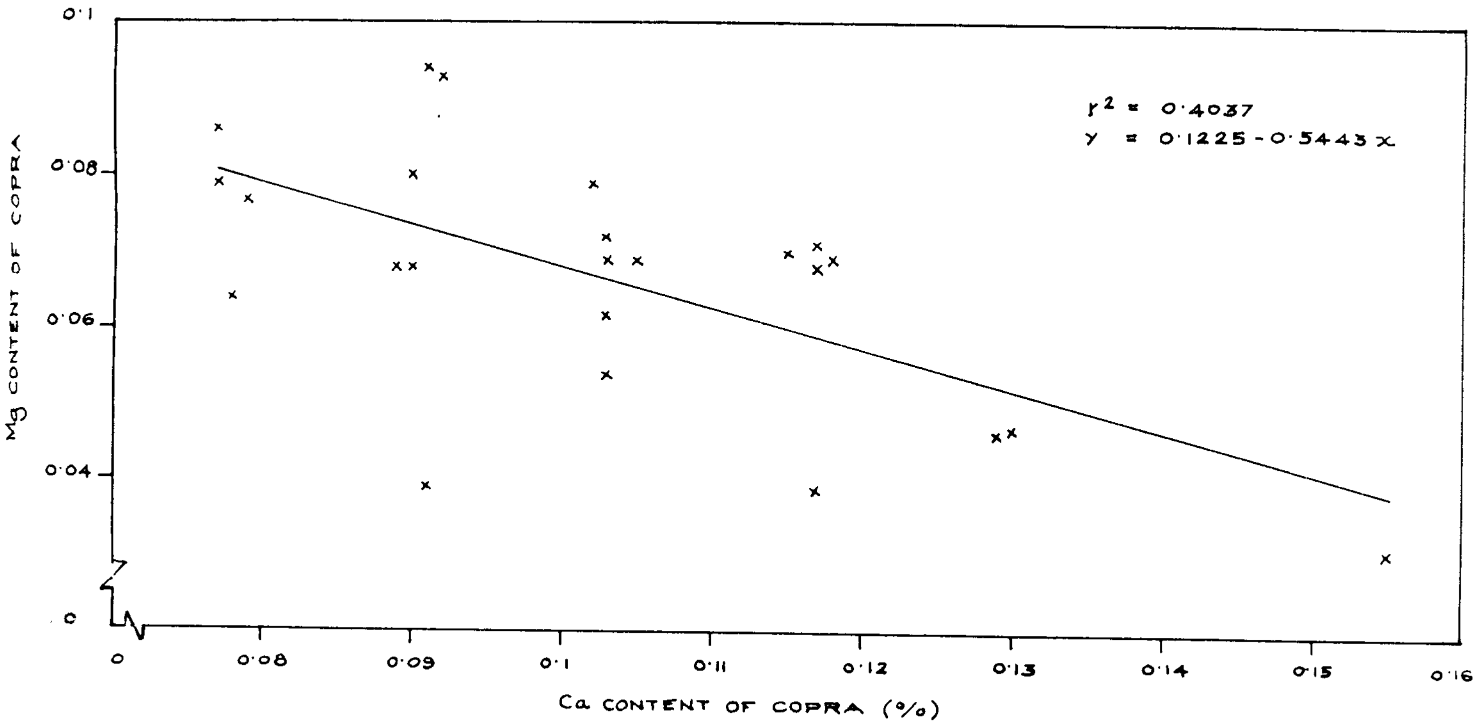


FIG. 12 RELATIONSHIP BETWEEN MAXIMUM WATER HOLDING CAPACITY AND PER CENT-CLAY.

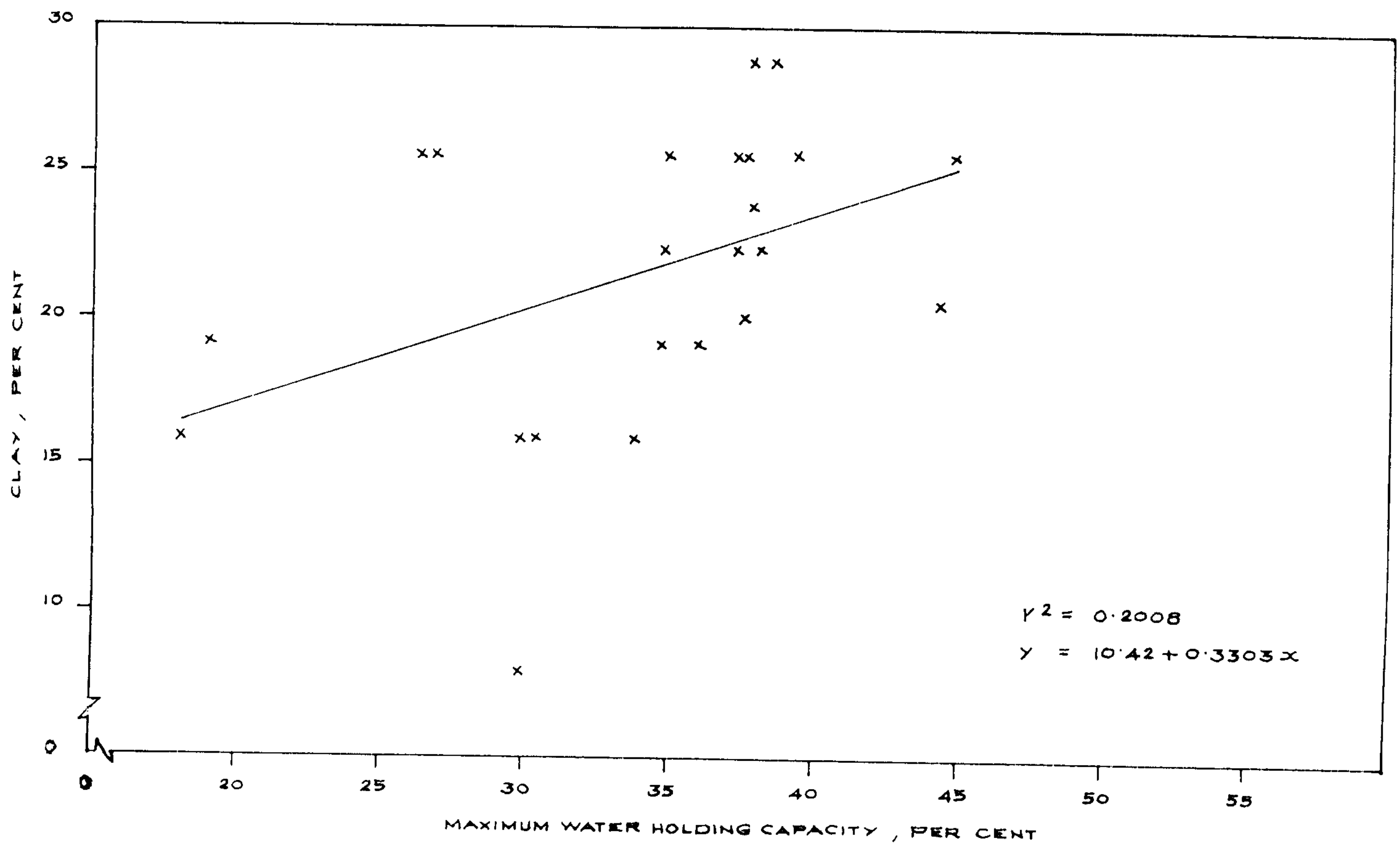


Table 22 Influence of fertilizer treatments on magnesium content in copra, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.031	0.080	0.072	0.070	0.063
2	0.046	0.069	0.062	0.039	0.054
3	0.054	0.068	0.086	0.068	0.069
4	0.071	0.094	0.079	0.039	0.071
5	0.069	0.093	0.068	0.064	0.074
6	0.047	0.077	0.079	0.069	0.068
SEM					0.006
CD (0.05)					0.019

Table 23 Influence of fertilizer treatments on chlorine content in copra, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.140	0.162	0.195	0.176	0.168
2	0.164	0.169	0.152	0.188	0.168
3	0.192	0.185	0.240	0.237	0.214
4	0.221	0.187	0.241	0.201	0.213
5	0.159	0.146	0.213	0.239	0.189
6	0.148	0.141	0.252	0.151	0.173
SEM					0.013
CD (0.05)					0.040

Table 24 Specific gravity of the content oil as influenced by fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.9008	0.9061	0.9117	0.9178	0.9090
2	0.9087	0.9157	0.9191	0.9143	0.9140
3	0.9139	0.9126	0.9078	0.9178	0.9130
4	0.9100	0.9117	0.9061	0.9196	0.9120
5	0.9057	0.9157	0.9130	0.9152	0.9120
6	0.9130	0.9126	0.9248	0.9243	0.9190
SEM					0.0022
CD (0.05)					0.0065

Table 25 Refractive index of the content oil as influenced by fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.449	1.449	1.449	1.449	1.449
2	1.450	1.450	1.449	1.450	1.450
3	1.450	1.450	1.449	1.449	1.449
4	1.450	1.449	1.450	1.449	1.449
5	1.450	1.449	1.449	1.450	1.449
6	1.449	1.450	1.450	1.450	1.450
SEM					0.1021
CD (0.05)					0.3078

A comparison of the treatment mean values indicated that the application of fertiliser treatments has no significant influence on the specific gravity of oil.

8.2 Refractive index

The refractive index of oil (Table 25) ranged from 1.449 to 1.450. The range of variation was well within the limits prescribed for coconut oil by the American Oil Chemists' Society (1962) and Eckey (1954).
The application of treatment could not influence the refractive index of the oil significantly.

8.3 Iodine number

The data on the iodine number of coconut oil are presented in Table 26. In general, values ranged from 6.518 to 8.965. Results indicated that differences between treatment mean values were not statistically significant. Thus the substitution of KCl by NaCl has no influence on this quality parameter of oil.

8.4 Saponification value

Table 27 presents the data on the saponification value of coconut oil. The values ranged from 256.01 to 274.17. As per the specification given by the British

Table 26 Iodine number of the coconut oil as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	7.973	7.808	7.580	7.805	7.792
2	7.623	7.849	7.655	7.564	7.673
3	8.276	8.429	7.401	7.464	7.893
4	7.361	7.137	7.892	6.518	7.227
5	8.786	7.322	8.325	8.686	8.280
6	8.093	7.333	8.965	7.521	7.978
SEM					0.260
CD (0.05)					0.783

Table 27 Saponification value of the coconut oil as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	263.80	271.56	266.04	268.70	267.53
2	265.42	266.70	256.01	267.37	263.88
3	271.19	270.73	272.62	274.09	272.16
4	269.65	259.08	270.37	274.17	268.32
5	269.65	258.40	266.96	272.51	266.88
6	261.33	266.18	272.30	266.31	266.53
SEM					2.379
CD (0.05)					7.169

Standard Institution (1950), the saponification value of coconut oil should be more than 225 while the American Oil Chemists' Society (1962) and the Indian Central Coconut Committee (1959) insisted a value not less than 250. The variation in the saponification value in this study is therefore within the prescribed limits. However, the variation was not found influenced by the application of the treatments. The results thus reveal that the quality of the oil is not affected by the substitution of KCl by NaCl to various extent.

9. Effect of fertiliser treatments on the physicochemical characteristics of the soil

9.1 Soil pH

The pH of the soil of the treatment plots ranged from 4.9 to 5.6 (Table 28). But when the treatment mean values were compared the variation in pH was rather negligible. The mean values of treatments ranged from 5.14 to 5.40. This indicates that substitution of KCl by NaCl in different treatments has no significant influence on the pH of the soil.

9.2 EC

The values of EC of the experimental plots are presented in Table 29 which showed a variation from

Table 28 Soil pH as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	5.35	5.10	5.20	4.90	5.14
2	5.55	5.00	5.10	5.50	5.29
3	4.90	5.65	4.95	5.50	5.25
4	5.45	5.10	5.50	5.50	5.39
5	5.50	5.55	5.00	5.50	5.39
6	5.50	5.60	4.90	5.60	5.40
SEM					0.135
CD (0.05)					0.406

Table 29 EC of soil as influenced by the fertilizer treatments, mmho/cm

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.170	0.080	0.095	0.115	0.115
2	0.094	0.110	0.105	0.155	0.116
3	0.080	0.100	0.120	0.125	0.106
4	0.084	0.091	0.115	0.105	0.099
5	0.170	0.091	0.087	0.155	0.126
6	0.090	0.079	0.145	0.140	0.114
SEM					0.0145
CD (0.05)					0.0437

0.080 to 0.155 mmho/cm. The EC of the soil was found unaffected by the application of fertiliser treatments. It is apparent that the amount of NaCl or KCl applied to the acid laterite soil of the experimental site is quite insufficient to cause any build up of salinity in this soil which is subjected to an annual rainfall of about 3200 mm.

9.3 Physical constants

9.3.1 Apparent density

The apparent density of the soil (Table 30) was not found influenced by the application of treatments. The values ranged from 1.152 to 1.419 per cent. Evidently the apparent density of soil was significantly correlated with absolute specific gravity of soil (r = 0.5503**). A low apparent density is usually associated with a relatively higher content of organic matter and clay. These relationships were reflected in the significant negative correlation of the apparent density with field capacity of soil (r = -0.4042*), wilting coefficient (r = -0.4632*), percentage clay in soil (r = -0.4859*), the maximum water holding capacity (r = -0.6593**), mean weight diameter (r = -0.4944*) and percentage pore space (r = -0.4872*) observed in this study.

Table 30 Effect of fertilizer treatments on the apparent density of soil, g/cm3

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.355	1.285	1.282	1.186	1.277
2	1.410	1.347	1.419	1.152	1.332
3	1.319	1.299	1.275	1.263	1.289
4	1.340	1.336	1.278	1.347	1.325
5	1.366	1.321	1.335	1.368	1.348
6	1.395	1.267	1.243	1.305	1.302
SEM					0.030
CD (0.05)					0.090

Table 31 Absolute specific gravity of soil as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	2.214	2.243	2.431	1.869	2.189
2	2.797	2.210	2.548	1.997	2.388
3	2.222	1.711	2.349	2.048	2.083
4	2.257	2.160	2.215	2.080	2.178
5	2.115	2.258	2.317	2.159	2.212
6	2.212	2.148	2.062	1.943	2.091
SEM					0.0882
CD (0.05)					0.2659

9.3.2 Absolute specific gravity

The values of absolute specific gravity presented in Table 31 ranged from 1.711 to 2.797. Comparison of the treatment mean values showed that the absolute specific gravity of soil was not affected by the fertilizer treatment. As already indicated, absolute specific gravity significantly correlated with apparent density ($r = 0.5503^{**}$). It was found negatively correlated with wilting coefficient ($r = -0.4305^{*}$).

9.3.3 Percentage pore space

The percentage pore space of the soil varied from 33.32 to 50.94 (Table 32). Though the mean values of the treatments varied significantly, this variation was not in order of increasing or decreasing rate of substitution of KCl by NaCl. The percentage pore space was significantly correlated with field capacity ($r = 0.5773^{**}$), wilting coefficient ($r = 0.5984^{**}$), maximum water holding capacity ($r = 0.5910^{**}$) and mean weight diameter ($r = 0.5950^{**}$). These relationships are quite understandable since the parameters involved are interrelated. A negative significant correlation was recorded between percentage pore space and apparent density ($r = -0.4872^{*}$). It is known that an

Table 32 Effect of fertilizer treatments on the pore space of soil, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	36.49	42.23	43.95	47.79	42.62
2	35.40	42.61	46.85	50.94	43.95
3	33.32	39.96	44.23	46.46	40.99
4	33.37	40.67	40.99	48.08	40.78
5	34.04	43.95	44.42	47.84	42.56
6	40.32	47.29	47.22	47.78	45.65
SEM					0.8068
CD (0.05)					2.4315

Table 33 Percentage volume expansion of soil as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	3.48	3.09	4.42	2.30	3.32
2	3.56	3.51	2.32	5.42	3.70
3	3.24	3.43	5.65	8.19	5.13
4	4.35	5.77	4.67	4.39	4.79
5	5.78	3.48	3.65	5.85	4.69
6	8.20	3.05	5.19	6.84	5.82
SEM					0.758
CD (0.05)					2.280

increase in the percentage pore space will naturally be associated with a decrease in apparent density of soil.

9.3.4 Percentage volume expansion

The data on the percentage volume expansion of soil are given in Table 33. The results showed that the percentage volume expansion ranged from 2.3 to 8.2. However, treatments did not differ significantly in their influence on this physical constant.

9.3.5 Maximum water holding capacity

Maximum water holding capacity of soil ranged from 18.21 to 44.92 per cent (Table 34). As in the case of other physical constants, the maximum water holding capacity was significantly correlated with clay per cent ($r = 0.4481^{*}$) and per cent pore space ($r = 0.5910^{**}$) since these factors possess a direct influence on the water holding capacity of soil. Fig.12 represents the relationship between maximum water holding capacity of soil and clay percentage in soil. Again, the water holding capacity was negatively correlated with the apparent density ($r = -0.6593^{**}$) of the soil. A decrease in the apparent density is obviously due to the increased pore space and relatively larger amounts of clay and organic matter. These factors also contribute to an increase in the water holding capacity of soil.

9.4 Moisture retention characteristics

9.4.1 Field capacity

Data presented in Table 35 show variation in the field capacity of soil as influenced by the treatments. The values ranged from 13.87 to 27.87 per cent. However, the treatments did not differ with respect to this moisture constant. The field capacity was found significantly correlated with other moisture retention characteristics such as wilting coefficient (r = 0.7756**) and percentage available water (r = 0.4085*). It was also correlated with the pore space (r = 0.5773**) and organic carbon in soil (r = 0.4724*). This relationship was further supported by the negative correlation established between field capacity and apparent density (r = -0.4042*). Again, the negative correlation between the field capacity and absolute specific gravity is also indicative of the role of organic matter, clay and micro pore space in the retention of water in soil. The relationship between field capacity and wilting coefficient has been graphically represented in Fig.13.

FIG. 13. RELATIONSHIP BETWEEN FIELD CAPACITY AND WILTING COEFFICIENT OF SOIL.

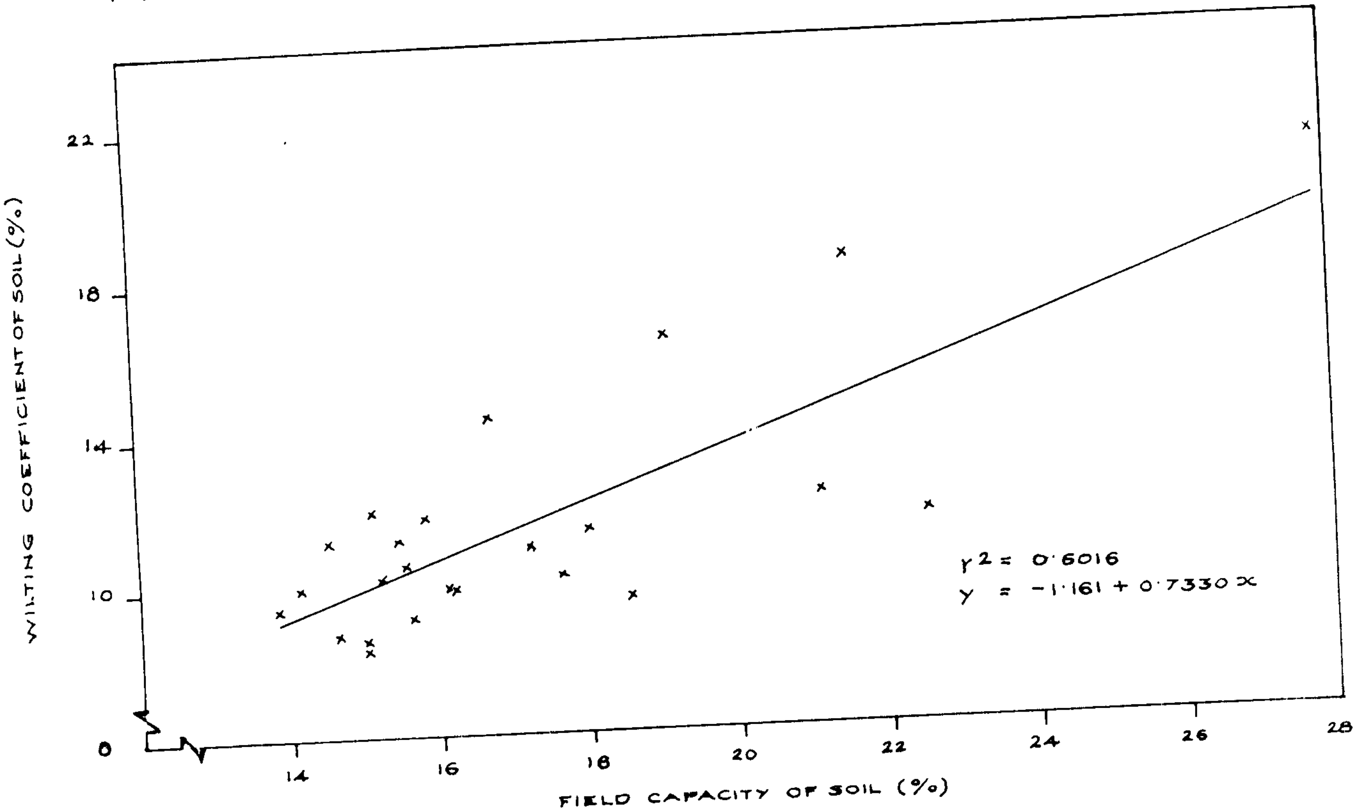


FIG. 14. RELATIONSHIP BETWEEN NUMBER OF FUNCTIONING LEAVES AND EARLY FLOWERING INDEX IN EXPERIMENT No. 2.

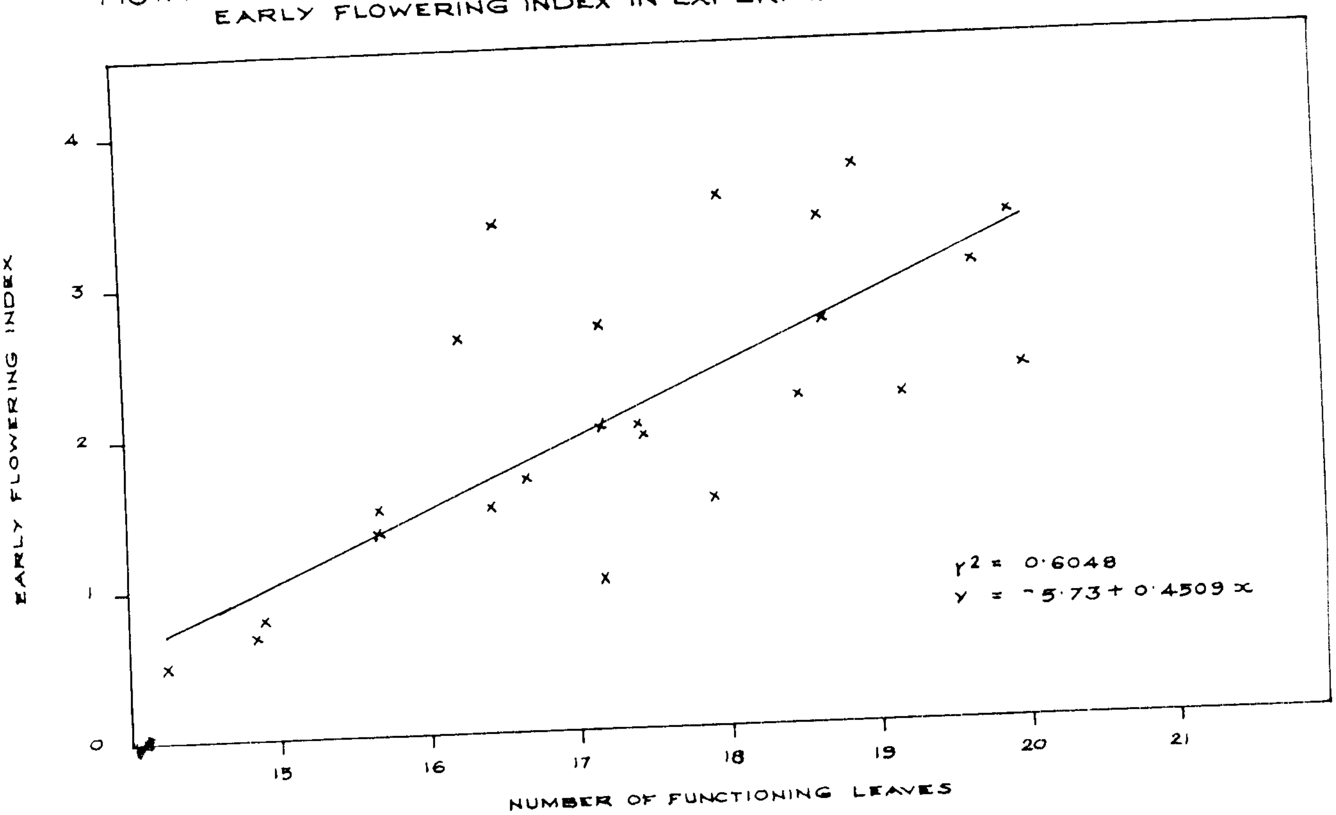


Table 34 Effect of fertilizer treatments on maximum water holding capacity of soil, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	19.07	34.90	38.74	39.46	33.04
2	18.21	37.72	37.39	44.92	34.56
3	30.48	36.06	37.91	38.15	35.65
4	29.93	34.88	37.82	26.33	32.24
5	29.97	34.80	37.27	26.85	32.22
6	33.77	44.31	37.80	37.40	38.22
SEM					2.728
CD (0.05)					8.221

Table 35 Effect of treatments on moisture retention of soil at 0.3 bar (field capacity), per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	16.16	16.12	15.84	19.15	16.82
2	15.64	15.24	17.21	22.54	17.66
3	15.04	15.55	14.55	27.87	18.25
4	15.53	14.13	17.67	21.17	17.13
5	13.87	15.11	18.59	18.09	16.42
6	14.64	15.46	16.71	21.59	17.10
SEM					1.047
CD (0.05)					3.157

9.4.2 Wilting coefficient

The amount of moisture held by the soil at 15 bar expressed as wilting coefficient ranged from 8.28 to 20.98 (Table 36). The treatment means varied from 10.20 to 13.10 and their examination revealed that they did not differ significantly. The wilting coefficient was significantly correlated with field capacity (r = 0.7756**), percentage pore space (r = 0.5984**) and soil organic carbon (r = 0.4318*). As already explained, it can be attributed to the effect of organic matter which possesses relatively high pore space and moisture holding capacity. It is further substantiated by the negative correlation of wilting coefficient with apparent density (r = -0.4632*) and absolute specific gravity (r = -0.4305*).

9.4.3 Available water

Data presented in Table 37 show the percentage available water in soil calculated as difference between field capacity and wilting coefficient of soil. The available water ranged from 2.42 to 11.02 per cent. The fertiliser treatments did not differ with regard to the content of available water in soil.

Table 36 Effect of fertilizer treatments on moisture retention of soil at 15 bar (wilting coefficient), per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	9.86	9.91	11.69	16.26	11.93
2	9.14	10.06	10.83	11.52	10.39
3	8.28	10.42	11.10	20.98	12.70
4	8.52	9.98	10.17	12.14	10.20
5	9.40	11.82	9.45	11.32	10.50
6	8.73	11.16	14.29	18.20	13.10
SEM					1.063
CD (0.05)					3.205

Table 37 Effect of fertilizer treatments on available water of soil, per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	6.30	6.20	4.15	2.89	4.89
2	6.50	5.18	6.38	11.02	7.27
3	6.76	5.13	3.45	6.89	5.56
4	7.01	4.15	7.50	9.03	6.92
5	4.47	3.29	9.14	6.77	5.92
6	5.91	4.30	2.42	3.39	4.01
SEM					1.018
CD (0.05)					3.069

9.5 Aggregate stability

Table 38 presents the values of mean weight diameter of soil which ranged from 0.773 to 1.475 mm. The variation between treatments was rather negligible, the values ranging from 1.046 to 1.416 mm. Accordingly, the differences between treatments in respect of the mean weight diameter of the soil were not significant. It is generally believed that application of Na salts will result in dispersion of soil thereby adversely affecting its aggregate stability. But the result of the study reveals that the substitution of KCl by NaCl to different extent has no influence on the aggregate stability of the soil. This may be due to the fact that the amount of NaCl added to this acid laterite soil which receives an annual rainfall of 3200 mm is rather insignificant to make any effect on the aggregate stability of the soil. As expected, the mean weight diameter recorded significant positive correlation with structural coefficient (r = 0.4196*) and percentage pore space (r = 0.5950**) and negative correlation with apparent density of the soil (r = -0.4944*).

The data on the structural coefficient of soil are presented in Table 39. The values of structural

Table 38. Effect of fertilizer treatments on mean weight diameter of soil, mm

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.801	1.037	1.171	1.299	1.077
2	1.207	1.100	0.803	1.475	1.146
3	0.773	1.035	1.287	1.165	1.065
4	0.973	0.935	1.380	1.750	1.259
5	0.846	1.190	1.121	1.027	1.046
6	1.188	1.717	1.640	1.117	1.416
SEM					0.124
CD (0.05)					0.373

Table 39 Structural coefficient of soil as influenced by fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.568	0.588	0.681	0.490	0.582
2	0.436	0.479	0.437	0.572	0.481
3	0.460	0.493	0.576	0.565	0.524
4	0.412	0.449	0.463	0.556	0.470
5	0.470	0.536	0.462	0.604	0.518
6	0.594	0.554	0.673	0.541	0.591
SEM					0.031
CD (0.05)					0.094

coefficient when multiplied by 100 gave percentage aggregate stability (Table 40). The structural coefficient which is an index of the fraction of the soil that existed as secondary aggregates ranged from 0.412 to 0.681. Statistical analysis showed that the treatments did not differ significantly. This is the additional evidence to indicate that application of NaCl to the extent tried in this experiment has no detrimental effect on the aggregate stability of the soil. As already pointed out, this may be due to the fact that the quantity of NaCl applied to this acid laterite soil receiving fairly good amount of rainfall is quite insufficient to make any impact on the formation and stability of aggregates in soil. The structural coefficient was found correlated with clay (r = 0.5127*), mean weight diameter (r = 0.4196*) and percentage pore space (r = 0.4895*). The water stable aggregates are usually formed by the flocculation of the finer fraction of the soil and the influence of clay on the aggregate formation is in turn reflected in the correlation between the structural coefficient and pore space.

9.6 Organic carbon

The organic carbon percentage of soil as influenced by treatments is presented in Table 41. In general, the

Table 40 Effect of fertilizer treatments on percentage aggregate stability of soil

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	56.8	58.8	68.1	49.0	58.18
2	43.6	47.9	43.7	57.2	48.10
3	46.0	49.3	57.6	56.5	52.35
4	41.2	44.9	46.3	55.6	47.00
5	47.0	53.6	46.2	60.4	51.80
6	59.4	55.4	67.3	54.1	59.05

Table 41 Influence of treatments on content of organic carbon in soil, per cent on moisture free basis

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.029	1.025	1.198	1.194	1.112
2	0.966	0.874	1.086	1.008	0.984
3	0.795	1.148	1.118	1.254	1.079
4	0.857	0.918	0.922	1.384	1.020
5	0.963	1.019	1.029	1.293	1.076
6	0.948	1.038	1.076	1.545	1.152
SEM					0.1169
CD (0.05)					0.3524

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values ranged from 0.795 to 1.198 per cent. Variation between treatment mean values was rather insignificant. Organic carbon content of soil was correlated with total N (r = 0.4773*). The relationship between C and N in soil is well established. The organic carbon content of soil was also found correlated with field capacity (r = 0.4724*) and wilting coefficient (r = 0.4318*). The ability of the soil organic matter to absorb and retain soil moisture is well known and this would have contributed to the relationship between organic carbon and the moisture retention characteristics.

9.7 Total nitrogen

Variation in the content of total N in soil was not found associated with the effect of treatments. The treatment mean values ranged from 0.110 to 0.137 (Table 42). The total N in soil was found significantly correlated with organic carbon (r = 0.4773*), percentage pore space (r = 0.4116*) and moisture retention characteristics like field capacity (r = 0.5584*) and wilting coefficient (r = 0.5929**). Again, it was negatively correlated with apparent density (r = -0.5611**) and absolute specific gravity (r = -0.7547**). These effects

Table 42 Influence of fertilizer treatments on total nitrogen content of soil, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.148	0.103	0.126	0.162	0.135
2	0.066	0.118	0.103	0.158	0.111
3	0.088	0.169	0.132	0.158	0.137
4	0.115	0.103	0.119	0.133	0.118
5	0.115	0.102	0.111	0.110	0.110
6	0.110	0.110	0.111	0.162	0.123
SEM					0.0111
CD (0.05)					0.0334

Table 43 Influence of fertilizer treatments on the available phosphorus content of soil, kg/ha

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	46.02	67.77	85.72	28.73	57.06
2	76.55	67.77	31.10	67.77	60.80
3	67.77	62.11	46.02	38.41	53.50
4	67.77	40.93	59.31	67.77	58.95
5	46.02	70.61	48.63	48.65	53.48
6	82.58	64.92	48.63	59.31	63.86
SEM					8.561
CD (0.05)					25.810

of soil N can be attributed to the influence of soil organic matter since soil organic matter and soil N are well correlated.

9.8 Available phosphorus

The values of available P in soil ranged from 28.73 to 82.58 kg per ha (Table 43). However, the differences between the treatment mean values were not significant, indicating that substitution of KCl by NaCl has little effect on the phosphate transformation in soil.

9.9 Available potassium

Data on the available K in soil are presented in Table 44. In general, the values ranged from 140 to 756 kg/ha. There was marked variation in the content of available K in soil between the fertiliser treatments. Treatments receiving higher amounts of K invariably retained higher amount of this element in soil. Consequently, the contents of available K in T_2, T_3, T_4, T_5 and T_6 were 623, 497, 469, 294 and 189 kg/ha, respectively. Treatments T_2 and T_3 differed significantly from all other treatments. However, T_5, T_6 and T_1 were statistically on par.
The antagonism between Na and K described earlier is further

Table 44 Influence of fertilizer treatments on available potassium content of soil, kg/ha

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	168	196	140	168	168
2	476	756	560	700	623
3	364	532	448	644	497
4	532	420	448	476	469
5	364	252	280	280	294
6	224	140	252	140	189
SEM					42.5
CD (0.05)					128

Table 45 Influence of fertiliser treatments on available sodium content of soil, kg/ha

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	105.49	119.55	121.90	119.55	116.62
2	98.46	124.24	91.42	119.55	108.42
3	100.80	89.08	114.87	119.55	106.08
4	105.49	100.80	128.93	138.31	118.38
5	117.21	103.40	133.62	128.93	120.79
6	140.65	112.52	114.89	154.72	130.70
SEM					6.60
CD (0.05)					19.89

evident from the negative correlation of available K with Na in leaf (r = -0.4230*) and Na in coconut water (r = -0.6244**).

9.10 Available sodium

Data presented in Table 45 showed that the content of available Na in soil ranged from 89.08 to 154.72 kg/ha. The variation in treatment mean values indicated that soil receiving a higher quantity of NaCl, in general, recorded relatively higher values for available Na in soil. Thus, the mean values for available Na in T_6, T_5, T_4 and T_3 were 130.70, 120.79, 118.38 and 106.08 kg/ha respectively. However, the differences between treatment means were not sufficient to establish statistical significance.
The available Na in soil was significantly correlated with Na content of coconut water (r = 0.5002*) and exchangeable Na in soil (r = 0.4073*).

9.11 Available chlorine

Data on the available Cl in soil are presented in Table 46. The values ranged from 39.90 to 179.75 kg/ha. Differences between mean values were not statistically significant. This is because of the fact that all the

Table 46 Influence of fertilizer treatments on available chlorine in soil, kg/ha

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	79.85	59.87	99.83	139.79	94.84
2	39.90	119.81	79.85	159.77	99.83
3	59.87	59.87	179.75	39.90	84.85
4	59.87	59.87	99.83	119.81	84.85
5	59.87	99.83	39.90	99.83	74.86
6	79.85	79.85	119.81	119.81	99.83
SEM					18.95
CD (0.05)					57.12

Table 47 Influence of fertilizer treatments on CEC of soil, me/100 g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	13.20	10.73	11.22	11.06	11.55
2	15.18	13.53	11.39	11.72	12.95
3	11.55	13.20	11.55	12.71	12.25
4	14.19	10.73	12.87	13.04	12.71
5	11.06	10.07	11.88	9.74	10.68
6	10.40	12.54	12.54	15.84	12.83
SEM					0.784
CD (0.05)					2.360

treatments except T_1 received almost the same quantities of Cl supplied either as NaCl or KCl.

9.12 CEC and exchangeable cations

The values of CEC ranged from 9.74 to 15.84 me/100 g (Table 47). The treatments did not differ significantly and the treatment mean values ranged from 10.68 to 12.95 me/100 g.

Table 48 presents the values of exchangeable Ca present in soil. The treatment mean values ranged from 1.49 to 1.73 me/100 g and the differences between treatment means were not significant. Exchangeable Ca was significantly correlated with the clay content of soil ($r = 0.4508^*$). This can be attributed to the presence of this element in the exchangeable site of the soil.

The values of exchangeable Mg ranged from 0.363 to 1.480 me/100 g (Table 49). The treatments did not differ significantly from one another in respect of exchangeable Mg in soil. In general, the exchangeable Mg in soil (0.856 me/100 g) is lower than the amount of exchangeable Ca (1.63 me/100 g). The exchangeable Mg percentage of soil, on an average was only 7.039. This can be attributed to the acidic nature of the soil where the preponderance of

Table 48 Influence of fertilizer treatments on exchangeable calcium in soil, me/100 g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.54	1.75	1.54	1.68	1.63
2	1.47	1.82	1.47	1.82	1.65
3	1.33	1.54	1.54	1.54	1.49
4	1.68	1.75	1.68	1.82	1.73
5	1.47	1.54	1.82	1.96	1.70
6	1.47	1.68	1.61	1.47	1.56
SEM					0.061
CD (0.05)					0.184

Table 49 Influence of fertilizer treatments on exchangeable magnesium in soil me/100 g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.610	1.475	0.825	0.685	0.899
2	0.788	1.083	0.573	1.190	0.909
3	0.605	0.933	0.933	0.610	0.770
4	0.363	0.733	1.008	0.975	0.770
5	0.680	1.040	0.545	1.480	0.936
6	0.680	0.970	0.755	1.003	0.852
SEM					0.129
CD (0.05)					0.388

exchangeable bases is considerably low as compared to the acid forming cations.

Values of exchangeable K are given in Table 50. The values ranged from 0.186 to 0.801 me/100 g. Comparison of the treatment mean values showed that the exchangeable K in soil was significantly influenced by the fertiliser treatment. In general, application of higher amounts of K resulted in high content of exchangeable K in soil. Thus the mean values of exchangeable K in T_2, T_3, T_4, T_5, T_6 and T_1 were 0.641, 0.526, 0.521, 0.327, 0.237 and 0.226 me/100 g, respectively. The treatment T_2, T_3 and T_4 were significantly superior to other treatments. Exchangeable K in soil was significantly correlated with K content of leaf (r = 0.8220**). As already indicated, antagonism between K and Na was reflected in the negative correlation of exchangeable K with Na in coconut water (r = -0.5788**), Na in copra (r = -0.4162*) and exchangeable Na percentage (r = -0.4271*).

The exchangeable Na content of soil ranged from 0.152 to 0.359 me/100 g (Table 51). However, the differences between the treatment means failed to attain statistical significance. A comparison of the treatment mean values revealed that an increase in the quantity of Na applied

Table 50 Influence of fertilizer treatments on exchangeable potassium in soil, me/100 g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.263	0.205	0.205	0.231	0.226
2	0.545	0.801	0.609	0.609	0.641
3	0.481	0.545	0.596	0.481	0.526
4	0.481	0.417	0.564	0.622	0.521
5	0.295	0.346	0.391	0.276	0.327
6	0.199	0.186	0.186	0.378	0.237
SEM					0.040
CD (0.05)					0.121

Table 51 Influence of fertilizer treatments on exchangeable sodium in soil, me/100 g

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.163	0.163	0.250	0.185	0.190
2	0.152	0.163	0.152	0.152	0.155
3	0.163	0.174	0.185	0.185	0.177
4	0.185	0.163	0.174	0.315	0.209
5	0.185	0.207	0.207	0.315	0.228
6	0.163	0.207	0.359	0.250	0.245
SEM					0.024
CD (0.05)					0.072

invariably reflected in an increase in exchangeable Na in soil. Accordingly, the values for exchangeable Na in soil corresponding to T_6, T_5, T_4, T_3 and T_2 were 0.245, 0.228, 0.209, 0.177 and 0.155 me/100 g, respectively. The exchangeable Na in soil was found to be positively correlated with the available Na in soil ($r = 0.4073^*$) and exchangeable Na percentage ($r = 0.9064^{**}$).

9.13 Exchangeable sodium percentage

Data presented in Table 52 reveal that the exchangeable sodium percentage of the soil varied from 1.003 to 2.860. This showed that the variation in the ESP of the soil is rather negligible. Consequently, a comparison of the treatment mean values indicated that substitution of KCl by NaCl had no significant influence on the ESP of the soil. This also supported the view that continuous application of NaCl at the rate employed in the experiment for the last 10 years could not result in the accumulation of Na in the exchangeable sites of the soil probably due to the humid tropical climate enjoyed by the experimental site.

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Table 52 Exchangeable sodium percentage of soil as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.235	1.520	2.228	1.672	1.664
2	1.003	1.205	1.337	1.299	1.210
3	1.412	1.318	1.600	1.454	1.446
4	1.302	1.520	1.351	2.418	1.648
5	1.672	2.052	1.738	3.238	2.175
6	1.569	1.647	2.860	1.578	1.913
SEM					0.2213
CD (0.05)					0.6668

Table 53 Coefficients of correlation between various characteristics

	x	Y	Correlation coefficient
1	No. of leaves produced per year per palm	No.of leaves retained per palm	0.7401**
2	No.of leaves produced per year per palm	Yield	0.5585**
3	No.of leaves retained per palm	Yield	0.6722**
4	No.of female flowers produced per palm	Yield	0.4964*
5	No.of female flowers produced per palm	Copra weight per nut	-0.4215*
6	Chlorine content of leaf	Yield	0.4900*
7	Percentage clay in soil	Copra weight per nut	0.5614**
8	Organic carbon in soil	Copra weight per nut	0.4189*
9	Wilting coefficient of soil	Copra weight per nut	0.5802**
10	Percentage pore space	P content of leaf	0.5773**
11	Exchangeable calcium in soil	Phosphorus content of leaf	0.4651*
12	Exchangeable magnesium in soil	Phosphorus content of leaf	0.5109*
13	Exchangeable potassium	Potassium content of leaf	0.8220**
14	Potassium content of leaf	Sodium content of leaf	-0.5914**
15	Potassium content of leaf	Sodium content of coconut water	-0.5670**

(Contd.)

Table 53 (Contd.)

	x	Y	Correlation coefficient
16	Potassium content of leaf	Sodium content of copra	-0.4679*
17	Potassium content of leaf	Phosphorus content of leaf	0.4226*
18	Sodium content of leaf	Sodium content of coconut water	0.4135*
19	Sodium content of leaf	Sodium content of copra	0.4212*
20	Sodium content of leaf	Available potassium	-0.4230*
21	Calcium content of leaf	Magnesium content of leaf	-0.4809*
22	Potassium content of coconut water	Copra weight per nut	0.5388**
23	Potassium content of coconut water	Magnesium content of leaf	-0.6698**
24	Sodium content of coconut water	Sodium content of copra	0.6985**
25	Sodium content of coconut water	Available potassium	-0.6244**
26	Sodium content of coconut water	Exchangeable potassium	-0.5788**
27	Sodium content of copra	Available potassium	-0.5159**
28	Sodium content of copra	Exchangeable potassium	-0.4162*
29	Calcium content of copra	Magnesium content of copra	-0.6354**
30	Apparent density of soil	Absolute specific gravity	0.5503**

Table 53 (Contd.)

	x	Y	Correlation coefficient
31	Apparent density of soil	Percentage pore space	-0.4872*
32	Apparent density of soil	Field capacity of soil	-0.4042*
33	Apparent density of soil	Wilting coefficient	-0.4632*
34	Apparent density of soil	Percentage clay	-0.4859*
35	Apparent density of soil	Maximum water holding capacity	-0.6593**
36	Absolute specific gravity of soil	Wilting coefficient of soil	-0.4305*
37	Percentage pore space	Field capacity of soil	0.5773**
38	Percentage pore space	Wilting coefficient	0.5984**
39	Percentage pore space	Maximum water holding capacity	00.5910**
40	Percentage pore space	Mean weight diameter	0.5950**
41	Maximum water holding capacity	Percentage pore space	0.4481**
42	Maximum water holding capacity	Percentage pore space	0.5910**
43	Field capacity	Wilting coefficient	0.7756**
44	Field capacity	Percentage of available water	0.4085*
45	Wilting coefficient	Organic carbon in soil	0.4318*
46	Mean weight diameter	Structural coefficient	0.4196*
47	Mean weight diameter	Apparent density	-0.4944*

(Contd.)

Table 53 (Contd.)

	X	Y	Correlation coefficient
48	Structural coefficient	Percentage clay	0.5127*
49	Structural coefficient	Percentage pore space	0.4895*
50	Organic carbon	Field capacity	0.4724*
51	Organic carbon	Total N in soil	0.4773*
52	Percentage pore space	Total N in soil	0.4116*
53	Total nitrogen in soil	Field capacity	0.5584**
54	Total nitrogen in soil	Absolute specific gravity	-0.7547**
55	Total nitrogen in soil	Apperent density	-0.5611**
56	Sodium content of coconut water	Available Na	0.5002*
57	Available sodium	Exchangeable sodium	0.4073*
58	Exchangeable calcium	Percentage clay content	0.4508*
59	Exchangeable potassium	Exchangeable sodium percentage	-0.4271*
60	Exchangeable sodium	Exchangeable sodium percentage	0.9064**

* Significant at 5% level

** Significant at 1% level

B. Experiment No.2

1. Effect of fertiliser treatments on morphological and growth characteristics of the palm

1.1 The number of functioning leaves

Data on the number of functioning leaves retained by the palm are furnished in Table 54. They are the mean values of the number of leaves retained by the palm recorded in 1984 and 1985 when the palms were 8 and 9 years old respectively. The values ranged from 14.25 to 20.00. The number of leaves retained by the palm was found to be significantly influenced by the application of treatments. The maximum number of leaves (18.48) was recorded by treatment No.4 (50% substitution of K_2O by Na_2O) and the minimum number of leaves (15.30) was registered by T_1 (control). Treatments T_4, T_3, T_5 and T_6 were superior to T_1 while T_2 and T_1 were statistically on par. This observation reveals that substitution of KCl by NaCl to the extent of 50 per cent is beneficial to the palm with respect to the number of leaves retained. In this connection, it should be pointed out that the number of leaves retained by the palm was significantly correlated with yield in experiment No.1 already discussed. In this experiment, since the palms have not reached their steady bearing age, the yield data have not been collected.

But considering the total number of leaves retained by the palm as an index of yield it may be possible to assume that maximum yield can be obtained in the treatment where KCl is replaced by NaCl to the extent of 50 per cent. It is very appropriate to recall the results of the experiment No.1, where the maximum yield was recorded in T_4 when the differences between the pretreatment yield and post-treatment yield were considered. The coefficients of correlation between various characteristics studied are presented in Table 89. The number of functioning leaves registered significant positive correlation with the Cl content of the leaf (r = 0.4450*) and the total number of leaves produced so far (r = 0.5866**). A significant positive correlation between yield and Cl content of leaf had been obtained in experiment No.1 which also suggests the validity of treating the number of leaves retained by the palm as an index of yield. Again, the number of leaves retained by the palm was found to be correlated with the total number of leaves produced so far (r = 0.5866**) and early flowering index (r = 0.7777**). The relationship between number of leaves retained by the palm and the early flowering index is quite understandable because of the strong correlation between yield and the number of leaves produced observed earlier. This relationship has been illustrated in Fig.14.

Table 54 Effect of fertilizer treatments on the number of functioning leaves retained by the palms in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	14.84	15.67	16.42	14.25	15.30
2	16.25	19.17	18.50	14.92	17.21
3	18.67	17.17	19.67	17.42	18.23
4	18.92	17.92	17.17	19.92	18.48
5	17.17	20.00	18.00	17.45	18.16
6	18.92	16.67	18.67	15.67	17.48
SEM					0.681
CD (0.05)					2.840

The data are mean of the number of functioning leaves in 1984 and 1985

Table 55 Effect of fertilizer treatments on the number of leaves produced so far in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	74.17	81.00	75.00	65.33	73.86
2	71.50	79.67	80.83	61.33	73.33
3	83.67	76.17	82.67	70.50	78.25
4	81.67	76.50	75.33	83.67	79.29
5	77.83	83.00	81.50	48.60	72.73
6	82.50	75.17	81.67	70.50	77.46
SEM					3.517
CD (0.05)					10.600

The data are the total number of leaves produced upto 1985

1.2 The total number of leaves produced so far

The number of leaves produced by the palms ranged from 48.60 to 83.67 (Table 55). A comparison of the treatment mean values showed that treatments did not differ significantly in respect of the total number of leaves produced. However, the results revealed that maximum number of leaves was produced by palms receiving treatment T_4. There was significant correlation between the number of leaves produced so far and the total number of functioning leaves retained by the palm (r = 0.5866**). Similar relationship was observed and discussed in the case of experiment No.1.

1.3 The early flowering nature of the palm

In order to study the effect of treatment on the early flowering nature of the palm, the flowering index was calculated (Table 56). The flowering index ranged from 0.50 to 3.67. In general, the treatment mean values did not differ significantly. However, the values corresponding to treatments in which KCl has been substituted by NaCl to various extent were relatively higher as compared to the treatments which did not receive the application of NaCl. However, the role of Na in inducing early flowering in coconut cannot be ascertained based on this experiment since the differences between flowering indices are not statistically significant. As already mentioned, early flowering index registered significant positive correlation with the number of functioning leaves retained by the palm (r = 0.7777**).

2. Effect of fertiliser treatments on the content of nutrient elements in leaf

2.1 Nitrogen

Table 57 furnishes the data on the N content of the leaf. The values ranged from 1.102 to 2.503 per cent. As in the case of the N content of leaf in the first experiment, the treatments could not influence the uptake of this nutrient. The mean values of the treatments showed a variation of 1.799 to 2.163 per cent which was not statistically significant. This confirms that the uptake and utilisation of N by the palm are not determined by the relative proportion of Na and K applied to the soil. A significant positive correlation was seen between the content of N in leaf and wilting coefficient of soil (r = 0.4422*). This may be attributed to the increased uptake of N by the palm due to increased moisture availability.

Table 56 Early flowering index of the palms in experiment No.2 as influenced by fertilizer treatment

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.67	1.33	1.50	0.50	1.00
2	2.60	2.17	2.17	0.80	1.94
3	3.33	2.00	3.00	2.00	2.58
4	3.67	1.50	1.00	3.33	2.38
5	2.67	2.33	3.50	2.00	2.63
6	3.67	1.67	2.67	1.50	2.38
SEM					0.39
CD (0.05)					1.78

Table 57 Influence of fertiliser treatments on nitrogen per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	2.063	1.935	2.251	1.953	2.050
2	2.107	2.396	1.962	1.898	2.091
3	2.008	2.263	2.503	1.879	2.163
4	1.731	2.236	1.765	1.970	1.926
5	2.067	2.052	1.836	2.088	2.011
6	1.985	2.037	1.102	2.073	1.799
SEM					0.1352
CD (0.05)					0.4074

2.2 Phosphorus

The data on the P content in leaf presented in Table 58 revealed that this nutrient element in leaf varied from 0.123 to 0.209 per cent. The relatively low requirement of P for coconut, compared to N and K is evident from the low uptake of this nutrient by the palm. The overall mean value of P content of leaf was 0.171 per cent while that of N and K were 2.007 and 1.273 per cent respectively. A similar trend of low uptake of P was seen in the first experiment also. Again, the differences between treatments were not statistically significant. This shows that the uptake of P is not influenced by the relative proportion of Na or K applied to the soil.

2.3 Potassium

The K content of leaf ranged from 0.779 to 2.271 per cent (Table 59). The statistical treatment of the data revealed that the K content in leaf was significantly influenced by the application of fertilizer treatments. The palms under treatments T_2, T_3, T_4, T_5 and T_6 which received 100, 75, 50, 25 and 0 per cent of the recommended dose of K_2O showed a corresponding decline in the uptake of K. The values corresponding to T_2, T_3, T_4, T_5 and T_6 were

1.857, 1.515, 1.308, 1.203 and 0.798 per cent respectively. This gradation of K content in leaf clearly reflects the influence of the treatments. A similar trend was also observed in the first experiment. The treatment T_2 and T_3 retained significantly higher amount of K than T_1 and T_6. Treatments T_2 and T_3 were on par. Treatments T_3, T_4 and T_5 were also on par. While the K content in leaf of palms in T_6 was 0.798 per cent, that of T_1 was 0.954 per cent. This increase in the content of K in T_1 over T_6 is attributed to the antagonism between K and Na (The treatment T_6 received 1000 g Na_2O while T_1 received neither Na_2O nor K_2O). Such a pattern of K uptake was also exhibited by the palms of T_6 and T_1 in experiment No.1. Antagonism between K and Na was also evident from the negative correlation of K content of leaf with available Na in soil ($r = -0.4414^*$), Na content of leaf ($r = -0.6289^{**}$) and exchangeable Na percentage ($r = -0.4074^*$). The relationship between K content of leaf and Na content of leaf has been graphically represented in Fig.15. The significant negative correlations of K content of leaf with Ca content of leaf ($r = -0.7118^{**}$) which is represented in Fig.16 and Mg content of leaf ($r = -0.4669^*$) which is represented in Fig.17 show the antagonistic effect of K on these elements.

FIG.15. RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND SODIUM CONTENT OF LEAF IN EXPERIMENT NO.2.

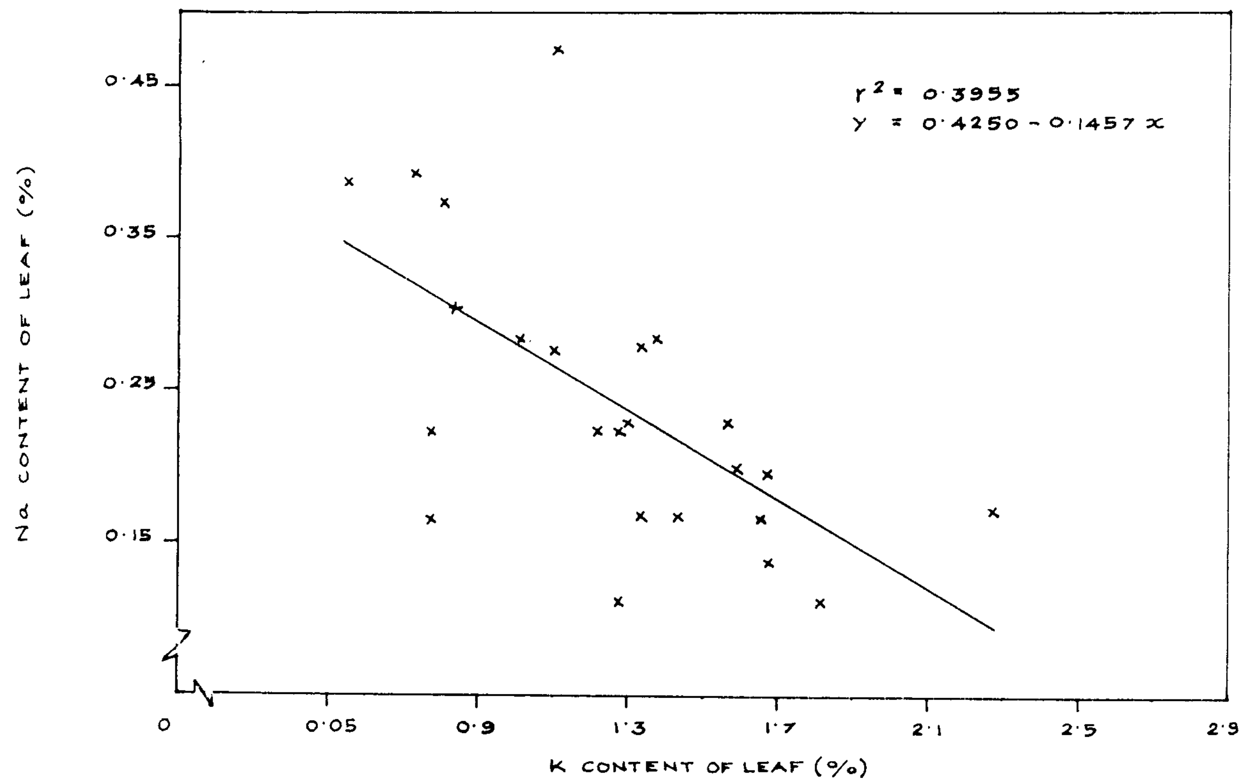

FIG.16. RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND CALCIUM CONTENT OF LEAF IN EXPERIMENT NO.2.

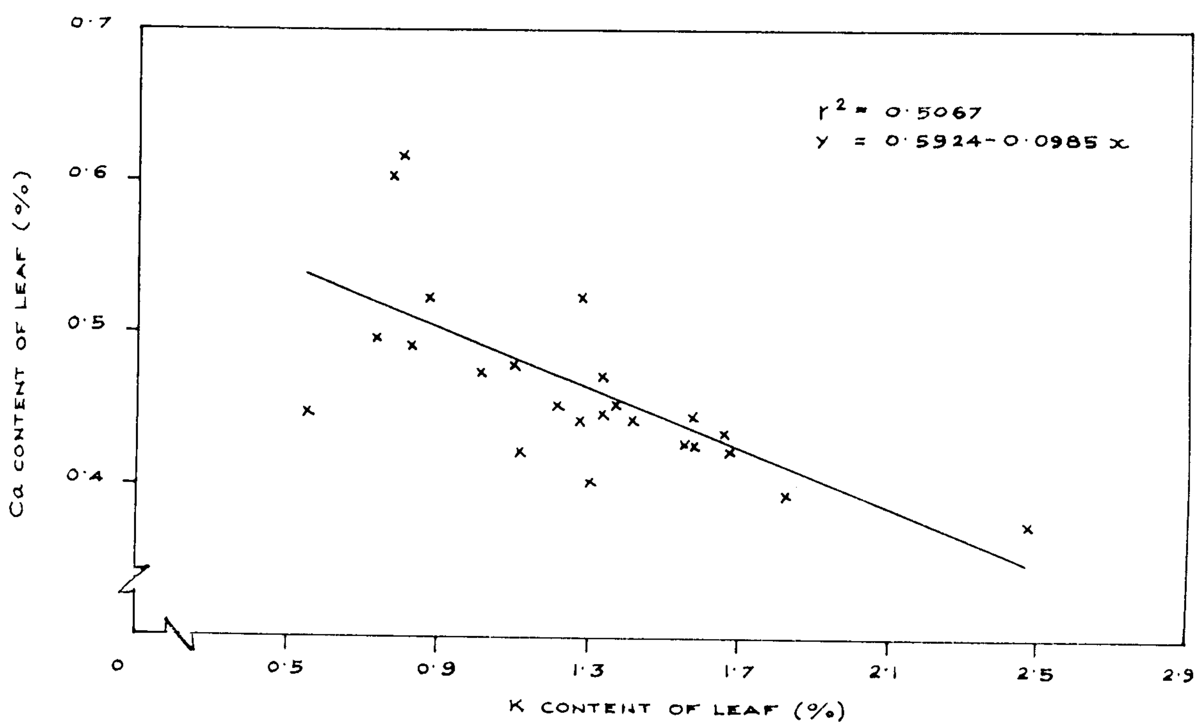

Table 58 Influence of fertilizer treatments on phosphorus per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.185	0.184	0.209	0.195	0.193
2	0.175	0.172	0.158	0.197	0.175
3	0.174	0.159	0.196	0.158	0.172
4	0.172	0.174	0.171	0.171	0.172
5	0.172	0.163	0.145	0.123	0.151
6	0.172	0.151	0.195	0.135	0.163
SEM					0.008
CD (0.05)					0.027

Table 59 Influence of fertilizer treatments on potassium per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.779	1.332	0.827	0.877	0.954
2	2.271	1.671	1.818	1.669	1.857
3	1.578	1.560	1.272	1.651	1.515
4	1.278	1.299	1.438	1.215	1.308
5	1.337	1.364	1.100	1.013	1.203
6	1.115	0.801	0.551	0.726	0.798
SEM					0.099
CD (0.05)					0.298

Positive correlations of K content of leaf with available K in soil ($r = 0.6844^{**}$) is self explanatory (Fig.18).

2.4 Sodium

The data presented in Table 60 showed that the content of Na ranged from 0.110 to 0.474 per cent. The treatments had significant influence on the uptake of Na by the palms. Palms receiving the highest amount of Na (T_6, 1000 g Na_2O) retained the highest amount of Na in their leaves (0.406 per cent). The minimum value was recorded by T_2 (0.153 per cent) which received no application of NaCl. The treatment T_1 (control) recorded a relatively higher value than T_2. This can be attributed to the antagonism between K and Na, since K applied to T_2 would have suppressed the uptake of Na. However, the treatment T_1 was not significantly different from T_2. The treatment T_6 differed significantly from all other treatments. As expected, significant positive correlations were exhibited by Na content of leaf with available Na ($r = 0.6175^{**}$) and exchangeable Na percentage ($r = 0.4954^{*}$). The antagonism between K and Na was also evident from the negative correlation of Na content of leaf with available K in soil ($r = -0.4836^{*}$) and K content of leaf ($r = -0.6289^{**}$).

FIG. 17. RELATIONSHIP BETWEEN POTASSIUM CONTENT OF LEAF AND MAGNESIUM CONTENT OF LEAF IN EXPERIMENT NO. 2.

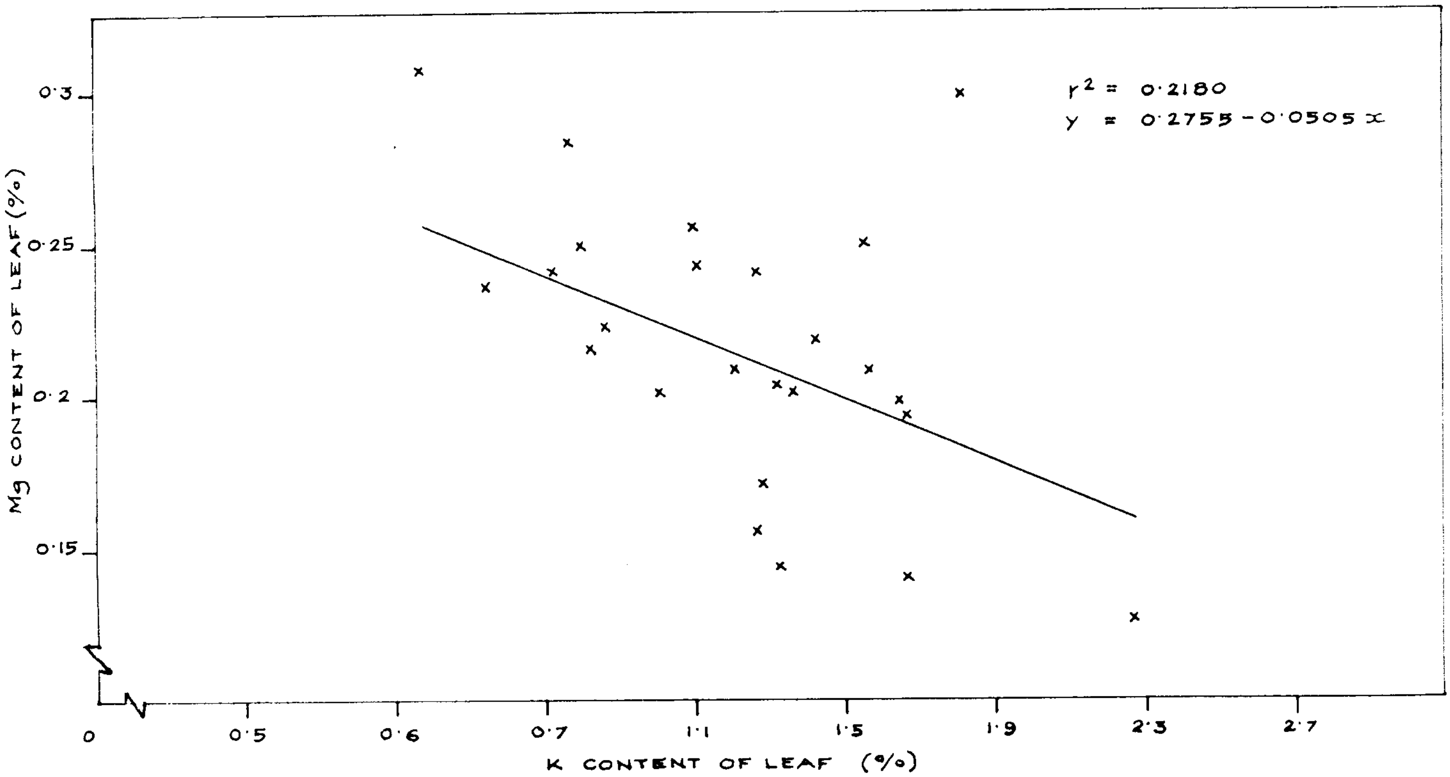

FIG. 18. RELATIONSHIP BETWEEN AVAILABLE K IN SOIL AND K CONTENT OF LEAF EXPERIMENT NO. 2.

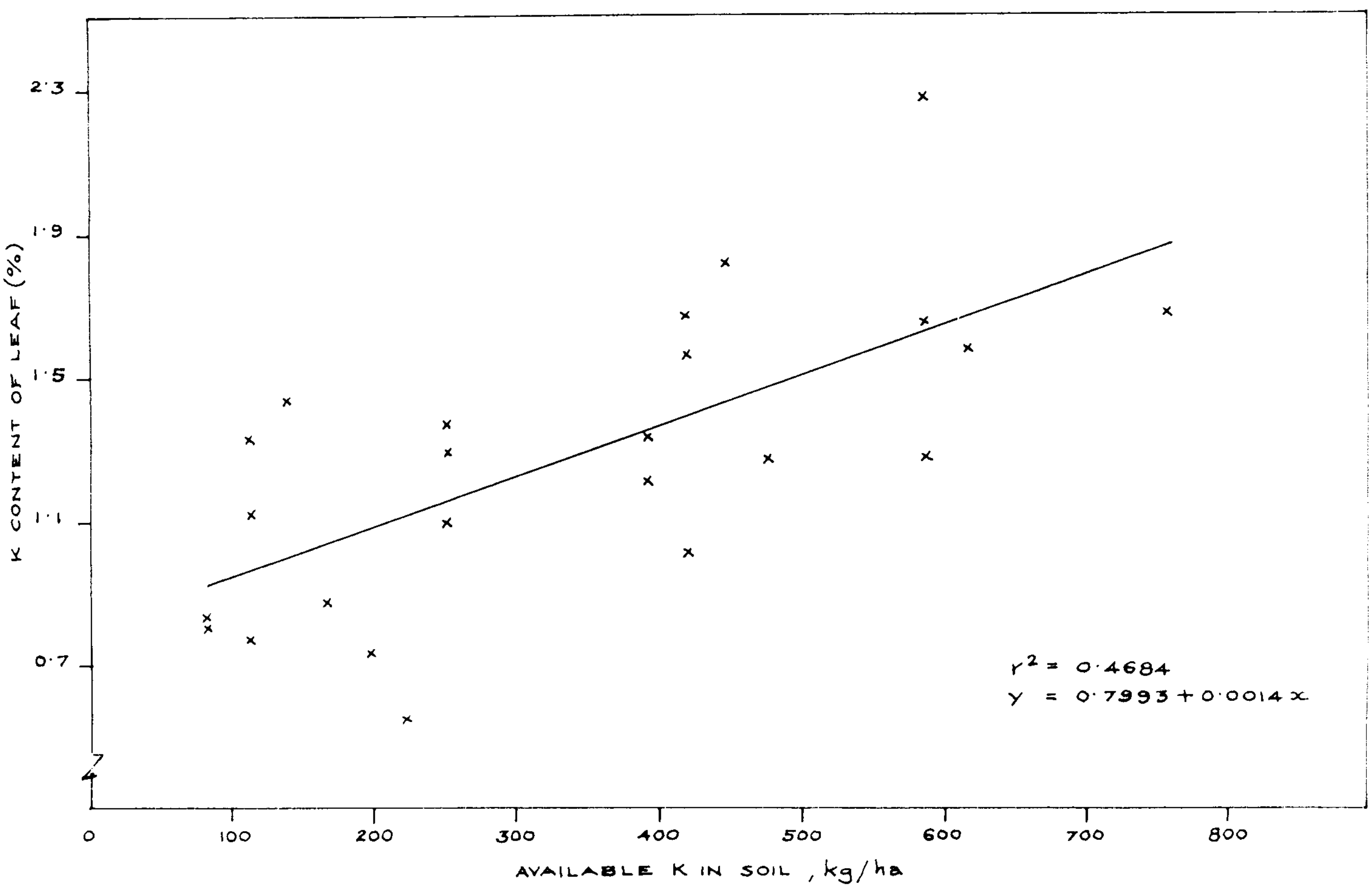

Table 60 Effect of fertilizer treatments on the sodium per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.222	0.167	0.303	0.165	0.214
2	0.170	0.139	0.110	0.195	0.153
3	0.197	0.226	0.111	0.165	0.175
4	0.222	0.227	0.166	0.221	0.209
5	0.279	0.282	0.275	0.281	0.279
6	0.474	0.372	0.386	0.391	0.406
SEM					0.219
CD (0.05)					0.066

Table 61 Effect of fertilizer treatments on the calcium per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.604	0.472	0.521	0.492	0.522
2	0.375	0.447	0.468	0.394	0.421
3	0.426	0.426	0.444	0.442	0.435
4	0.524	0.403	0.444	0.443	0.453
5	0.447	0.453	0.519	0.480	0.475
6	0.421	0.567	0.546	0.448	0.496
SEM					0.025
CD (0.05)					0.067

2.5 Calcium

Table 61 shows that the content of Ca in leaf varies from 0.375 to 0.604 per cent. The statistical treatment of the data showed that the content of this nutrient in leaf was not significantly affected by the treatments. On an average, the level of Ca (0.467 per cent) was found to be more than that of Mg (0.212 per cent). Antagonism between Ca and K was expressed by the negative correlation of Ca content of leaf with available K in soil ($r = -0.5146^{**}$), exchangeable K ($r = -0.4511^{*}$) and K content of leaf ($r = -0.7118^{**}$).

2.6 Magnesium

The statistical analysis of the data (Table 62) showed that the treatments did not differ significantly with respect to the Mg content in leaf. The values of Mg in leaf ranged from 0.140 to 0.299 per cent. The mean values of the treatments ranged from 0.194 to 0.242 per cent, the maximum being recorded by T_6 (1000 g Na_2O). This shows that application of Na in place of K has no influence on the uptake of Mg by the palms. Similar results were observed in the first experiment also. The Mg content of leaf was found negatively correlated with K content of leaf ($r = -0.4669^{*}$) exhibiting the antagonism between the two elements.

2.7 Chlorine

The data on the Cl content of leaf in different plots are presented in Table 63, which range from 0.550 to 0.861 per cent. The treatments were found to have a decisive influence on the content of Cl in the leaf. The treatment T_1 (control) which received no application of Cl recorded the minimum value for this element which was significantly lower from other treatment mean values. All other treatments were statistically on par. This is obviously due to the fact that the amount of Cl supplied in these treatments either as KCl or as NaCl, remained almost the same irrespective of the proportion of K_2O or Na_2O, except T_1. The significant positive correlation between Cl content of leaf and number of functioning leaves at the crown ($r = 0.4450^*$) suggests the importance of Cl in growth and yield of the palms. The number of functioning leaves is a well established index of yield in coconut which has been further confirmed in this experiment. Again a significant positive correlation between yield and Cl content of leaf was observed in Experiment No.1. Nair and Sreedharan (1983) while reviewing the work on the nutrition of oil palm, stated that the Cl content of leaf was correlated with yield greater than K with yield.

Table 62. Effect of fertilizer treatments on magnesium per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.284	0.189	0.203	0.217	0.223
2	0.209	0.126	0.140	0.299	0.194
3	0.176	0.208	0.251	0.156	0.198
4	0.205	0.242	0.172	0.219	0.210
5	0.205	0.144	0.202	0.256	0.202
6	0.237	0.243	0.250	0.237	0.242
SEM					0.0234
CD (0.05)					0.0706

Table 63 Effect of fertilizer treatments on the chlorine per cent of leaf in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.606	0.633	0.601	0.550	0.598
2	0.715	0.739	0.694	0.710	0.715
3	0.710	0.807	0.791	0.768	0.769
4	0.710	0.861	0.631	0.700	0.726
5	0.706	0.653	0.618	0.716	0.673
6	0.683	0.722	0.684	0.580	0.667
SEM					0.0253
CD (0.05)					0.0763

3. Effect of fertilizer treatments on the physico-chemical properties of the soil

3.1 Soil pH

The pH of the soil of the treatment plots ranged from 4.85 to 5.90 (Table 64). The variation between the mean values of the treatment was negligible with respect to the soil pH. The mean values ranged from 5.15 to 5.49. This indicates that the substitution of KCl by NaCl to various extent has no significant influence on the pH of the soil. This is in conformity with the inference from Experiment No.1 where the application of NaCl to experimental soil for 10 years did not alter the pH of the soil. The pH was found significantly correlated with exchangeable K (r = 0.4305*) and exchangeable Ca (r = 0.5866**). An increase in the proportion of exchangeable bases in soil reduces the preponderance of H^+ and increases the pH of the soil.

3.2 EC

Table 65 presents the data on EC of the soil. The values ranged from 0.125 to 0.285 mmho/cm. It was found that the EC of the soil did not differ significantly by the application of treatments. As discussed in the first experiment, the amount of NaCl or KCl applied to the

Table 64 Effect of fertilizer treatments on soil pH in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	4.85	5.10	5.35	5.30	5.15
2	5.20	5.35	5.50	5.90	5.49
3	5.10	5.50	5.60	5.65	5.46
4	5.30	5.20	5.00	5.30	5.20
5	5.00	5.00	5.50	5.40	5.23
6	5.20	5.20	5.50	5.30	5.30
SEM					0.0850
CD (0.05)					0.2561

Table 65 Effect of fertilizer treatment on EC of soil in experiment No.2, mmho/cm

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.250	0.160	0.145	0.145	0.175
2	0.205	0.125	0.135	0.285	0.188
3	0.210	0.145	0.205	0.240	0.200
4	0.140	0.130	0.195	0.150	0.154
5	0.270	0.150	0.135	0.145	0.175
6	0.275	0.175	0.140	0.210	0.200
SEM					0.0227
CD (0.05)					0.0684

acid laterite soil of the experimental site is quite insufficient to cause any build up of salinity in this soil. Moreover, the area is subjected to an annual rainfall of about 3200 mm which results in a good amount of leaching of the salts from the soil.

3.3 Physical constants

3.3.1 Apparent density

The data on the apparent density of the soil presented in Table 66 ranged from 1.326 to 1.509 g/cm^3. The apparent density did not vary between treatments. The mean values of the treatments ranged from 1.385 to 1.415 g/cm^3. Apparent density of soil was found to be negatively correlated with organic carbon in soil (r = -0.4602*), exchangeable Mg (r = -0.4240*) and CEC (r = -0.4009*). A low apparent density is associated with a higher amount of organic matter and clay which is reflected in the above relationships.

3.3.2 Absolute specific gravity

The values presented in Table 67 show the absolute specific gravity of the soil (1.869 to 2.797). The substitution of KCl by NaCl did not influence the

Table 66 Effect of treatments on the apparent density of soil in experiment No.2, g/cm3

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.392	1.436	1.441	1.379	1.412
2	1.346	1.417	1.509	1.354	1.406
3	1.382	1.459	1.444	1.374	1.415
4	1.447	1.386	1.376	1.349	1.390
5	1.390	1.397	1.427	1.326	1.385
6	1.385	1.424	1.347	1.413	1.392
SEM					0.021
CD (0.05)					0.063

Table 67 Absolute specific gravity of soil in experiment No.2 as influenced by the fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	2.214	2.243	2.431	1.869	2.189
2	2.797	2.210	2.548	1.997	2.388
3	2.222	2.171	2.349	2.048	2.197
4	2.257	2.160	2.215	2.080	2.178
5	2.115	2.258	2.317	2.159	2.212
6	2.212	2.148	2.062	1.943	2.019
SEM					0.073
CD (0.05)					0.220

absolute specific gravity of soil. This is in agreement with the results of the first experiment.

3.3.3 Percentage pore space

Table 68 presents the data on percentage pore space ranging from 30.37 to 42.37. The statistical analysis of the data revealed that no significant difference was seen between treatments with respect to the percentage pore space as in the case of the first experiment. This shows that the application of NaCl to this soil for 10 years could not affect the percentage pore space in soil.

3.3.4 Percentage volume expansion of soil

The data on the percentage volume expansion of soil are given in Table 69. The results showed that the percentage volume expansion ranged from 1.52 to 4.91 per cent and there was no significant difference in percentage volume expansion among the treatments. As observed in the previous experiment, this physical constant of the soil was not affected by the long term (10 years) application of NaCl.

Table 68 Influence of fertilizer treatments on per cent pore space of soil in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	41.10	40.08	41.86	30.37	38.35
2	38.98	38.67	40.75	35.21	38.40
3	42.37	38.43	41.52	35.91	39.56
4	39.05	39.10	39.20	38.25	38.90
5	37.85	39.57	41.26	39.98	39.67
6	40.72	38.06	37.08	42.18	39.51
SEM					1.365
CD (0.05)					4.115

Table 69 Percentage volume expansion of soil in experiment No.2 as influenced by fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	4.44	4.70	2.74	3.12	3.75
2	4.30	2.28	1.89	1.82	2.57
3	4.91	4.56	2.44	2.10	3.50
4	2.49	2.76	3.66	2.15	2.77
5	3.35	4.34	1.74	2.94	3.09
6	2.18	4.18	1.52	5.74	3.41
SEM					0.591
CD (0.05)					1.779

3.3.5 Maximum water holding capacity

The maximum water holding capacity ranged from 24.49 to 34.15 per cent (Table 70). As in the case of other physical constants, maximum water holding capacity remained unaffected by the application of treatments. This is in agreement with the results of the first experiment. As expected maximum water holding capacity was significantly correlated with percentage pore space ($r = 0.5088^{*}$).

3.4 Moisture retention characteristics

3.4.1 Field capacity

Data presented in Table 71 show variation in field capacity of soil as influenced by the treatments. The values ranged from 11.60 to 21.17 per cent by weight. The mean values ranging from 14.61 to 16.89 per cent varied significantly between treatments. But this variation was not in increasing or decreasing order of substitution of KCl by NaCl. Field capacity was positively correlated with other moisture retention characteristics like wilting coefficient ($r = 0.6346^{**}$) and percentage available water ($r = 0.7223^{**}$). The relationship between field capacity and percentage available water has been represented graphically in Fig.19. It was also correlated with percentage

FIG. 19. RELATIONSHIP BETWEEN FIELD CAPACITY OF SOIL AND PERCENTAGE AVAILABLE WATER IN SOIL IN EXPERIMENT No. 2.

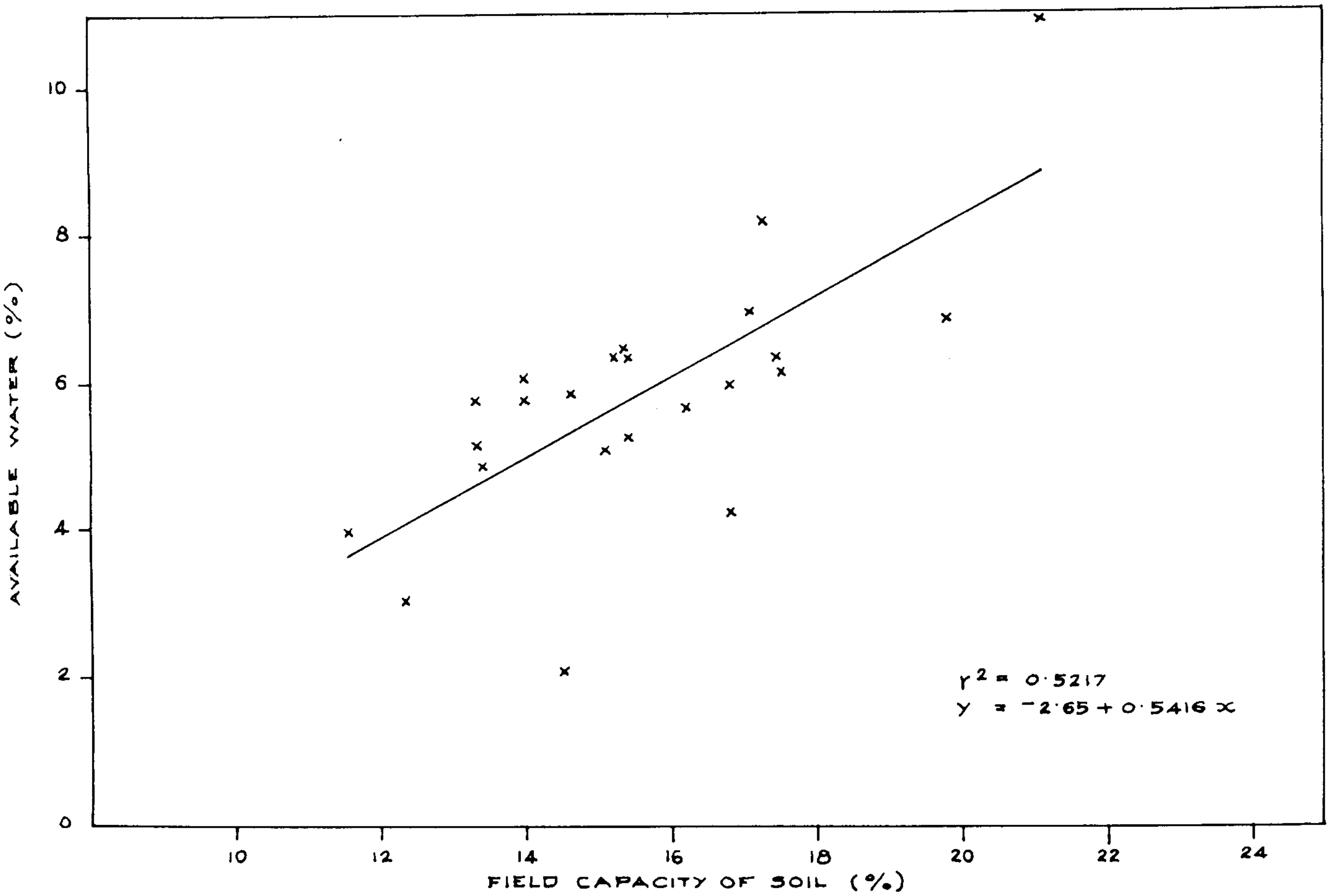

FIG. 20. RELATIONSHIP BETWEEN AVAILABLE Na IN SOIL AND EXCHANGEABLE SODIUM-PERCENTAGE IN EXPERIMENT No. 2.

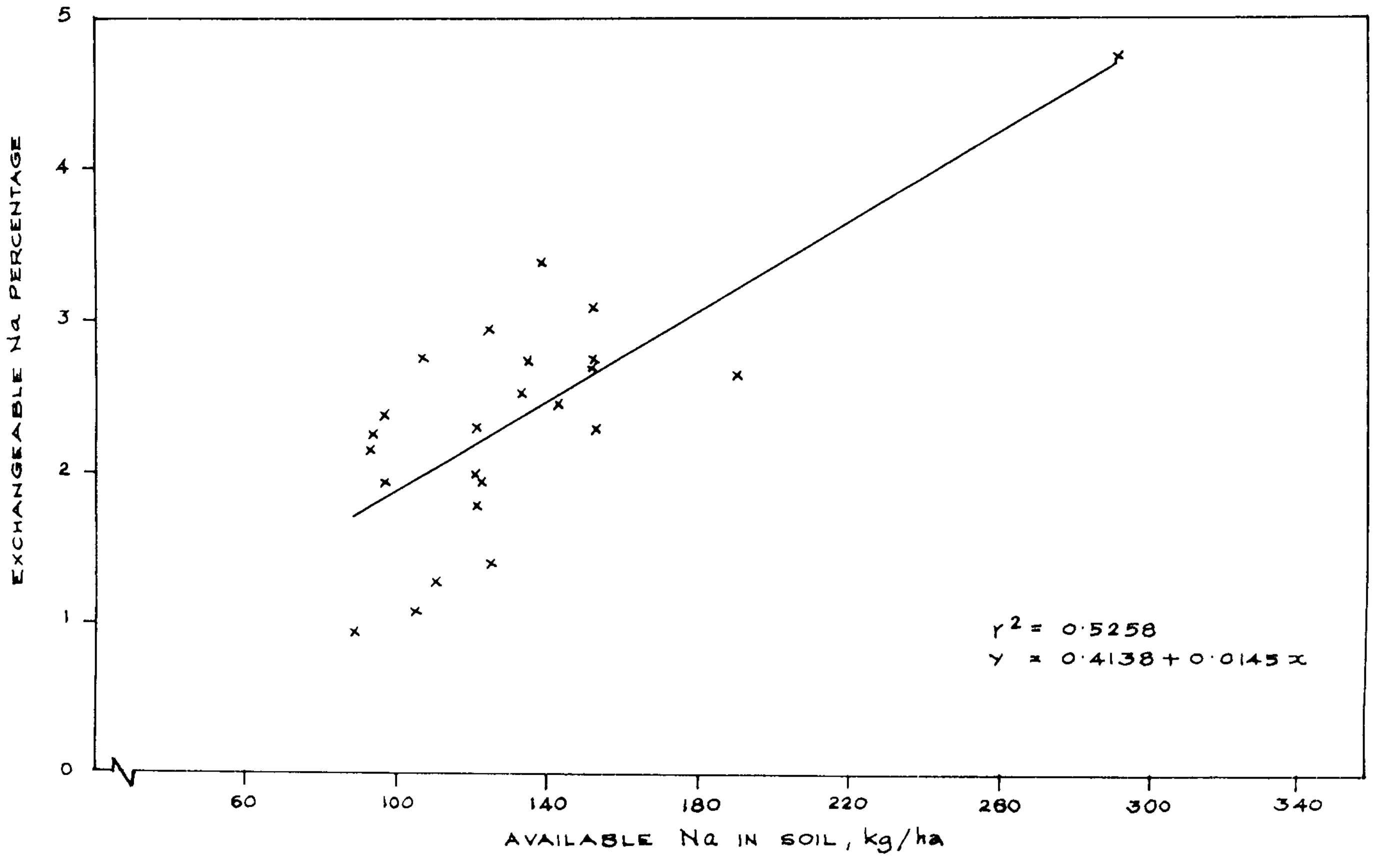

Table 70 Influence of fertilizer treatments on maximum waterholding capacity of soil in experiment No.2, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	27.20	28.89	29.54	25.37	27.75
2	26.26	27.55	31.62	25.51	27.79
3	31.70	26.05	28.94	26.24	28.23
4	24.49	28.87	29.42	28.00	27.70
5	24.84	34.15	29.10	33.66	30.41
6	26.83	27.79	27.32	26.35	27.57
SEM					1.33
CD (0.05)					4.01

Table 71 Influence of fertilizer treatments on moisture retention of soil at 0.3 bar (field capacity) in experiment No.2, per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	17.50	17.27	15.47	13.35	15.90
2	16.86	16.23	14.01	13.44	15.14
3	16.83	15.46	14.55	11.60	14.61
4	21.17	17.18	14.01	13.34	16.43
5	19.81	17.30	15.27	15.19	16.89
6	17.59	15.40	14.66	12.39	15.01
SEM					0.470
CD (0.05)					1.417

clay ($r = 0.6531^{**}$) since the increase in clay content increases micro pore space which in turn increases the moisture retention capacity of the soil.

3.4.2 Wilting coefficient

The treatments did not differ with respect to the wilting coefficient of soil, significantly (Table 72). The values ranged from 7.61 to 12.96 and the mean values of the treatments showed a variation of 9.76 to 10.27. Wilting coefficient was positively correlated with field capacity ($r = 0.6346^{**}$) and percentage clay ($r = 0.6288^{**}$). This further substantiates the effect of clay on moisture retention capacity of the soil.

3.4.3 Available water

The data on the percentage available water are presented in Table 73. The values ranged from 2.10 to 10.88 per cent. The mean values of the treatments differed significantly (4.33 to 7.40 per cent). Though the treatments differed significantly no gradation in percentage available water in the increasing or decreasing order of substitution of K_2O by Na_2O, was observed. Percentage available water was positively correlated with field capacity ($r = 0.7223^{**}$). Since percentage available water is the difference between

Table 72 Influence of fertilizer treatments on moisture retention of soil at 15 bar (wilting coefficient) in experiment No.2, per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	11.15	10.50	9.17	8.21	9.76
2	12.64	10.59	8.25	8.56	10.01
3	10.88	10.17	12.45	7.61	10.28
4	10.29	10.25	7.95	9.60	9.52
5	12.96	9.10	8.92	10.09	10.27
6	11.47	8.92	8.79	9.33	9.63
SEM					0.626
CD (0.05)					

Table 73 Influence of fertilizer treatments on available water of soil in experiment No.2, per cent by weight

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	6.35	6.79	6.33	5.14	6.15
2	4.22	5.64	5.76	4.88	5.13
3	5.95	5.29	2.10	3.99	4.33
4	10.88	6.93	6.06	5.73	7.40
5	6.85	8.20	6.35	5.10	6.63
6	6.12	6.48	5.87	3.06	5.38
SEM					0.626
CD (0.05)					1.887

field capacity and wilting coefficient, an increase in the field capacity will cause an increase in the percentage available water also.

3.5 Aggregate stability

Table 74 furnishes the data on the mean weight diameter which ranged from 0.692 to 1.589 mm. The mean values of the treatments varied from 1.033 to 1.181 mm and the variation was negligible. Accordingly, the treatments could not differ significantly with respect to the mean weight diameter of the soil. This contradicts the general belief that application of Na salts will result in dispersion of soil, thereby adversely affecting its aggregate stability. This may be due to the fact that the amount of NaCl added to the acid laterite soil of the experimental site subjected to an annual rainfall of about 3200 mm is rather insignificant to make any effect on aggregate stability of the soil. A similar result was obtained in the first experiment also. The mean weight diameter was significantly correlated with exchangeable Ca ($r = 0.6327^{**}$). This may be attributed to the ability of Ca ions to flocculate the soil, thereby increasing the aggregate stability of the soil.

The data on the structural coefficient ranged from 0.330 to 0.593 (Table 75). The values of structural coefficient

Table 74 Influence of fertilizer treatments on mean weight diameter of soil in experiment No.2, mm

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.042	0.692	1.130	1.268	1.033
2	0.999	0.964	0.920	1.473	1.089
3	0.830	1.114	1.525	1.255	1.181
4	1.269	1.008	1.008	1.355	1.160
5	0.759	0.744	1.075	1.589	1.042
6	0.697	1.208	1.322	1.126	1.088
SEM					0.1140
CD (0.05)					0.3357

Table 75 Structural coefficient of soil in experiment No.2 as influenced by fertilizer treatments

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.490	0.484	0.428	0.556	0.490
2	0.489	0.546	0.491	0.330	0.464
3	0.556	0.565	0.490	0.533	0.536
4	0.528	0.474	0.500	0.593	0.524
5	0.461	0.434	0.504	0.526	0.481
6	0.471	0.413	0.392	0.423	0.425
SEM					0.0290
CD (0.05)					0.0875

multiplied by 100 give the percentage aggregate stability which are presented in Table 76. The structural coefficient is an index of the fraction of the soil that existed as secondary aggregates. The mean values of the treatments ranged from 0.425 to 0.536. This reveals the fact that the treatments had no significant influence on the structural coefficient of the soil. This is a further proof to show that the application of NaCl to the extent tried in this experiment has no detrimental effect on the soil structure. As already pointed out in the first experiment it may be due to the insufficiency of the quantity of NaCl applied to this laterite soil receiving fairly high rainfall to make any impact on the aggregation of soil particles.

3.6 Organic carbon

Organic carbon percentage in soil varied from 0.516 to 0.845 (Table 77). The treatments could not influence the content of organic carbon in soil. This shows that application of NaCl or KCl has no effect on the rate of decomposition of organic matter in soil irrespective of the proportion of Na_2O or K_2O. Organic carbon content was positively correlated with the CEC of the soil ($r = 0.4769^*$) and negatively correlated with the apparent density of soil ($r = -0.4602^*$). The positive correlation

Table 76 Effect of fertiliser treatments on percentage aggregate stability of soil in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	49.0	48.4	42.8	55.6	48.95
2	48.9	54.6	49.1	33.0	46.40
3	55.6	56.5	49.0	53.3	53.60
4	52.8	47.4	50.0	59.3	52.38
5	46.1	43.4	50.4	52.6	48.13
6	47.1	41.3	39.2	42.6	42.48

Table 77 Influence of fertilizer treatments on the organic carbon content of soil in experiment No.2, per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.701	0.516	0.730	0.714	0.665
2	0.762	0.623	0.533	0.735	0.663
3	0.750	0.667	0.684	0.563	0.666
4	0.656	0.655	0.716	0.691	0.680
5	0.745	0.686	0.845	0.814	0.773
6	0.564	0.627	0.753	0.751	0.674
SEM					0.0405
CD (0.05)					0.1221

may be attributed to the fact that an increase in organic matter in the soil causes an increase in exchange sites, thus increasing the CEC of the soil. The indirect effect of organic matter in increasing pore space and thus reducing the apparent density of the soil is reflected in the negative correlation with them.

3.7 Total nitrogen in soil

The data on total N in soil are given in Table 78. The values ranged from 0.059 to 0.103 per cent. The statistical analysis of the data revealed that there was no significant difference between treatments. In other words, the total N in soil remains unaffected irrespective of application of K or Na in various proportions to the soil. Similar result was obtained in the case of total N in the first experiment also. The maximum amount of total N was seen in T_6 (1000 g Na_2O) and the minimum in T_1 (control).

3.8 Available phosphorus

The statistical treatment shows that the values of available P in soil do not vary significantly (Table 79). The values ranged from 31.10 to 67.77 kg/ha whereas the mean values of the treatments varied from 47.56 to 58.08 kg/ha, the variation being statistically not significant.

Table 78 Effect of fertilizer treatments on total nitrogen content of soil in experiment No,2,per cent

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.103	0.066	0.102	0.088	0.090
2	0.081	0.080	0.073	0.059	0.073
3	0.096	0.066	0.088	0.069	0.080
4	0.066	0.095	0.088	0.096	0.086
5	0.073	0.059	0.074	0.103	0.077
6	0.073	0.088	0.081	0.066	0.077
SEM					0.0269
CD (0.05)					0.0381

Table 79 Effect of fertilizer treatments on available P in soil, kg/ha (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	59.33	48.62	56.61	67.77	58.08
2	59.33	43.45	46.02	59.33	52.03
3	59.33	56.61	59.31	56.61	57.97
4	31.10	53.90	48.63	56.61	47.56
5	40.93	64.92	51.24	56.61	53.43
6	40.93	53.90	62.11	59.33	54.07
SEM					4.12
CD (0.05)					12.41

This indicates that application of K_2O or Na_2O in various ratio has no influence on the available P in soil.

3.9 Available potassium

Table 80 furnishes the data on the available K in soil which ranged from 84.0 to 756.0 kg/ha. The treatments had significant influence on the available K in soil. The maximum amount of available K was seen in T_2 (1000 g K_2O) and the minimum by T_1 (control). Treatments receiving higher amount of K invariably retained higher amount of this element in soil. Accordingly, the available K in T_2, T_3, T_4, T_5, T_6 and T_1 were 553, 525, 343, 329, 154 and 119 kg/ha, respectively. Pairs of treatments, T_2 and T_3, T_4 and T_5 and T_6 and T_1 were statistically on par. T_2 and T_3 differed significantly from the rest. Treatments T_4 and T_5 differed significantly from T_2, T_3, T_6 and T_1. As expected, available K was positively correlated with K content in leaf ($r = 0.6844^{**}$) and exchangeable K ($r = 0.5829^{**}$). The antagonism between K and Na is evident from the negative correlation of available K with Na content of leaf ($r = -0.4836^{*}$) and exchangeable Na percentage ($r = -0.4398^{*}$). This is in conformity with the results of the first experiment.

3.10 Available sodium

The data on the available Na in soil are presented in Table 81. The values ranged from 89.08 to 293.02 kg/ha. The treatments had significant influence on the available Na in soil. The mean values of the treatments varied from 104.17 to 193.98 kg/ha the maximum being recorded by T_6 (1000 g Na_2O) and the minimum by T_2 (1000 g K_2O). Accordingly the treatments receiving higher amount of Na registered higher values of available Na in soil. The treatment T_6 differed significantly from all other treatments. Treatments T_6, T_5, T_4, T_3 and T_2 showed mean values of 193.98, 144.75, 124.24, 120.00 and 104.17 kg/ha, respectively. The treatment T_1 registered a slightly higher value (106.22 kg/ha) of available Na than T_2. This marginal increase may be due to the antagonism between K and Na which is exhibited in T_2 where added K would have adversely affected the available Na in soil. The treatments T_5, T_4, T_3, T_1 and T_2 were statistically on par. As expected, available Na was positively correlated with Na content of leaf (r = 0.6175**) and exchangeable Na percentage (r = 0.7251**). The positive relationship between available Na in soil and exchangeable Na percentage in soil has been graphically represented in

Table 80 Effect of fertilizer treatments on available potassium in soil, kg/ha (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	112.0	112.0	84.0	168.0	119.0
2	588.0	420.0	448.0	756.0	553.0
3	616.0	420.0	476.0	588.0	525.0
4	588.0	252.0	140.0	392.0	343.0
5	392.0	252.0	252.0	420.0	329.0
6	112.0	84.0	224.0	196.0	154.0
SEM					180.6
CD (0.05)					134.0

Table 81 Effect of fertilizer treatments on available sodium in soil, kg/ha (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	89.08	96.11	133.62	106.07	106.22
2	121.90	93.78	96.11	104.70	104.17
3	110.18	121.90	124.24	123.66	120.00
4	135.96	143.00	93.77	124.24	124.24
5	152.37	121.90	152.37	152.37	144.75
6	138.31	293.02	152.37	192.22	193.98
SEM					16.79
CD (0.05)					50.59

Fig.20. Antagonism between Na and K described earlier is further proved by the negative correlation between available Na in soil and K content of leaf (r = -0.4414*).

3.11 Available chlorine

The values of available Cl in soil ranged from 59.87 to 159.77 kg/ha (Table 82). The substitution of KCl by NaCl had no significant influence on the available Cl in soil. This is because of the fact that all the treatments except T_1 received almost the same quantities of Cl supplied either as NaCl or as KCl. The difference between T_1 and other treatments was not statistically significant.

3.12 CEC and exchangeable cations

Table 83 furnishes the values of CEC which ranged from 6.60 to 9.57 me/100 g. The statistical analysis of the data showed that the CEC of the soil did not vary significantly by the application of fertilizer treatments. The mean values ranged from 7.253 to 8.621 me/100 g. CEC was found positively correlated with percentage clay (r = 0.5752**) and organic carbon in soil (r = 0.4769*). This is because of the fact that the major portion of the exchange sites is possessed by clay and organic matter. Accordingly CEC was negatively correlated with apparent density (r = -0.4009*) due to the indirect effect of organic matter and clay.

Table 82 Effect of fertilizer treatments on available chlorine in soil, kg/ha (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	79.853	59.874	159.769	79.853	94.837
2	59.874	79.853	99.832	59.874	74.858
3	99.832	119.811	119.811	99.832	109.821
4	59.874	79.853	59.874	79.853	69.864
5	79.853	79.853	119.809	139.790	104.826
6	99.832	59.874	79.853	119.811	89.843
SEM					12.490
CD (0.05)					37.650

Table 83 Effect of fertilizer treatments on CEC of soil, me/100 g (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	9.570	7.425	8.250	7.920	8.291
2	9.240	7.250	6.930	8.250	7.918
3	9.405	8.250	7.755	6.765	8.044
4	7.230	7.590	6.600	7.590	7.253
5	8.910	9.075	7.425	9.075	8.621
6	8.085	7.095	8.250	7.425	7.714
SEM					0.3624
CD (0.05)					1.0921

The data on exchangeable Ca are presented in Table 84. The values ranged from 1.33 to 2.66 me/100 g. The statistical analysis of the data showed that the treatments did not differ significantly with respect to exchangeable Ca. The mean values of the treatments ranged from 1.5 to 1.93 me/100 g.

The values of exchangeable Mg ranged from 0.25 to 1.64.me/100 g (Table 85). The treatments did not differ significantly with respect to the exchangeable Mg in soil. The mean values ranged from 0.457 to 0.978 me/100 g. In general, the overall mean value for exchangeable Mg (0.736 me/100 g) is less than that of Ca (1.7 me/100 g). The exchangeable Mg percentage of soil on an average was only 9.23. This can be attributed to the acidic nature of the soil where the predominance of exchangeable bases is low compared to the acid forming cations.

Table 86 gives the values of exchangeable K which ranged from 0.122 to 1.090 me/100 g. The statistical treatment showed that differences between treatments were not significant. The mean values of the treatment ranged from 0.203 to 0.592 me/100 g, the maximum being shown by T_2 (1000 g K_2O) and the minimum by T_1 (control). Exchangeable

Table 84 Effect of fertilizer treatment on exchangeable calcium, me/100 g (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	1.40	1.33	1.68	1.89	1.58
2	1.47	1.40	1.82	1.96	1.66
3	1.40	1.75	2.03	1.89	1.77
4	1.47	1.47	1.54	1.54	1.51
5	1.54	1.54	1.96	2.66	1.93
6	1.82	1.68	1.75	1.61	1.72
SEM					0.113
CD (0.05)					0.341

Table 85 Effect of fertilizer treatments on exchangeable magnesium in soil, me/100 g (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.858	0.605	0.363	1.228	0.759
2	0.895	0.428	0.868	1.158	0.837
3	0.320	0.400	0.980	1.013	0.678
4	0.250	0.358	0.503	0.718	0.457
5	1.040	0.503	0.728	1.640	0.978
6	1.190	0.470	0.615	0.540	0.704
SEM					0.1416
CD (0.05)					0.2003

K was found significantly correlated with available K (r = 0.5829**). Antagonism between K and Ca is shown by the negative correlation obtained by the exchangeable K and Ca content of leaf (r = -0.4511*).

The values of exchangeable Na content of soil ranged from 0.087 to 0.337 me/100 g (Table 87). A comparison of the treatment means revealed that the treatments could not differ significantly. The mean values of treatments ranged from 0.144 to 0.375 me/100 g.

3.13 Exchangeable sodium percentage

The data on exchangeable Na percentage presented in Table 88 showed a variation from 0.909 to 4.749 me/100 g. The mean values of the treatments ranged from 1.855 to 3.378 me/100 g and the differences were not statistically significant. This shows that application of Na even in the complete absence of added K does not raise the ESP of the soil significantly. However, the maximum value of ESP was seen in T_6 and the minium in T_2. The significant positive correlation of exchangeable Na percentage with Na content of leaf (r = 0.4954*) and available Na in soil (r = 0.7251**)

Table 86 Influence of fertilizer treatments on exchangeable potassium in soil, me/100 g (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.122	0.147	0.417	0.128	0.203
2	0.609	0.577	0.571	0.609	0.592
3	0.583	0.558	0.635	0.545	0.580
4	0.558	0.378	0.135	0.397	0.367
5	0.295	0.314	0.321	0.391	0.330
6	0.122	0.115	0.160	1.090	0.372
SEM					0.1107
CD (0.05)					0.3336

Table 87 Influence of fertilizer treatments on exchangeable sodium in soil, me/100 g (experiment No.2)

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.087	0.141	0.207	0.217	0.163
2	0.163	0.163	0.163	0.087	0.144
3	0.120	0.163	0.228	0.130	0.160
4	0.196	0.185	0.141	0.978	0.375
5	0.239	0.207	0.228	0.207	0.220
6	0.272	0.337	0.228	0.196	0.258
SEM					0.0881
CD (0.05)					0.2654

Table 88 Exchangeable sodium percentage of soil as influenced by fertilizer treatments in experiment No.2

Treatment No.	R_1	R_2	R_3	R_4	Mean
1	0.909	1.903	2.503	2.745	2.015
2	1.765	2.249	2.353	1.054	1.855
3	1.271	1.976	2.943	1.928	2.030
4	2.076	2.435	2.141	1.289	2.143
5	2.684	2.276	3.074	2.276	2.578
6	3.361	4.749	2.767	2.635	3.378
SEM					0.3394
CD (0.05)					1.0288

are self explanatory. As described earlier, the antagonism between K and Na is reflected in the significant negative correlation of exchangeable Na percentage with K content of leaf ($r = -0.4074^*$) and available K in soil ($r = -0.4398^*$).

Table 89 Coefficients of correlation between various characteristics in experiment No.2

	X	Y	Correlation coefficient
1	Chlorine content of leaf	Number of functioning leaves	0.4450*
2	Total number of leaves produced so far	Number of functioning leaves	0.5866**
3	Number of functioning leaves	Early flowering index	0.7777**
4	Nitrogen content in leaf	Wilting coefficient of soil	0.4422*
5	Available sodium	Potassium content of leaf	-0.4414*
6	Potassium content of leaf	Sodium content of leaf	-0.6289**
7	Potassium content of leaf	Exchangeable sodium percentage	-0.4074*
8	Potassium content of leaf	Calcium content of leaf	-0.7118**
9	Potassium content of leaf	Magnesium content of leaf	-0.4669*
10	Potassium content of leaf	Available K in soil	0.6844**
11	Sodium content of leaf	Available sodium in soil	0.6175**
12	Sodium content of leaf	Exchangeable sodium percentage in soil	0.4954*
13	Available potassium in soil	Calcium content of leaf	-0.5146**
14	Exchangeable potassium	Calcium content of leaf	-0.4511*
15	Soil pH	Exchangeable potassium	0.4305*

(Contd.)

Table (Contd.)

	x	Y	Correlation coefficient
16	Soil pH	Exchangeable calcium	0.5866**
17	Maximum water holding capacity	Percentage pore space	0.5088*
18	Field capacity	Wilting coefficient	0.6346**
19	Field capacity	Percentage available water	0.7223**
20	Wilting coefficient	Percentage clay	0.6288**
21	Mean weight diameter	Exchangeable calcium	0.6327**
22	Organic carbon	CEC	0.4769*
23	Organic carbon	Apparent density	-0.4602*
24	Available potassium in soil	Sodium content of leaf	-0.4836*
25	Available potassium in soil	Exchangeable sodium percentage	-0.4398*
26	Available sodium	Exchangeable sodium percentage	0.7251**
27	CEC	Percentage clay	0.5752**
28	CEC	Apparent density	-0.4009*
29	Exchangeable potassium	Available potassium	0.5829**

* Significant at 5% level

** Significant at 1% level

SUMMARY

SUMMARY

The coconut palms of two field experiments receiving different levels of K_2O and Na_2O, laid out at the Regional Agricultural Research Station, Pilicode, Kerala were made use of for the study. The soil of the experiment site is laterite (Oxisol) and the area receives an annual rainfall of about 3200 mm. The treatments were the substitution of K_2O (applied as KCl) by Na_2O (applied as NaCl) to the extents of 100, 75, 50, 25 and 0 per cent. In the first experiment the fertilizer treatments were superimposed on 24 year old coconut palms in 1976 which were receiving N, P and K as per the recommended dose till that year. The second experiment was laid out in 1976, with newly planted coconut seedlings and therefore the treatments were given from the very start of the experiment. In both experiments, the crop is rainfed. The soil and leaf samples for the present study were collected from these two experimental sites in January 1986. The soil and leaf samples of both the experiments were analysed to find out the effect of sodium chloride on uptake of nutrients and soil characteristics. The analysis of copra and quality

evaluation of oil were done only in the case of the first experiment since the palms of the second experiment have not yet reached the steady bearing age.

The following conclusions were drawn:

1. The fertilizer treatments did not differ significantly in respect of the number of functioning leaves retained by the palms in the experiment No.1. Yield was significantly correlated with the number of functioning leaves and a unit increase in number of leaf would correspond to an increase in yield of 5.045 nuts per palm.

In the second experiment number of functioning leaves was significantly influenced by the fertilizer treatments. The maximum number of leaves (18.48) was recorded by treatment No.4 (50% substitution of K_2O by Na_2O) and the minimum number of leaves (15.3) was registered by T_1 (control).

2. The treatments did not differ significantly in their influence on the total number of leaves produced per palm per year in the case of the first experiment and on the total number of leaves produced so far by the palms of the second experiment.

3. Differences between treatments were not significant with regard to the number of female flowers produced per palm in the first experiment or the early flowering nature of the palms of the second experiment.

4. Observations on yield, in the first experiment revealed that yield of palms increased continuously with progressing period of time and the maximum increase in yield was in T_4 (50% substitution of K_2O by Na_2O). Though there was 104.15 per cent increase in yield in T_4 as compared to T_1, the difference was not found statistically significant, the significance being lost by marginal difference. When the data were subjected to the analysis of covariance the adjusted treatment mean values varied significantly, the maximum being recorded by T_2 (1000 g K_2O) and the minimum by T_1 (control). Treatment T_2 was closely followed by T_4 and the differences between T_2, T_4, T_5, T_6 and T_3 were not significant.

5. The treatments did not differ significantly in their influence on the copra weight per nut.

6. The percentage oil recovery of copra did not differ significantly by the application of treatments.

7. Nitrogen and phosphorus uptake by the palms in both the experiments did not differ significantly by the application of treatments.

8. The potassium uptake was decisively influenced by the treatments in both experiments. Treatments receiving higher levels of K showed a correspondingly higher uptake of this element. The treatment T_1 (control) registered a higher uptake of K than T_6 (1000 g Na_2O).

9. The sodium uptake by the palms in both the experiments was also significantly influenced by the treatments. In general, palms receiving higher levels of Na retained higher amount of Na in their leaves. Antagonism between K and Na in leaves was also exhibited in both experiments.

10. The uptake of divalent cations (Ca and Mg) by the palms was not decesively influenced by the application of treatments in both experiments.

11. The treatments did not differ significantly in the uptake of Cl by the palms in the case of the first experiment. But in the second experiment, the Cl uptake of the palms was decisively influenced by the treatments. The treatment T_1 (control) which received no application of Cl recorded the minimum value which was significantly lower than all other treatment mean values. All other treatment mean values were statistically on par.

12. The soluble K content of coconut water did not differ significantly by the application of treatments whereas the soluble Na content of coconut water showed significant variation between treatments. The maximum amount of Na was in T_6 (1000 g Na_2O).

13. The copra analysis showed that the treatments did not differ significantly with regard to their influence on the extent of N, P and K in copra.

14. The sodium content of copra was found to be influenced by the treatments. The Na content increased with increasing application of Na.

15. The differences among treatments in the case of Ca, Mg and Cl contents of copra were not statistically significant.

16. The analysis on the quality of oil revealed that there was no significant difference in the specific gravity, refractive index, iodine number and saponification value of oil, between treatments.

17. The pH and EC of the soil did not differ between the treatments in both the experiments.

18. The soil physical constants viz., apparent density, absolute specific gravity, percentage pore space

percentage volume expansion and maximum water holding capacity were not significantly different under various treatments in both the experiments.

19. The moisture retention characteristics like field capacity and wilting coefficient and the percentage available water of the soil were not significantly influenced by the substitution of KCl by NaCl to various extent.

20. The aggregate analysis of the soil of both the experiment sites showed that there was no significant difference between treatments in the percentage aggregate stability of the soil. Thus the structure of the soil was not found affected due to the application of NaCl at the rate employed in the experiment.

21. The treatments did not differ in their influence on the percentage organic carbon, total N and available P in soil in both the experiments.

22. Available K in soil registered significant difference between treatments in both the experiments. Invariably, treatment receiving the highest amount of K (T_2 1000 g K_2O) retained the highest amount of this element in soil.

23. In general, soil receiving a higher quantity of NaCl recorded higher values for available Na in soil. However, the differences between treatment means were not sufficient to establish statistical significance, in the case of the first experiment. In the second experiment the treatments had significant influence on available Na in soil and the treatment T_6 (1000 g of Na_2O) registered a significantly higher value of available Na than all other treatments.

24. The available chlorine in soil did not differ significantly due to the application of treatments.

25. The treatments did not differ significantly as far as CEC of the soil in both experiments was considered.

26. Exchangeable Ca and Mg contents in soil in both the experiments did not differ significantly between treatments.

27. The treatments could decisively influence the exchangeable K in soil in the first experiment but failed to do so in the second experiment. The values of exchangeable K registered by individual treatments increased in accordance with the increasing order of application of K to soil in the first experiment.

28. Exchangeable Na as well as exchangeable Na percentage in soil were not significantly different when the treatment means were compared.

The above observations tend to conclude that substitution of K_2O applied to coconut palms as KCl, by Na_2O applied as NaCl to the extent of 50 per cent is possible without a reduction in the yield, quality of oil and adverse effects on soil characteristics, under the climatic and soil conditions comparable to that tried in this experiment.

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*Original not seen

APPENDICES

Appendix 1 Meteorological parameters of the experimental site at the Regional Agricultural Research Station, Pilicode, Kerala

Month	Rainfall mm	Temperature °C		Relative humidity per cent		Sunshine hours
		Maximum	Minimum	Maximum	Minimum	
January	8.90	32.20	21.80	96.99	59.40	9.19
February	-	32.77	22.61	94.87	60.43	9.65
March	48.65	33.15	23.85	92.91	64.79	9.44
April	7.00	33.67	25.66	87.96	65.83	9.08
May	251.75	33.35	25.86	89.60	69.04	8.64
June	1183.40	29.61	23.54	98.44	87.60	2.38
July	630.70	29.46	23.71	98.05	85.57	3.13
August	495.20	29.40	23.44	99.60	84.11	5.16
September	122.85	30.31	23.42	97.61	77.33	7.53
October	387.40	30.24	22.84	97.60	77.15	6.93
November	70.25	31.84	22.16	95.58	62.69	8.62
December	12.60	31.85	20.23	97.53	57.01	9.72
Total	3218.70					

Appendix 2 Textural composition of soil in experiment No.1

Treatment No.	R_1			R_2			R_3			R_4		
	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %
1	77.62	3.20	19.19	71.22	3.20	25.59	68.02	3.20	28.78	68.02	3.20	25.59
2	80.81	3.20	15.99	71.22	8.63	20.15	71.21	4.80	25.59	71.22	9.60	25.59
3	80.81	3.20	15.99	74.41	6.40	19.19	71.21	6.40	23.99	68.02	3.20	22.39
4	80.81	3.20	15.99	71.22	6.40	22.39	68.01	6.40	25.59	71.22	3.20	25.59
5	87.21	4.80	8.00	74.41	6.40	19.19	71.21	4.80	22.39	71.22	3.20	25.59
6	80.81	3.20	15.99	71.22	6.40	22.39	66.41	6.40	28.79	74.41	3.20	22.39

Appendix 3 Textural composition of soil in experiment No.2

Treatment No.	R_1			R_2			R_3			R_4		
	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %
1	71.21	3.20	25.59	74.40	3.20	22.40	74.40	3.20	22.40	71.21	6.4	22.40
2	68.01	6.40	25.59	72.80	4.80	22.40	77.60	3.20	19.20	74.41	6.4	19.20
3	68.01	3.20	28.79	74.40	3.20	22.40	74.40	3.20	22.40	71.21	6.4	22.40
4	71.21	3.20	25.59	74.40	3.20	22.40	77.60	3.20	19.20	74.41	3.2	22.40
5	71.21	3.20	25.59	74.40	3.20	22.40	74.40	3.20	22.40	74.41	3.2	22.40
6	69.21	3.20	27.19	74.40	3.20	22.40	74.40	1.60	24.00	77.61	3.2	19.19

Appendix 4 Effect of fertilizer treatments on the number of leaves retained by the palm (ANOCOVA)

Source	df	SXX	SXY	SYY
Replications	3	101.37	27.89	12.74
Treatments	5	29.05	18.89	17.73
Error	15	85.91	46.81	60.40
Total	23	216.32	93.58	90.88
Treatments + error	20	114.96	65.70	78.13

Adjusted error SS = 34.90
Adjusted (treatment + error) SS = 40.59
Adjusted treatment SS = 5.69
Adjusted treatment mean SS = 1.14
Adjusted error mean SS = 2.49
F with 5, 14 df = 0.456 NS

NS = Not significant

Appendix 5 Effect of treatments on the number of leaves produced per palm per year (ANOCOVA)

Source	df	SXX	SXY	SYY
Replications	3	4.86	0.70	0.64
Treatments	5	2.94	1.36	2.10
Error	15	4.07	2.52	4.50
Total	23	11.87	4.58	7.24
Treatment + error	20	7.01	3.88	6.60

Adjusted error SS = 2.94
Adjusted (treatment + error)SS = 4.46
Adjusted treatment SS = 1.51
Adjusted (treatment) mean SS = 0.303
Adjusted (error) mean SS = 0.210

F with 5, 14 df = 1.44 NS

NS = Not significant

Appendix 6 Effect of treatments on the number of female flowers produced per palm per year (ANOVA)

Source	df	SS	MS	F	
Blocks	3	4073.38	1357.79	2.17	
Treatments	5	4465.75	893.15	1.43	NS
Error	15	9398.63	626.58		
Total	23	17937.75			

Appendix 7 Difference between treatment yield and pre-treatment yield of the palms, nuts per palm per year (ANOVA)

Source	df	SS	MS	F	
Blocks	3	3115.34	1038.45	12.70	
Treatments	5	652.91	130.58	1.597	NS
Error	15	1226.36	81.76		
Total	23	3115.34			

Appendix 8 Effect of fertilizer treatments on the yield of palm, nuts per palm per year (ANOCOVA)

Source	df	SXX	SXY	SYY
Replications	3	6391.94	1188.27	449.10
Treatments	5	1615.75	903.42	1358.99
Error	15	2678.27	2148.76	3028.18
Total	23	10685.96	4240.45	4836.27
Treatment + error	20	4294.02	3052.18	4387.17

Adjusted error SS = 1304.24
Adjusted (treatment + error) SS = 3153.60
Adjusted (treatment) mean SS = 369.86
Adjusted (error) mean SS = 93.16

F with 5, 14 df = 3.97*

T_2 T_4 T_5 T_6 T_3 T_1

*Significant at 5% level

Appendix 9 Effect of fertilizer treatments on copra weight per nut, g (ANOVA)

Source	df	SS	MS	F	
Block	3	11074.09	3691.36	5.68	
Treatment	5	2730.53	546.11	0.84	NS
Error	15	9744.25	649.62		
Total	23	23548.87			

Appendix 10 Effect of fertilizer treatments on percentage oil recovery (ANOVA)

Source	df	SS	MS	F	
Block	3	101.98	33.995	0.774	
Treatments	5	151.422	30.28	0.689	NS
Error	15	659.21	43.95		
Total	23	912.62			

Appendix 11 Effect of fertilizer treatment on content of nitrogen in leaf, per cent (ANOVA)

Source	df	SS	MS	F	
Block	3	0.140	0.047	0.702	
Treatments	5	0.607	0.121	1.830	NS
Error	15	0.995	0.066		
Total	23	1.742			

Appendix 12 Effect of fertilizer treatments on phosphorus content of leaf, per cent (ANOVA)

Source	df	SS	MS	F	
Block	3	0.002	0.001	3.16	
Treatments	5	0.001	0.002	0.684	NS
Error	15	0.002	0.001		
Total	23	0.004			

Appendix 13 Effect of fertilizer treatments on potassium content of leaf, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.090	0.030	1.606
Treatments	5	0.773	0.155	8.278**
Error	15	0.280	0.019	
Total	23	1.142		

T_2 T_3 T_4 T_5 T_1 T_6

** Significant at 1% level

Appendix 14 Effect of fertilizer treatments on content of sodium in leaf, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.004	0.001	0.716
Treatments	5	0.031	0.006	3.546*
Error	15	0.026	0.002	
Total	23	0.062		

T_5 T_6 T_4 T_1 T_3 T_2

*Significant at 5% level

Appendix 15 Effect of fertilizer treatments on calcium content of leaf, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.403	0.134	12.022
Treatments	5	0.026	0.005	0.463 NS
Error	15	0.168	0.011	
Total	23			

Appendix 16 Effect of fertilizer treatments on the content of magnesium in leaf, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.119	0.040	3.665	
Treatments	5	0.056	0.011	1.026	NS
Error	15	0.162	0.011		
Total	23	0.337			

Appendix 17 Effect of fertilizer treatments on the chlorine content of leaf, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.017	0.006	1.241	
Treatments	5	0.011	0.002	0.486	NS
Error	15	0.070	0.005		
Total	23	0.098			

Appendix 18 Effect of fertilizer treatments on soluble potassium content of coconut water, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.041	0.014	8.358	
Treatments	5	0.019	0.004	2.290	NS
Error	15	0.024	0.002		
Total	23	0.084			

Appendix 19 Effect of fertilizer treatments on soluble sodium content of coconut water, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.001	0.0003	1.174
Treatments	5	0.002	0.0004	6.811**
Error	15	0.001	0.00006	
Total	23	0.004		

T_6 T_5 T_1 T_4 T_3 T_2

**Significant at 1% level

Appendix 20 Effect of fertilizer treatments on percentage nitrogen in copra (ANOVA)

Source	df	SS	MS	F
Block	3	0.088	0.029	1.024
Treatments	5	0.136	0.027	0.947 NS
Error	15	0.430	0.029	
Total	23	0.655		

Appendix 21 Effect of fertilizer treatments on phosphorus per cent in copra (ANOVA)

Source	df	SS	MS	F
Block	3	0.001	0.0003	0.630
Treatments	5	0.003	0.0010	1.528 NS
Error	15	0.006	0.0004	
Total	23	0.010		

Appendix 22 Effect of fertilizer treatments on potassium content of copra, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.136	0.045	2.14
Treatments	5	0.092	0.018	0.865 NS
Error	15	0.318	0.021	
Total	23	0.548		

Appendix 23 Effect of fertilizer treatments on sodium content of copra, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.001	0.00033	1.004
Treatments	5	0.001	0.00020	3.642 *
Error	15	0.001	0.00007	
Total	23	0.003		

T_6 $\underline{T_1 \quad T_5 \quad T_4 \quad T_3 \quad T_2}$

* Significant at 5% level

Appendix 24 Effect of fertilizer treatments on calcium content of copra, per cent (ANOVA)

Source	df	SS	MS	F
Block	3	0.066	0.022	0.784
Treatments	5	0.166	0.023	0.832 NS
Error	15	0.419	0.028	
Total	23	0.601		

Appendix 25 Effect of fertilizer treatments on percentage magnesium in copra (ANOVA)

Source	df	SS	MS	F
Block	3	0.003	0.0010	6.464
Treatments	5	0.001	0.0002	1.254 NS
Error	15	0.002	0.00010	
Total	23	0.006		

Appendix 26 Influence of fertilizer treatments on the per cent chlorine in copra (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.010	0.003	4.857
Treatments	5	0.009	0.002	2.58 NS
Error	15	0.010	0.001	
Total	23	0.030		

Appendix 27 Influence of fertilizer treatments on the specific gravity of oil (ANOVA)

Source	df	SS	MS	F
Block	3	0.0003	0.00010	4.966
Treatments	5	0.0002	0.00004	2.189 NS
Error	15	0.0003	0.00002	
Total	23	0.0008		

Appendix 25 Effect of fertilizer treatments on percentage magnesium in copra (ANOVA)

Source	df	SS	MS	F
Block	3	0.003	0.0010	6.464
Treatments	5	0.001	0.0002	1.254 NS
Error	15	0.002	0.00010	
Total	23	0.006		

Appendix 26 Influence of fertilizer treatments on the per cent chlorine in copra (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.010	0.003	4.857
Treatments	5	0.009	0.002	2.58 NS
Error	15	0.010	0.001	
Total	23	0.030		

Appendix 27 Influence of fertilizer treatments on the specific gravity of oil (ANOVA)

Source	df	SS	MS	F
Block	3	0.0003	0.00010	4.966
Treatments	5	0.0002	0.00004	2.189 NS
Error	15	0.0003	0.00002	
Total	23	0.0008		

Appendix 28 Effect of fertiliser treatments on the refractive index of oil (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.125	0.042	0.999
Treatments	5	0.208	0.042	0.999 NS
Error	15	0.626	0.042	
Total	23	0.959		

Appendix 29 Effect of fertilizer treatments on iodine number of coconut oil (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.858	0.286	1.059
Treatments	5	2.459	0.492	1.821 NS
Error	15	4.050	0.270	
Total	23	7.367		

Appendix 30 Effect of treatments on the saponification value of coconut oil (ANOVA)

Source	df	SS	MS	F
Blocks	3	82.75	27.58	1.219
Treatments	5	147.00	29.40	1.299 NS
Error	15	339.50	22.63	
Total	23	569.25		

Appendix 31 Soil pH as influenced by the fertilizer treatments (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.341	0.114	1.569	
Treatments	5	0.216	0.043	0.596	NS
Error	15	1.086	0.072		
Total	23	1.643			

Appendix 32 EC of the soil as influenced by the fertilizer treatments, mmho/cm (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.005	0.0020	1.982	
Treatments	5	0.002	0.0004	0.402	NS
Error	15	0.013	0.0010		
Total	23	0.019			

Appendix 33 Effect of fertilizer treatments on the apparent density of soil, g/cm^3 (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.027	0.009	2.537	
Treatments	5	0.015	0.003	0.825	NS
Error	15	0.053	0.004		
Total	23	0.095			

Appendix 34 Effect of fertilizer treatments on the absolute specific gravity of soil (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.388	0.129	4.152	
Treatments	5	0.245	0.049	1.57	NS
Error	15	0.467	0.631		
Total	23	1.100			

Appendix 35 Effect of fertilizer treatments on the pore space of soil, per cent (ANOVA)

Source	df	SS	MS	F
Blocks	3	511.86	170.62	65.53
Treatments	5	67.59	13.52	5.19**
Error	15	39.06	2.60	
Total	23	618.50		

T_6 T_2 T_1 T_5 T_3 T_4

**Significant at 1% level

Appendix 36 Effect of fertilizer treatments on percentage volume expansion of soil (ANOVA)

Source	df	SS	MS	F	
Blocks	3	10.105	3.368	1.468	
Treatments	5	16.983	3.397	1.480	NS
Error	15	34.430	2.295		
Total	23	61.518			

Appendix 37 Effect of fertiliser treatments on maximum water holding capacity of soil, per cent (ANOVA)

Source	df	SS	MS	F
Blocks	3	458.84	152.95	5.14
Treatments	5	112.73	22.55	0.757 NS
Error	15	446.51	29.77	
Total	23	1018.08		

Appendix 38 Effect of treatments on moisture retention at 0.3 bar (field capacity), per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	172.22	57.410	13.08
Treatments	5	8.36	1.672	0.381 NS
Error	15	65.82	4.390	
Total	23	246.40		

Appendix 39 Effect of fertilizer treatments on moisture retention at 15 bar (wilting coefficient) per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	119.78	39.99	8.84
Treatments	5	32.31	6.46	1.43 NS
Error	15	67.84	4.52	
Total	23	220.12		

Appendix 40 Effect of fertilizer treatments on available water of soil, per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	12.89	4.30	1.036
Treatments	5	30.17	6.03	1.460 NS
Error	15	62.21	4.15	
Total	23	105.27		

Appendix 41 Effect of fertilizer treatments on mean weight diameter, mm (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.387	0.129	2.112
Treatments	5	0.415	0.083	1.359 NS
Error	15	0.917	0.061	
Total	23	1.720		

Appendix 42 Influence of fertilizer treatments on the structural coefficient of soil (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.016	0.005	1.382
Treatments	5	0.050	0.010	2.543 NS
Error	15	0.059	0.004	
Total	23	0.125		

Appendix 43 Influence of treatments on the organic carbon, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.027	0.009	1.396	
Treatments	5	0.037	0.007	1.100	NS
Error	15	0.098	0.007		
Total	23	0.162			

Appendix 44 Influence of fertilizer treatments on total nitrogen content of soil, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.0002	0.00006	0.207	
Treatments	5	0.0008	0.00016	0.055	NS
Error	15	0.0435	0.00290		
Total	23	0.0445			

Appendix 45 Influence of fertilizer treatments on available phosphorus content in soil, kg/ha (ANOVA)

Source	df	SS	MS	F	
Blocks	3	356.13	118.71	1.75	
Treatments	5	311.77	62.35	0.92	NS
Error	15	1016.99	67.80		
Total	23	1684.89			

Appendix 46 Influence of fertilizer treatments on available potassium content in soil, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	9407.97	3135.99	0.435
Treatments	5	676853.3	135370.66	18.770**
Error	15	108192.03	7212.802	
Total	23	794453.30		

$\underline{T_2 \quad T_3 \quad T_4} \quad \underline{T_5 \quad T_6 \quad T_1}$

**Significant at 1% level

Appendix 47 Influence of fertiliser treatments on available sodium in soil, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	1680.76	560.25	3.22
Treatments	5	1587.25	317.45	1.82 NS
Error	15	2612.35	174.16	
Total	23	5880.36		

Appendix 48 Influence of fertiliser treatments on available chlorine in soil, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	9180.63	3060.21	2.13
Treatments	5	1995.75	399.15	0.278 NS
Error	15	21554.66	1436.98	
Total	23	32731.03		

Appendix 49 Influence of fertiliser treatments on CEC of soil, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	2.52	0.84	0.34
Treatments	5	15.73	3.15	1.28 NS
Error	15	36.89	2.46	
Total	23	55.13		

Appendix 50 Influence of fertiliser treatments on exchangeable calcium, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.172	0.057	3.85
Treatments	5	0.163	0.033	2.18 NS
Error	15	0.224	0.015	
Total	23	0.558		

Appendix 51 Influence of fertilizer treatments on exchangeable magnesium, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.682	0.227	3.43
Treatments	5	0.103	0.021	0.312 NS
Error	15	0.994	0.066	
Total	23	1,779		

Appendix 52 Influence of fertilizer treatments on exchangeable potassium, me/100 g

Source	df	SS	MS	F
Blocks	3	0.011	0.004	0.568
Treatments	5	0.598	0.120	18.593**
Error	15	0.097	0.006	
Total	23	0.706		

T_2 T_3 T_4 T_5 T_6 T_1

** Significant at 1% level

Appendix 53 Influence of fertilizer treatments on exchangeable sodium, me/100 g (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.018	0.006	2.625	
Treatments	5	0.022	0.004	1.958	NS
Error	15	0.034	0.002		
Total	23	0.074			

Appendix 54 Influence of fertilizer treatments on exchangeable sodium percentage of soil (ANOVA)

Source	df	SS	MS	F	
Blocks	3	1.298	0.433	2.210	
Treatments	5	2.302	0.460	2.351	NS
Error	15	2.937	0.196		
Total	23	6.538			

Appendix 55 Effect of fertilizer treatments on the number of functioning leaves retained by the palm in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	7.19	2.40	1.29
Treatments	5	27.49	5.50	2.96 *
Error	15	27.85	1.86	
Total	23	62.53		

T_4 T_3 T_5 T_6 T_2 T_1

* Significant at 5% level

Appendix 56 Effect of fertilizer treatments on the number of leaves produced so far in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	676.08	225.36	4.56
Treatments	5	160.67	32.13	0.65 NS
Error	15	741.94	49.46	
Total	23	1578.69		

Appendix 57 Early flowering index of the palms in experiment No.2 as influenced by fertilizer treatments (ANOVA)

Blocks	3	4.32	1.44	2.36
Treatments	5	7.54	1.51	2.47 NS
Error	15	9.17	0.61	
Total	23	21.02		

Appendix 58 Influence of fertilizer treatments on nitrogen per cent in leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.199	0.066	0.907
Treatments	5	0.333	0.067	0.910 NS
Error	15	1.097	0.073	
Total	23	1.629		

Appendix 59 Influence of fertilizer treatments on phosphorus per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.001	0.0003	1.000
Treatments	5	0.004	0.0010	2.554 NS
Error	15	0.005	0.0003	
Total	23	0.010		

Appendix 60 Influence of fertilizer treatments on potassium per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.218	0.073	1.85
Treatments	5	0.933	0.587	14.97**
Error	15	0.588	0.039	
Total	23	3.739		

T_2 T_3 T_4 T_5 T_1 T_6

** Significant at 1% level

Appendix 61 Effect of fertilizer treatments on the sodium per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.004	0.001	0.707
Treatments	5	0.170	0.034	17.65**
Error	15	0.029	0.002	
Total	23	0.202		

T_6 T_5 T_1 T_4 T_3 T_2

** Significant at 1% level

Appendix 62 Effect of fertilizer treatments on the calcium per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.005	0.022	0.700
Treatments	5	0.029	0.006	2.34 NS
Error	15	0.037	0.002	
Total	23	0.072		

Appendix 63 Effect of fertilizer treatments on magnesium per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.005	0.002	0.802
Treatments	5	0.007	0.001	0.606 NS
Error	15	0.033	0.002	
Total	23	0.045		

Appendix 64 Effect of fertilizer treatments on the chlorine per cent of leaf in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.017	0.006	2.25
Treatments	5	0.070	0.014	5.44**
Error	15	0.038	0.003	
Total	23	0.126		

T_3 T_4 T_2 T_5 T_6 T_1

** Significant at 1% level

Appendix 65 Effect of fertilizer treatments on soil pH in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.508	0.169	5.86
Treatments	5	0.398	0.080	2.76 NS
Error	15	0.433	0.029	
Total	23	1.340		

Appendix 66 Effect of fertilizer treatments on EC of soil, mmho/cm (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.023	0.008	3.64
Treatments	5	0.006	0.001	0.61 NS
Error	15	0.031	0.002	
Total	23	0.060		

Appendix 67 Effect of treatments in the apparent density of soil in experiment No.2, g/cm3 (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.013	0.004	2.559
Treatments	5	0.003	0.001	0.368 NS
Error	15	0.026	0.002	
Total	23	0.046		

Appendix 68 Absolute specific gravity of soil in experiment No.2 as influenced by the fertilizer treatments (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.351	0.117	5.48
Treatments	5	0.190	0.038	1.77 NS
Error	15	0.320	0.021	
Total	23	0.862		

Appendix 69 Influence of fertilizer treatments on per cent pore space of soil in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	40.254	13.418	1.799
Treatments	5	7.012	1.420	0.190 NS
Error	15	111.867	7.458	
Total	23	159.223		

Appendix 70 Percentage volume expansion of soil in experiment No.2 as influenced by fertilizer treatments (ANOVA)

Source	df	SS	MS	F
Blocks	3	8.011	2.670	1.915
Treatments	5	4.114	0.823	0.590 NS
Error	15	20.918	1.395	
Total	23	33.043		

Appendix 71 Influence of fertilizer treatments on maximum water holding capacity of soil in experiment No.2, per cent (ANOVA)

Source	df	SS	MS	F
Blocks	3	20.66	6.89	0.972
Treatments	5	23.65	4.73	0.670 NS
Error	15	106.31	7.09	
Total	23	150.62		

Appendix 72 Influence of fertilizer treatments on moisture retention at 0.3 bar (field capacity) in experiment No.2, per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	87.33	29.11	32.92
Treatments	5	15.85	3.17	3.58*
Error	15	13.27	0.88	
Total	23	116.44		

T_5 T_4 T_1 T_2 T_6 T_3

*Significant at 5% level

Appendix 73 Influence of fertilizer treatments on moisture percentage of soil at 15 bar (wilting coefficient) in experiment No.2, per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	25.13	8.38	5.35
Treatments	5	2.11	0.42	0.27 NS
Error	15	23.51	1.57	
Total	23	50.74		

Appendix 74 Influence of fertilizer treatments on available water of soil in experiment No.2, per cent by weight (ANOVA)

Source	df	SS	MS	F
Blocks	3	17.37	5.79	3.69
Treatments	5	24.55	4.91	3.13*
Error	15	23.52	1.57	
Total	23	65.44		

T_4 T_5 T_1 T_6 T_2 T_3

*Significant at 5% level

Appendix 75 Influence of fertilizer treatments on mean weight diameter of soil in experiment No.2, (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.676	0.225	4.542
Treatments	5	0.073	0.015	0.295 NS
Error	15	0.745	0.050	
Total	23	1.494		

Appendix 76 Structural coefficient of soil in experiment No.2 as influenced by fertilizer treatments (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.003	0.001	0.038	
Treatments	5	0.033	0.007	1.944	NS
Error	15	0.051	0.003		
Total	23	0.087			

Appendix 77 Influence of fertilizer treatments on the organic carbon content of soil in experiment No.2, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.027	0.009	1.396	
Treatments	5	0.036	0.007	1.100	NS
Error	15	0.098	0.007		
Total	23	0.162			

Appendix 78 Effect of fertilizer treatments on total nitrogen content of soil in experiment No.2, per cent (ANOVA)

Source	df	SS	MS	F	
Blocks	3	0.0002	0.00006	0.207	
Treatments	5	0.0008	0.00016	0.055	NS
Error	15	0.0435	0.0029		
Total	23	0.0445			

Appendix 79 Effect of fertilizer treatments on available phosphorus in soil in experiment No.2, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	356.13	118.71	1.75
Treatments	5	311.77	62.35	0.92 NS
Error	15	1016.99	67.80	
Total	23	1684.89		

Appendix 80 Effect of fertilizer treatments on available potassium in soil in experiment No.2, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	131287.3	43762.43	5.53
Treatments	5	652451.3	13049.26	16.5**
Error	15	118612.7	7907.51	
Total	23	902351.3		

T_2 T_3 T_4 T_5 T_6 T_1

**Significant at 1% level

Appendix 81 Effect of fertilizer treatments on available sodium in soil in experiment No.2, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	1613.03	537.68	0.48
Treatments	5	22588.46	4517.69	4.01*
Error	15	16909.55	1127.30	
Total	23	41111.04		

T_6 T_5 T_4 T_3 T_1 T_2

*Significant at 5% level

Appendix 82 Effect of fertiliser treatments on available chlorine in soil in experiment No.2, kg/ha (ANOVA)

Source	df	SS	MS	F
Blocks	3	3110.047	1036.682	1.661
Treatments	5	5072.578	1014.516	1.625 NS
Error	15	9363.653	624.244	
Total	23	17546.281		

Appendix 83 Effect of fertilizer treatments on CEC of soil in experiment No.2, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	5.012	1.671	3.181
Treatments	5	4.464	0.893	1.700 NS
Error	15	7.879	0.525	
Total	23	17.355		

Appendix 84 Effect of fertilizer treatments on exchangeable calcium in soil in experiment No.2, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.737	0.246	4.783
Treatments	5	0.440	0.088	1.715 NS
Error	15	0.770	0.051	
Total	23	1.947		

Appendix 85 Effect of fertilizer treatments on exchangeable magnesium in soil in experiment No.2, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	1.069	0.356	4.442
Treatments	5	0.606	0.121	1.511 NS
Error	15	1.203	0.080	
Total	23	2.879		

Appendix 86 Influence of fertilizer treatments on exchangeable potassium in soils, in experiment No.2, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.117	0.039	0.799
Treatments	5	0.457	0.091	1.864 NS
Error	15	0.735	0.049	
Total	23	1.310		

Appendix 87 Influence of fertilizer treatments on exchangeable sodium in soil, in experiment No.2, me/100 g (ANOVA)

Source	df	SS	MS	F
Blocks	3	0.056	0.019	0.600
Treatments	5	0.152	0.030	0.982 NS
Error	15	0.465	0.031	
Total	23	0.673		

Appendix 88 Exchangeable sodium percentage of soil as influenced by fertilizer treatments in experiment No.2 (ANOVA)

Source	df	SS	MS	F
Blocks	3	1.949	0.650	1.410
Treatments	5	6.438	1.288	2.795 NS
Error	15	15.297	0.461	
Total	23			

EFFECT OF SODIUM CHLORIDE ON SOIL CHARACTERISTICS, YIELD AND QUALITY OF COCONUT GROWN IN A LATERITE SOIL

By

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ABSTRACT OF THESIS

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ABSTRACT

The coconut palms of the sodium chloride trial conducted at the Regional Agricultural Research Station (K.A.U.), Pilicode, Kasaragod district, Kerala were made use of for the present study. At the Regional Agricultural Research Station, Pilicode there are two field experiments laid out in 1976, in order to evaluate the effect of NaCl on coconut palms. The soil type of the experiment site is laterite. The design, layout and treatments were the same for both the experiments. It is randomised block design with six treatments and four replications retaining six palms per plot.

Treatments

T_1 Control

T_2 1000 g K_2O/palm/year

T_3 750 g K_2O + 250 g Na_2O/palm/year

T_4 500 g K_2O + 500 g Na_2O/palm/year

T_5 250 g K_2O + 750 g Na_2O/palm/year

T_6 1000 g Na_2O/palm/year

Potassium was applied as KCl and sodium as NaCl. In both experiments the crop is rainfed and the area receives an average annual rainfall of 3200 mm. The present study was conducted with soil and leaf samples drawn from these two experimental sites. The first experiment was conducted with 24 year old stock of hybrid palms (TxD) which received N, P and K as per the recommended dose till 1976 after which the above treatments were superimposed. Thus the palms received the treatments only for the last 10 years from 1976 to till the time of sampling for this study (January, 1986). The second experiment was laid out with newly planted coconut seedlings (DxT) and therefore the treatments were given from planting to till the date of sampling.

The soil, leaf and nut samples were collected from the first experiment for chemical analysis to find out the effect of NaCl on soil characteristics, nutrient uptake, yield and quality of copra. In the second experiment, as the palm had not reached the bearing stage only the soil and leaf samples were collected. Data on the yield and morphological characteristics of the palms were collected from the R.A.R.S., Pilicode. In the second experiment as the palms have not reached stabilized yield, the yield data were not collected. The nutrient contents of leaf and copra were analysed and the quality of oil was estimated. The soil samples were subjected to physical and chemical analysis.

The fertilizer treatments did not differ significantly in respect of the number of functioning leaves retained by the palms in the experiment No.1. Yield was significantly correlated with the number of functioning leaves and a unit increase in number of leaf would correspond to an increase in yield of 5.045 nuts per palm. In the second experiment, the number of functioning leaves was significantly influenced by the fertilizer treatments. The maximum number of leaves (18.48) was recorded by treatment No.4 (50% substitution of K_2O by Na_2O) and the minimum number of leaves (15.3) was registered by T_1 (control).

The treatments did not differ significantly in their influence on the total number of leaves produced per palm per year in the case of the first experiment and on the total number of leaves produced so far by the palms of the second experiment. Differences between treatments were not significant with regard to the number of female flowers produced per palm in the first experiment or the early flowering nature of the palms of the second experiment.

Observations on yield, in the first experiment revealed that yield of the palms increased continuously with progressing period of time and the maximum increase in yield was in T_4 (50% substitution of K_2O by Na_2O). Though there was 104.15 per cent increase in yield in T_4 as compared to T_1, the difference was not found statistically significant, the significance being lost by marginal difference. When the data were subjected to the analysis of covariance the adjusted treatment mean values varied significantly, the maximum being recorded by T_2 (1000 g K_2O) and the minimum by T_1 (control). Treatment T_2 was closely followed by T_4 and the differences between T_2, T_4, T_5, T_6 and T_3 were not significant.

The treatments did not differ significantly in their influence on the copra weight per nut. The percentage oil recovery of copra did not differ significantly by the application of treatments.

Nitrogen and phosphorus uptake by the palms in both the experiments did not differ significantly by the application of treatments. The potassium uptake was decisively influenced by the treatments in both experiments. Treatments receiving higher levels of K showed a correspondingly higher uptake of this element. The treatment T_1 (control) registered a higher uptake of K than T_6 (1000 g Na_2O). The sodium uptake by the palms in both the experiments was also significantly influenced by the treatments. In general, palms receiving higher levels of Na retained higher amount of Na in their leaves. Antagonism between K and Na in leaves was also exhibited in both experiments. The uptake of divalent cations (Ca and Mg) by the palms was not decesively influenced by the application of treatments in both experiments. The treatments did not differ significantly in the uptake of Cl by the palms in the case of the first experiment. But in the second experiment, the Cl uptake of the palms was decisively influenced by the treatments. The treatment T_1 (control) which received no application of Cl recorded the minimum value which was significantly lower than all other treatment mean values. All other treatment mean values were statistically on par.

The soluble K content of coconut water did not differ significantly by the application of treatments whereas the soluble Na content of coconut water showed significant variation between treatments. The maximum amount of Na was in T_6 (1000 g Na_2O).

The copra analysis showed that the treatments did not differ significantly with regard to their influence on the extent of N, P and K in copra. The sodium content of copra was found to be influenced by the treatments. The Na content increased with increasing application of Na. The differences between treatments in the case of Ca, Mg and Cl contents of copra were not statistically significant.

The analysis on the quality of oil revealed that there was no significant difference in the specific gravity, refractive index, iodine number and saponification value of oil, between treatments.

The pH and EC of the soil did not differ between the treatments in both the experiments. The soil physical constants viz., apparent density, absolute specific gravity, percentage pore space, percentage volume expansiion and maximum water holding capacity were not significantly different under various treatments in both the experiments. The moisture retention characteristics like field capacity and wilting coefficient and the percentage available water of the soil were not significantly influenced by the substitution of KCl, by NaCl to various extent.

The aggregate analysis of the soil of both the experiment sites showed that there was no significant difference between treatments in the percentage aggregate stability of the soil. Thus the structure of the soil was not found affected due to the application of NaCl at the rate employed in the experiment.

The treatments did not differ in their influence on the percentage organic carbon in soil, total N in soil and available P in soil in both the experiments.

Available K in soil registered significant difference between treatments in both the experiments. Invariably, treatment receiving the highest amount of K (T_2 1000 g K_2O) retained the highest amount of this element in soil. In general soil receiving a higher quantity of NaCl recorded higher values for available Na in soil. However, the differences between treatment means were not sufficient to establish statistical significance, in the case of the first experiment. In the second experiment the treatments had significant influence on available Na in soil and the treatment T_6 (1000 g of Na_2O) registered a significantly higher value of available Na than all other treatments. The available chlorine in soil did not differ significantly due to the application of treatments.

The treatments did not differ significantly as far as CEC of the soil in both experiments was considered. Exchangeable Ca and Mg contents in soil in both the experiments did not differ significantly between treatments. The treatments could decisively influence the exchangeable K in soil in the first experiment but failed to do so in the second experiment. The values of exchangeable K registered by individual treatments increased in accordance with the increasing order of application of K to soil in the first experiment. Exchangeable Na as well as exchangeable Na percentage in soil were not significantly different when the treatment means were compared.

These results showed that substitution of K_2O applied to coconut palms as KCl, by Na_2O applied as NaCl to the extent of 50 per cent is possible without a reduction in the yield, quality of soil and adverse effects on soil characteristics, under the climatic and soil conditions comparable to that tried in this experiment.