STUDIES ON A MANURE SUPPLEMENT CONTAINING SECONDARY AND TRACE ELEMENTS PREPARED FROM SEA WATER (SAGAR) ON THE GROWTH, YIELD, QUALITY AND ABSORPTION OF NUTRIENTS BY RICE

BY

N P CHINNAMMA B Sc (Ag)

THESIS SUBMITTED TO
THE FACULTY OF AGRICULTURE KERALA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL CHEMISTRY)

DIVISION OF AGRICULTURAL CHEMISTRY,
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TRIVANDRUM

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C E R T I F I C A T E

Certified that this thesis is a record of research work done independently by Smt. N.P. Chinnamma 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.

(N.S. Money)

Chairman, Advisory Committee
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Faculty of Agriculture,
Kerala Agricultural University

College of Agriculture,
Vellayani, Trivandrum

July, 1975

APPROVED BY:

Chairman:

(N.S. Money)

Members:

(M.M. Koshy) 13/10.71

(K.P.Madhavan Nair)

(P. Balakrishna Pillai)

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N. P. CHINNAMMA

C O N T E N T S

INTRODUCTION

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It is now well established that sixteen elements are essential for the proper growth and sustenance of plants. Nine of them, carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur are taken up in larger amounts by the plants, and are, therefore called major or macronutrients. Boron, copper, manganese, zinc, molybdenum, iron and chlorine are needed in very small amounts or traces and are hence known as micronutrients or trace elements. In addition to these, sodium, silicon, vanadium and cobalt appear to be helpful for the growth of certain species and are grouped as beneficial elements.

Use of balanced fertilisation is advocated for maximum returns and maintenance of soil fertility. Balanced fertilization aims at not only the use of NPK in optimum quantities but includes also the use of other nutrients. The deficiencies of secondary and micronutrients were not occurring widely because of lower rate of production and because of incidental applications through manures and fertilizers. With higher production levels and the use of high analysis fertilizers, the need for applying secondary nutrients like calcium, magnesium and sulphur and micronutrients like iron, manganese, zinc, copper, boron and molybdenum is being increasingly felt.

The maximum benefit from application of NPK fertilizers and even the secondary nutrients is not obtained in the absence of adequate amounts of available micronutrients in soil. The nutrition of plants with micronutrients depends on several factors other than the ability of the soil to supply these elements. Among them may be mentioned the rate of nutrient absorption, mobility within the plant and its distribution to functional sites. Each one of these processes is affected by interactions among the micronutrients and also between micro and macro nutrients. This shows that the relative proportion of elements in the medium may be of more significance than the absolute amount present either in external medium or in the plant tissue. Therefore, for achieving higher yields, balanced fertilizer schedules will have to be evolved, keeping in view not only the contents of macronutrients but also the secondary and micronutrients and their interactions in soils and plants.

Varghese and Money (1965) have reported the beneficial effects of secondary elements like calcium and magnesium in increasing the efficiency of NPK fertilizers for rice in Kerala soils. But a detailed study taking into consideration of the secondary and micronutrients has not been so far conducted on rice in Kerala. Hence the present investigation was envisaged to study the effect of a manure supplement prepared from sea water containing secondary and trace elements on the growth, yield and quality of rice and the absorption of nutrients from soil.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The manure supplement prepared from sea water and used for study in this experiment is available in two forms. (1) Sagar manure and (2) Sagar complex. Both these products are used in a 50:50 ratio in this experiment. They are a rare combination of nutrients and contain nitrogen, phosphorus, potassium, magnesium, sulphur, boron, copper, manganese, zinc, molybdenum, chlorine, vanadium, bromine and iodine. Therefore, in the following pages the literature pertaining to the effect of these supplementary nutrients in increasing the efficiency of N, P and K, when used in conjunction with them are briefly reviewed.

Magnesium

Magnesium is the only mineral constituent of the chlorophyll molecule. It appears to be related to phosphorus metabolism and is considered to be specific in the activation of a number of plant enzyme systems.

Influence on the growth, yield and other characteristics of rice plant

The experiment conducted by Volker (1915) indicated that magnesium treated rice plants tillered better and produced healthier tillers.

Narayana and Vasudevan (1957) obtained three per cent increase in yield of rice by foliar application of magnesium sulphate.

The experiment conducted by Sadapal and Das (1961) in a sandy loam of pH 7.0 and of medium fertility showed an appreciable increase in the number of grains per panicle and 1000 grain weight in wheat by magnesium application.

Sadapal and Das (1961) obtained increased protein content in wheat grain due to magnesium application.

Contrary to the above, Schropp (1949) and Kobayashi et al (1956) obtained a negative response to magnesium in relation to protein content in rice.

Varghese and Money (1965) reported that magnesium applied alone or in combination with calcium had a beneficial effect in reducing the ratio of the number of grain to chaff. It was also observed that magnesium application increased the length of panicle and the number of grains per panicle.

Nair and Koshy (1966) reported that the form (magnesium oxide, magnesium carbonate and magnesium sulphate) or level of magnesium (25 and 50 kg MgO/ha) had no effect on tillering of rice. The yield of grain and straw were not significantly influenced by the different forms of magnesium at the rates applied. However the magnesium treatments tended to increase the yield of rice over control. The weight of 1000 grains was also higher for treatments with these compounds.

Kurup and Ramankutty (1969) observed that on an alluvial clay soil of pH 4.5, application of magnesium silicate or magnesium carbonate did not affect the yield or tiller production of paddy but magnesium silicate at higher rates (50 kg/ha SiO_2) increased the straw yield. Magnesium carbonate and magnesium silicate at lower levels, suppressed the height of the plants; this effect of magnesium carbonate was nullified by the presence of sodium silicate.

Padmaja and Varghese (1972) observed that the quality of grain and straw as indicated by their protein content was markedly increased by the application of soil amendments like calcium oxide or magnesium carbonate.

Interactions with other nutrients

Loew (1901) was of the opinion that magnesium helped to improve the phosphorus economy in plants.

Zimmerson (1947) and Sadapal and Das (1961) also obtained an increased phosphorus content of crops following magnesium application.

Contradictory results have been reported by various workers as regards the influence of magnesium on potash availability.

Griffith (1959) in his investigations on the influence of magnesium on the availability of potash, obtained a decrease in the uptake of potassium. Koshy (1960) also obtained a similar result.

The study by Chambers (1953) indicated that magnesium increased crop yields by increasing the potassium supply.

Dewan and Hunter (1949) and Schachtschabel and Hoffman (1958) reported increase in the magnesium content of plants by the application of magnesium. Padmaja and Varghese (1972) also obtained similar results.

Graham (1956) observed that the addition of magnesium did not affect the magnesium or the potash content of crops.

Kemp and Geurink (1970) reported that magnesium fertilisation over an eight year period on grassland on a sandy soil increased the magnesium content of the soil from 50 - 400 mg per kg of dry soil (58 - 88 kg/ha MgO). With light potassium dressings, magnesium fertilization increased the magnesium content of the grass from about 0.15 - 0.25 per cent; the effect was less pronounced with heavy potassium dressings.

Contradictory views have been expressed by various workers on the effect of magnesium on calcium uptake and availability.

Blair et al (1939) noted that the addition of magnesium compounds resulted in a decrease in calcium content of plants. Griffith (1959) observed a decreased uptake of calcium due to magnesium application. Albrecht (1937), on the other hand, found that the application of magnesium released calcium from the soil.

Maas et al (1969) reported that magnesium decreased the manganese absorption rate. Manganese did not effect calcium absorption, but inhibited magnesium absorption.

Sulphur

Sulphur is required for the synthesis of sulphur containing amino acids. It activates certain proteolytic enzymes. Sulphur is a constituent of certain vitamins like thiamine and biotin.

With the intensification of Agriculture, there is an increasing use of sulphur free high analysis fertilizers. A decreased use of sulphur as a fungicide and insecticide has also been noted. These developments, along with the fact that many soils are low in sulphur, emphasise the need for a planned programme for sulphur fertilization of soils.

Sulphur as an essential element for plants

The importance of sulphur as a nutrient was first reported by Bogdanoff (1899).

Influence on the growth, yield and other characteristics of rice plant

Lockard (1972) reported that rice plant responded to sulphur in two out of the three Luzon soils tested.

Das and Datta (1973) showed that the continuous use of sulphur free fertilizers under intensive cropping pattern caused a depletion in available sulphur in soil, which resulted in obtaining response to sulphur application. The study also demonstrated that the protein content of the grains of wheat and rice was increased significantly with sulphur fertilization and that the protein quality was maintained in respect of the tryptophan and methionine contents of grain.

Das *et al* (1975) reported from the investigations carried out at the I.A.R.I. that sulphur application showed a favourable effect on the contents of essential and sulphur containing amino acids in the grain of maize, wheat and rice thus maintaining and improving protein quality.

Requirements and deficiencies

Aiyer (1945) indicated that 10 lb of sulphur per acre was adequate for rice. Chlorotic plants contained much less sulphur than healthy plants and responded to sulphate treatment by giving good results.

Saran (1949) observed that application of 40 lb per acre of sodium, aluminium and ammonium sulphates corrected sulphur deficiency and increased rice yields by 89.1, 69.6 and 91.7 per cent respectively.

Dijshoorn et al (1960) and Ashford and Bolton (1961) found that chlorosis and stunted growth of the plants were the characteristic symptoms of sulphur deficiency.

Kochler (1965) indicated that application of sulphur at the rate of 5 to 10 lb of sulphur per acre per year is generally recommended in Eastern Washington to prevent sulphur deficiencies resulting in reduced yields in cereals.

Interactions with other nutrients

Annichiarico (1964) found that application of nitrogen or nitrogen and sulphur considerably increased the nitrogen content of dry matter and amino acids of maize, the sulphur content was increased by sulphur and decreased by nitrogen and the interaction between nitrogen and sulphur was positive and significant.

Ahmed and Rahman (1969) reported that in pot experiments with a soil of pH 6.7, plant response to, and uptake of phosphorus by rice from rock phosphate were increased by the addition of elemental sulphur to soil maintained at field capacity, but were uninfluenced by the addition of sulphur to waterlogged soil.

Boron

Boron is believed to promote the nitrogen metabolism and nutrient uptake, especially calcium metabolism in the rice plant and its deficiency disturbs the meristematic action of the growing point and affects the pollen formation resulting in immature grains.

Boron as an essential element for plants

Warrington (1923) was first to establish the essentiality of the element for plant growth.

Sommer and Lipman (1926) in their study of the indispensable nature of boron for higher green plants concluded that it was essential to the life and growth of a considerable number of widely different higher plants.

Berger (1949) has described the important role of boron in cell division and in the synthesis of proteins. He has also found boron to be a necessary component of cell wall.

Influence on the growth, yield and other characteristics of rice plant

Working under field conditions Buckley (1952) observed that sodium borate applied to soil fertilized with ammonium sulphate increased the grain and straw yield of rice.

Beneficial effects of boron on the growth and yield of rice plant has been described by Patnaik (1955). Increase in paddy yield through use of boron (10 and 20 lb of borax per acre) has been reported from Central Rice Research Institute, Cuttack (Ghose et al, 1960). Mehrotra and Saxena (1967) reported that at six locations in U.P., 1.12 - 2.24 kg/ha boron as borax generally increased paddy yields. Sreedharan and George (1969) concluded from the results of experiments conducted for 3 years, that the application of boron has not increased the yield of paddy.

Gupta (1971) observed that in pot experiments application of 0.25 ppm boron to a sandy loam soil resulted in increased yield of cereals. On the other hand Mandal et al (1956) from Bihar and Grewal et al (1969) from Punjab reported no response to boron.

Lockard et al (1970) observed that additions of boron to Luzon soils significantly increased the yield of rice plants only in one soil, while in another one boron application sharply reduced the yield of plants.

Lockard (1972) also observed similar results while studying the response of rice plants grown in three potted Luzon soils to additions of boron. None of the soils was deficient in boron, as additions of boron resulted in decreased yield and the development of foliar symptoms resembling those of boron toxicity. The level of boron in the straw was increased by the addition of that nutrient to the soil.

Requirements and deficiencies

Mc Hargue et al (1940) reported that the boron requirement of cereals is only one thirtieth of the amount required by legumes.

Hirai (1948) reported that the boron content of rice varied with the position of organs, ie. more in the leaves and less in roots. In a nutrient solution containing 1 ppm boron, catalase activity was found to increase.

According to Hirai (1950) the quantity of boron absorbed by rice plants was only 10.5 g/ha.

Ishizuka and Tanaka (1962) examined the influence of boron concentration on the growth of rice. According to their studies, no boron deficiency symptoms were caused even at 0.004 ppm, while clear toxicity symptoms were observed at concentrations of more than 5 ppm.

Interactions with other nutrients

Lockard et al (1970) observed from the experiments on rice that there was a significant interaction between sulphur and boron treatments on the full grain weight.

Lockard (1972) observed while studying the response of rice plants grown on three potted Luzon soils to additions of boron, that the highest level of boron applied to the soil, significantly increased the level of sulphur in the straw compared to no application of boron, but it did not increase yield.

Pothiraj et al (1973) reported that boron application markedly increased its availability in soil, but had no marked influence on the availability of other nutrients.

Molybdenum

Molybdenum is seen related to nitrogen fixation and reduction of nitrate to nitrite. Molybdenum is known to be specific for the activation of the enzymes nitrate - reductase and xanthine oxidase.

Molybdenum as an essential element for plants

Arnon and Stout (1939) were the first to report a clear out response of tomato plants to molybdenum in water culture.

Influence on the growth, yield and other characteristics of rice plant

Sreedharan and George (1969) concluded from experiments conducted for 3 years that application of molybdenum had no beneficial influence on the yield of grain and straw in rice.

Requirements, deficiencies and toxicities

Ishizuka and Tanaka (1962) confirmed that in water culture rice did not show any deficiency symptoms, even if the content of molybdenum in tissue was 0.04 ppm. With a concentration of 1 ppm in the nutrient solution, the rice plant produced symptoms of molybdenum toxicity and the content of molybdenum in the plant was 4 ppm. They suggested that the upper limit of molybdenum content in the rice plant might be less than 2 ppm.

Gupta and Ram (1967) reported that in general molybdenum concentration of 0.08 to 0.19 ppm in cereal straw was considered to be in the sufficiency range.

Das Gupta et al (1972) reported that in two varieties of rice (Jaya and IR 8) in sandy loam soil reveals that in both varieties yield increased almost linearly with the increase in the levels of either nitrogen or molybdenum and the response to higher doses was significantly greater in presence of molybdenum. The linear trend of the effects of both nitrogen and molybdenum indicated that the effects were largely additive.

Interactions with other nutrients

Anderson and Spencer (1950) noted that the application of nitrogen resulted in increased molybdenum uptake. They also reported that the application of heavy dressings of manganese sulphate to soil depressed the concentration of molybdenum in the plants considerably.

According to Barshad (1951) application of phosphorus in acid soils tends to increase the uptake of molybdenum ions by the formation of phosphomolybdate ion which is absorbed more easily by the plant than the molybdate ion alone. The sulphate ion suppresses the uptake of molybdate ion as the two are of equal ionic radii and the plant is unable to distinguish between the two, thus resulting in competition.

In neutral or alkali soils according to Bingham and Garber (1960) phosphate ion itself reduces molybdenum availability by greater fixation or precipitation of molybdates induced by phosphorus fertilisation.

Mehta <u>et al</u> (1964) and Dube (1964) have reported the antagonistic effect of copper and molybdenum.

Mishra <u>et al</u> (1970) observed that different doses of nitrogen have positive effect on molybdenum uptake by wheat. The effect of adding phosphorus either alone or in combination with nitrogen is found to be non-significant on molybdenum uptake.

According to Pasricha and Randhawa (1971) excess molybdenum uptake in pastures can be controlled by sulphur application.

Copper showed antagonistic effect while phosphorus showed synergistic effect with molybdenum content (Hulagur et al 1974).

Patel and Mehta (1974) have reported that in an experiment on loamy sand of Lihoda, to study the effect of copper, molybdenum and phosphorus on alfalfa using single superphosphate as the source of phosphorus, both the content and total uptake of molybdenum were decreased by the combined effect of molybdenum and superphosphate.

Copper

Copper is an activator of several enzymes which bring about the oxidation of organic compounds by means of molecular oxygen in the rice plant.

Copper as an essential element for plants

The essentiality of copper as a plant nutrient was first established by Sommer (1931) and Lipman and Mackinney (1931) although the beneficial effect of this element in increasing the yield of grain and straw in rice had been reported much earlier by Harrison and Iyer (1917).

Influence on the growth, yield and other characteristics of rice plant

Tokuoko and Gyo (1938) observed that the growth and yield of rice increased when 0.005 ppm of copper was added to the culture solution. Similar significant increases in yield have been reported by many authors (Karunakar, 1952; Buckley, 1952; Joshi and Joshi 1952; Gopal Rao and Govindarajan, 1954; Bokde 1963; Chao and Tsui, 1963; Sreedharan and George, 1969; Primavesi and Primavesi, 1970).

Contrary results have been reported by Datta and Bains (1960) and Grewal et al (1969).

Requirements, deficiencies and toxicities

Roxas (1911) reported that the concentration of copper in plant tissue was more or less the same as that of manganese and iron.

Piper (1940) found that the copper deficiency symptoms were accompanied by some chlorophyll defect and necrosis of the leaves in rice.

Hasoda (1942) in a pot culture experiment found that the growth of rice plant was promoted by adding less than 25 ppm copper to the soil. Concentration of 100 ppm caused severe toxicity.

Lucas (1948) showed that copper was helpful in chlorophyll formation and its deficiency cause low carotene content in field crops.

Yawalkar (1953) reported a range of 2 - 50 ppm of copper for normal growth of cereals. Lal and Subharao (1953) described the role of copper in crop production and concluded the requirement of rice as 6.25 ppm. Dubey (1964) reported that the copper content of rice straw ranged from 3.1 to 7.6 ppm.

Tahtinan (1971) concluded that cereals reacted more strongly and responded more readily than ley plants to copper deficiency and copper fertilization.

<u>Interactions with other nutrients</u>

Mulder (1949) observed a positive correlation between nitrogen supply and copper requirement of plants.

Experiments by Dunne (1956) showed that the zinc level and yield of cereal grains were influenced by the copper level of the soil on which they were grown. As the copper level was increased, the zinc content of the tissue as well as yield were reduced.

According to Greenwood and Hallsworth (1960) copper and phosphorus interacted significantly in soils and the application of copper at low levels of phosphorus increased the yields to a greater extent than at higher levels of phosphorus.

Agarwala and Sharma (1961) observed that copper concentration in barley was doubled when the concentration of manganese in the nutrient solution was reduced from 0.55 to 0.0055 ppm.

Dakhore et al (1963) reported that copper treatments to wheat considerably stimulated the uptake of phosphorus, potassium and copper by wheat plants in proportion to the dose of copper applied.

Gautam et al (1964) observed that in the presence of nitrogen, phosphorus and potassium, foliar application of copper increased the nitrogen content of maize by 32.4 per cent over plants which received nitrogen, phosphorus and potassium alone.

Mehta et al (1964) have reported an inverse molybdenum-copper relationship.

Bandyopadhya and Adhikari (1968) reported that application of copper sulphate depressed the availability of soil manganese resulting in a decreased manganese content of rice straw.

Borchmann and Fibian (1971) indicated the existence of a 3 - 10 per cent yield increase and an improvement in quality as indicated by crude protein content, due to the interaction between copper and nitrogen treatments on soils of low copper status in field and pot experiments with cereals.

Manganese

Though manganese does not form a part of chlorophyll, it helps in its formation. Manganese is also related to the enzymatic oxidation in plants and is one of the micronutrients required in comparatively large amounts by the rice plant and it can even withstand excessive absorption.

Manganese as an essential element for plants

Mc Hargue (1922) confirmed the importance of manganese for higher plants.

Influence on the growth, yield and other characteristics of rice plant

Many workers have reported increase in the yield of grain and straw of paddy due to the application of manganese (Jimenez 1925; Hashimoto and Kawamori, 1951; Karunakar, 1952; Raheja *et al*, 1959; Mariakulandai and Chami, 1964; Pillai 1967; Verma, 1968; Grewal *et al*, 1969).

Kuriakose (1962) reported that manganese had beneficial effects on the number of grains per earhead and the number of productive tillers in rice.

Mandal (1954), Datta and Bains (1960) and Sreedharan and George (1969) could not find any response to manganese application.

While reviewing the response of rice to micronutrients Padhi (1971) indicated that manganese increased the grain yield of the rice crop at certain regions but not universally. The response depended largely on several soil factors such as its reaction, texture, organic matter content, microbial activity and availability of micronutrients in soil.

Requirements, deficiencies and toxicities

Tokuoka's soil culture (Tokuoka and Gyo 1940) showed that the addition of 300 ppm manganese increased the height of paddy and 600 ppm manganese reduced it. The addition of upto 1000 ppm manganese accelerated the tillering. The largest grain yield was obtained at 5 ppm.

Addition of 1 ppm and 5 ppm of manganese increased the catalase activity of rice shoots and leaves respectively (Patnaik 1950).

Abichandani (1955), summarising the results of experiments conducted on paddy in India, concluded that a concentration beyond 20 ppm was toxic to rice. Under waterlogged condition, however, manganese readily went into solution and as such deficiency cases were rare.

Patnaik (1955) reported that optimum concentration of manganese in solution culture for rice was 1 ppm and in sand culture 2.78 ppm.

The manganese requirement of rice is comparatively high. The rice plant can withstand excessive absorption of manganese (Clark et al, 1957). According to Kobayashi et al (1956) barley and wheat require 100 to 200 g/ha. But the requirement for rice was ten times more.

Agarwala and Sharma (1961) showed that iron deficiency, manganese deficiency and manganese toxicity depressed chlorophyll formation in rice suggesting that synthesis of chlorophyll was determined both by iron and manganese.

Ishizuka, et al (1961) have reported the results of nutrient solution experiments on the manganese requirement of the rice plant. A concentration of less than 0.1 ppm increased the yield, 0.1 to 10 ppm also increased the yield but only slightly and concentrations above 10 ppm reduced the yield.

Interactions with other nutrients

Mulder and Gerretsen (1952) proved that the application of phosphatic fertilizers to acid soils increased the uptake of manganese. In the case of soils low in available manganese phosphatic application had a depressing effect on the uptake of phosphorus.

Hossner and Richards (1968) obtained a highly significant correlation between plant concentrations of manganese and phosphorus in rice.

Nitrogen and sulphur additions were shown to affect the availability of manganese beneficially in arable crops (Tisdale and Betramson 1949).

Venkateswarlu (1964) found a significant increase in the manganese content of rice when he added extra sulphur, as sulphate.

There is an antagonism between iron and manganese. This has been shown by Grasmanis and Leaper (1966) who reduced toxicity due to manganese in apple leaf by injecting iron citrate and by Wallihan and Miller (1968) who induced manganese deficiency symptoms in avocado trees by applying Fe EDDHA.

Warnock (1970) observed that in phosphorus induced zinc deficient corn plants, mobilities and concentrations of manganese were inversely related to the mobility of zinc.

Sekhon and Chopra (1971) reported that in incubation studies, the application of calcium and magnesium to soil decreased the availability of exchangeable and water soluble manganese. Application of iron and zinc increased manganese availability.

Zinc

Zinc has been observed to be connected with the production of auxins inside the rice plant. It also acts as a metallic activator of enzymes.

Zinc as an essential element for plants

As early as in 1926, Sommer and Lipman and Sommer (1927) presented evidences that zinc was essential to the growth of plants.

Influence on the growth, yield and other characteristics of rice plant

The rice crop has been reported to have responded to the application of zinc to an appreciable extent (Buckley 1952, Raheja *et al* 1959, Nagarajan and Shunmughasundaram 1963).

Karunakar (1952) reported increases in the yield of paddy by 10 - 28 per cent through spraying zinc sulphate at the rate of 10 lb/acre in Mysore. Singh and Jain (1964) obtained increases in the yield and crude protein content of grain by the foliar application of zinc sulphate at the rate of 2.53 kg/ha in Udaipur. They also reported that application of 2.53 kg per hectare of zinc in the soil increased the production of dry weight and tillering of paddy, but when applied as spray higher levels appreciably increased grain production.

Pillai (1967) recorded 15.6 per cent increase in the yield of paddy by soil application of 56 kg zinc sulphate per hectare over control.

On the contrary Sreedharan and George (1969) reported a nil response on the grain and straw yield of paddy.

Requirements, deficiencies and toxicities

Tokuoka and Gyo (1939) found that adding 1 ppm of zinc in culture solution increased the yield of rice, that 5 ppm gave a toxic effect the zinc content being 0.0027 per cent in leaves, and that 10 ppm killed the plant.

In a pot experiment, Hasoda (1942) indicated an effective response when less than 75 ppm of zinc was added to the rice plant, while toxicity appeared with the addition of 250 ppm.

Aiyar (1946) and Lal and Subharao (1951) have discussed the role of zinc in crop production and reported that zinc deficiency symptoms appeared in rice when zinc concentration in solution was less than 0.2 ppm and growth was optimum at 0.5 ppm.

Bear (1954) has reported that when the zinc content falls below 25 ppm in soil, deficiency may develop in crop plants. Viets et al (1954) found that plants suffering from zinc deficiency showed poor growth and generally had interveinal chlorosis and necrosis of lower leaves.

Ishizuka and Tanaka (1962) observed that deficient and excess critical level of zinc in the shoots of rice was below 15 ppm and 600 ppm respectively when the yield of rice was maintained constant.

In U.P. zinc deficiency has been found to cause 'Khaira' disease in paddy (Nene, 1965). Zinc sulphate applied at the rate of 5 kg/ha through spray or 10 kg/ha through soil cured the disease.

Souza and Hiroce (1970) reported that deficiency symptoms of zinc in rice growing in acid soils appeared when the plants contained less than 15, ppm zinc in the dry matter. No symptoms were observed when 5 kg/ha $ZnSO_4$ were applied at planting.

Krishnamoorthy et al (1971) showed that plants with zinc deficiency showed mid-rib bleaching. 10 ppm zinc in the third leaf was considered as the critical level. Deficiency was cured by soil application of upto 100 kg/ha $ZnSO_4$ with response upto 25 per cent in some areas.

<u>Interactions with other nutrients</u>

Chapman et al (1940) emphasised that the high level of phosphates in soil would produce zinc deficiency symptoms in citrus. It has been shown by many workers that phosphorus induced zinc deficiency symptoms in plants (Thorne, 1957; Langin et al 1962; Boawn and Leggett, 1964).

Seatz (1960) showed that increasing the pH of soil by liming had an adverse effect on the availability of zinc in soil. However, this effect could be altered to some extent by the nature of liming materials. The use of liming materials containing magnesium sulphate would decrease the severity of zinc deficiency.

Millikan (1963) and some Russian workers feel that zinc is essential for phosphorus utilization.

Watanabe et al (1965) found that the yield of corn was reduced considerably as the zinc level was increased from 0.75 to 2.25 µM when the iron level was 40 µM as Fe EDDHA. At the higher level of zinc in the nutrient solution, the plants were suffering from iron deficiency at all phosphorus levels, but deficiency symptoms disappeared when iron level was increased at 80 µM. These results indicate that a balance between iron, zinc and phosphorus is essential for good growth.

In some cases applied phosphorus reduced the concentration of zinc in the above ground portion of the plant and lowered the total uptake of zinc (Stukenholtz et al 1966).

Jain and Singh (1967) reported that soil application of 2.53 kg zinc/ha significantly increased nitrogen and copper uptake by rice plants.

Bandyopadhya and Adhikari (1968) reported that high rates of nitrogen and phosphorus increased the availability of zinc slightly.

On account of copper-zinc interaction, the rate of zinc application needs careful control because if zinc is applied in large quantities a zinc induced copper deficiency may occur as reported by Gilbey et al (1970).

Chaudhary and Loneragan (1970) reported that in pot experiments on wheat plants in acid loamy sands, copper deficiency was aggrevated by zinc sulphate and zinc deficiency was aggrevated by copper sulphate.

Chapman et al (1973) subscribe to the idea that high levels of phosphate decrease the availability of zinc due to precipitation of sparingly soluble zinc phosphate compounds.

In experiments conducted to study the effect of increasing levels of phosphorus and zinc and their interactions on dry matter yields of maize in red loam and calcareous soils of Bihar, it was found that in all cases interaction of P x Zn were significant (Sarkar and Sinha, 1974).

Chlorine

It is one of the latest addition to the list of trace elements needed for nutrition of rice plant. In Japan it has been noticed that the rain water contains adequate amounts of chlorides to meet the requirements of rice crop. Shimose (1954) reported that rice plant grew normally with less than 0.5 per cent of chlorine in culture solution, but could not grow in solutions containing more than 0.8 per cent chlorine. With the increase of the chlorine content in the solution, the protein nitrogen decreased and the soluble nitrogen in plant tissue increased. The chlorine requirement of the rice crop under field conditions lack detailed investigations.

Combined application of micronutrients

Substantial responses of paddy have been noticed by many workers for applications of more than one micronutrient in combination (Karunakar 1952; Sahu, 1959; Nagarajan and Shanmughasundaram, 1963).

Some of the micronutrients applied together exhibit antagonism resulting in either deficiency or toxicity to the rice plant (Mariakulandai and Chami, 1964 and Sreedharan and George, 1966).

Lack of response to combined application of all micronutrients has been reported by Kanwar (1964) and Gupta and Ram (1967).

Misra and Bhattacharya (1967) noted an increase in the 1000 kernal weight of Pennisetum typhoides due to the combined application of all trace elements.

Mehrotra and Saxena (1968) concluded that mixed micronutrients, even at a reduced level of application gave a significant increase in yield of paddy. An increase of 27 per cent calculated with control as 100 was recorded from micronutrient application over the maximum NPK treatment at the Fertilizer Research Station, Pura.

Sreedharan and George (1969) did not obtain any response for rice to micronutrient application in their experiments extending over a period of three years.

Nair et al (1972) reported that magnesium and Spartin, - a commercial product containing all micronutrients, had no significant influence either on grain yield or in enhancing response to phosphorus application in rice.

Chimania et al (1972) reported that the interaction between fertility levels and micronutrient treatments had significant effect on the dry matter yield of paddy. At higher fertility levels, application of manganese, copper, molybdenum and mixture of micronutrients generally increased the dry matter yield, whereas at lower levels their effect was not apparent.

Ramji Lal et al (1973) indicated that none of the micronutrients, either alone or in combination, could affect the grain yields of rice on the sandy loam soils of Bichpur.

Singh and Singh (1974) reported from an experiment conducted to study the relative efficiency of different dose combinations of micronutrient cations (iron, manganese, copper and zinc) on the yield and growth characteristics of wheat, that the different combinations were found to be significantly superior over control in increasing the growth and productive tillers. Both the grain and straw yields were considerably increased by the combined addition of iron, manganese, copper and zinc. The harvest index (grain-straw ratio) was also increased by micronutrient application.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment was designed to study the effect of a manure supplement prepared from sea water (Sagar) in increasing the efficiency of NPK for rice in a low level laterite soil. The manure supplement was available in two forms - Sagar manure and Sagar complex. The analysis of the Sagar manure supplement is as follows.

Nutrient	Per cent composition
Nitrogen (N)	2.500
Potassium (K_2O)	3.500
Magnesium (hydroxide)	11.000
Sulphur	3.000
Sodium	2.000
Boron	0.150
Copper	0.100
Manganese	0.100
Zinc	0.100
Molybdenum	0.001
Chlorine	10.000
Bromine	0.280
Iodine	0.270

Sagar complex contains 3 per cent phosphorus also in addition to the above components.

1. Location of the experiment

The experiment was laid out at the Agricultural College Farm, Vellayani in a low level laterite under waterlogged condition. The site selected had facilities for controlled irrigation, drainage and uniform soil conditions. The area is one usually cropped with wet land paddy.

2. Season

The trial was conducted during the second crop season (Mundakan) of 1974.

3. The soil

The chemical and mechanical analysis of the soil collected from the area are presented in Table I.

Table I

The mechanical and chemical composition of soil
(On oven dry basis)

	Percentage
Coarse sand	35.5
Fine sand	15.5
Silt	20.4
Clay	26.2
Organic matter	1.30
Moisture	3.45
Loss on ignition	1.52
Total nitrogen	0.033
Total P_2O_5	0.011
Total K_2O	0.473
Total CaO	0.123
Total MgO	0.007
Available nitrogen	0.0042
Available P_2O_5	0.0001
Available K_2O	0.0020
Exchangeable zinc	1.0 ppm
Exchangeable manganese	13.0 ..
Available copper	1.5 ..
Available iron	300 ..
pH	4.5
Electrical conductivity	0.7 millimhos/cm

4. Lay out of the experiment

The experiment was laid out in a 3 x 2 factorial experiment in randomised block design, with 6 treatments and 5 replications. The treatments consisted of combinations of 3 levels of NPK and 2 levels of Sagar as detailed below.

Levels of Sagar

S_0	-	0 kg Sagar/ha
S_1	-	250 kg ..

Levels of NPK

F_0	-	0 kg N, P_2O_5 and K_2O/ha
F_1	-	30:15:15 kg/ha N, P_2O_5 and K_2O respectively
F_2	-	60:30:30 kg/ha N, P_2O_5 and K_2O respectively

The various treatment combinations were as follows.

1. F_0 S_0	2. F_0 S_1	3. F_1 S_0
4. F_1 S_1	5. F_2S_0	4. F_2 S_1

Size of the plots:	5 m x 4 m
Gross area per plot:	20 sq.m
Net area per plot:	16.625 sq.m
Spacing:	10 cm between plants
	15 cm between lines
Variety:	Annapurna of 90-100 days duration

5. Experimental procedure

1) Nursery

Seeds of Annapurna obtained from the Agricultural College Farm, Vellayani were sown in a well prepared nursery bed which received no manures or fertilizers.

2) Main field

The experimental site was ploughed twice. Plots of size 5 m x 4 m were marked out with 6 plots per block and spaded well. The plots were separated with bunds 30 cm in width and individual blocks were given an outer bund 50 cm in width. Provision was also made for irrigating the plots by means of channels.

3) Application of manures and fertilizers

Half the dose of Sagar as Sagar complex was given as basal dressing while the other half was applied as Sagar manure 20 days after planting as per treatments. Half the quantity of nitrogen and full dose of P_2O_5 and K_2O were supplied as basal application. The fertilizers were applied as ammonium sulphate, ammonium phosphate and muriate of potash. The remaining half quantity of nitrogen was applied 20 days after planting as top dressing.

4) Transplanting

The seedlings were transplanted in the main field with two seedlings per hill on 21-10-1974.

5) Irrigation

Controlled irrigation and drainage were given so as to maintain optimum moisture conditions throughout the cropping period.

6) Weeding

The plots were hand weeded twice, fifteen days and forty five days after transplanting.

7) Plant protection

The plants were sprayed with paramer as a prophylactic measure against stem borer attack.

8) Harvesting

The crop was harvested on 30-12-1974. The weights of the grain and straw from each plot were recorded after 2 days sun drying. Samples of grain and straw were collected from all the plots for chemical analysis. The grain and straw from each plot were placed in separate paper bags and dried in an air oven at 70°C. The straw was ground in an electrical grinding mill. The ground straw and grain were stored in air tight plastic container for chemical analysis.

6. Observations

1) Sampling technique

After eliminating the guard rows a sampling unit of 1.0 sq.m was measured from each plot adopting random sampling technique. Sampling unit had 77 plants. The tiller counts and other observations were recorded for all the plants of the sampling unit. Height of the plants were recorded only for the 4 corner plants of the sampling unit. Panicle from the 4 corner plants were separately collected before harvest for recording the panicle characteristics and post harvest observations. Two plants adjacent to the observational plot were collected as samples for analysis.

2) Observations recorded

1. Height of the plant as on the 35th day after planting
2. Number of tillers per plant one month after planting
3. Number of productive tillers as on the 70th day after planting
4. Length of panicle
5. Number of grains per panicle
6. Yield of grain/plot
7. Yield of straw/plot
8. Grain-straw ratio
9. Weight of 1000 grains
10. Percentage of chaff

7. Periodical analysis of soil samples

Samples of soil were removed from each plot one month after planting and at the time of harvest and the soils under the different replications of one treatment mixed and pH of the composite sample determined. After harvest, soil samples were taken from the plots and available nitrogen, phosphorus and potassium and total calcium and magnesium were determined.

8. Laboratory studies

1) Soil samples

The pH of the soil samples were determined in 1:2.5 soil water suspension using a photovolt pH meter.

Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956).

Available phosphorus was determined according to the procedure described by Jackson (1967).

Available potassium was estimated photometrically using an EEL flame photometer.

Calcium and magnesium were determined in the hydrochloric acid extract of the soil by the versenate titration method (Jackson, 1967).

2) Plant samples

The grain and straw samples from all the 30 plots were analysed for the content of N, P, K, Ca and Mg.

Nitrogen was determined by micro-kjeldhal method as given by Jackson (1967).

The triple acid digestion of samples was carried out for the analysis of P, K, Ca and Mg as detailed by Piper (1950).

Phosphorus was determined by the vanadomolybdate method using Klett-Summerson photoelectric colorimeter.

Potassium was estimated photometrically using an EEL flame photometer.

Calcium and magnesium were determined by versenate titration of tripple acid extract of the material (Jackson, 1967).

RESULTS

RESULTS

The experimental results relating to the influence of different levels of NPK and Sagar on the growth, yield, quality and uptake of nutrients by rice are given in Tables II to VII. The data are analysed statistically and the analysis of variance tables are presented in Appendix 1 to 6.

The results of analysis of the soil samples collected from the experimental plots are furnished in Table VIII.

A. Growth

The average growth characteristics of rice for the various treatments are presented in Table II.

1. Number of tillers

The results in Table II indicate that the differences between the levels of NPK as regards this character are statistically significant. The maximum number of tillers (11.5) was produced at the highest level of NPK and the zero level of NPK produced the minimum number of tillers (6.6).

In the case of Sagar it may be noted that the treatments which contained this material increased considerably the number of tillers per plant compared to the treatment in which it was not included, at all the three levels of

Table No. II

Effect of different levels of NPK and Sagar on the growth characteristics of rice, variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	Number of tillers per plant	Number of productive tillers	Height of plant cm
0	0	6.3	5.8	44.6
	250	6.8	6.3	44.2
	Mean	6.6	6.1	44.4
	0	8.8	8.1	48.4
30:15:15	250	9.0	8.5	50.4
	Mean	8.9	8.3	49.4
	0	11.1	10.7	50.6
60:30:30	250	11.8	11.3	51.2
	Mean	11.5	11.0	50.9
	0	8.7	8.2	48.5
Mean	250	9.2	8.7	48.6

C.D. at 0.05 level for comparison between levels of NPK	2.1	1.8	2.2
,, ,, Sagar	N.S	N.S.	N.S
,, between combinations of treatments	3.0	2.6	3.2

fertilizers tried. The mean number of tillers has increased from 8.7 to 9.2 by the application of Sagar, though the difference is statistically non-significant. The maximum number of tillers is produced by the treatment in which Sagar was applied in combination with NPK at the highest level. The interaction was not significant.

2. Productive tillers

From Table II it can be seen that the number of productive tillers was influenced significantly by the different levels of NPK. The highest level of NPK was found to be most effective in increasing the number of tillers, and the lowest level, the least effective. The mean number of tillers produced at the zero, half and full dose of NPK were 6.1, 8.3 and 11.0 respectively.

The number of productive tillers per plant has increased from 5.8, 8.1 and 10.7 to 6.3, 8.5 and 11.3 by the application of Sagar at zero, half, and full dose of NPK respectively eventhough the effect was not statistically significant. The maximum number of productive tillers per plant (11.3) was obtained by the treatment in which Sagar was applied with NPK at the highest level.

3. Height of the plant

Height of the plant is increased significantly by increased levels of NPK. The maximum plant height (50.9 cm) was observed for the highest level of fertilizer applied. The height of the plants at the zero and half dose of NPK were 44.4 cm and 49.4 cm respectively.

Application of Sagar at the half and full dose of NPK tried has increased the height of the plant from 48.4 cm and 50.6 cm to 50.4 cm and 51.2 cm respectively, while at the zero level of fertilizers tried, application of Sagar slightly decreased the height of the plant from 44.6 cm to 44.2 cm. However, the effect of Sagar with regard to this character was not statistically significant. The maximum height of the plant (51.2 cm) was given by the treatment in which NPK was applied at the highest level in combination with Sagar.

B. Yield

The results relating to the influence of different levels of NPK and Sagar on yield characters of rice are presented in Table III and IV.

1. Length of panicle

The influence of the different levels of NPK on this character was statistically significant. Out of the three levels of NPK, application of NPK at the highest level has given the maximum length of panicle (18.3 cm) and the zero level of NPK the minimum (16.5 cm).

Table No.III

Effect of different levels of NPK and Sagar on the yield characteristics of rice, variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	Length of panicle cm	Number of grains per panicle
0	0	15.8	60.0
	250	17.2	62.0
	Mean	16.5	61.0
	0	17.6	64.0
30:15:15	250	17.8	75.0
	Mean	17.7	69.5
	0	17.8	74.0
60:30:30	250	18.8	84.0
	Mean	18.3	79.0
Mean	0	17.1	66.0
	250	17.9	73.7
C.D. at 0.05 level for comparison between levels of NPK		0.8	3.6
,, Sagar		0.7	2.9
,, between combinations of treatments		1.2	5.1

The effect of Sagar on this character was also significant. The mean length of panicle has increased from 17.1 cm to 17.9 cm by the application of Sagar. The maximum length of panicle 18.8 cm was produced by the treatment in which Sagar was applied in combination with NPK at full dose. The interaction between NPK and Sagar was not significant.

2. Number of grains per panicle

Application of NPK was found to have significant effect on the number of grains per panicle. The number of grains increased steadily with increase in the levels of NPK and the number of grains produced at the zero, half and full dose of NPK were 61.0, 69.5 and 79.0 respectively.

The number of grains per panicle is increased significantly by the application of Sagar from 60, 64 and 74 to 62, 75 and 84 respectively by the application of Sagar at the zero, half and full dose of NPK. The interaction between NPK and Sagar is significant and the application of Sagar with NPK has increased the number of grains per panicle. The maximum number of grains per panicle has been produced by the treatment which contained Sagar along with NPK at the full dose. This is significantly superior to all other combinations of treatments with regard to this factor.

There is no significant difference between the treatments, control, Sagar alone and NPK at half dose. The treatments in which NPK applied at full dose and NPK at half dose with Sagar are on a par.

3. Yield of grain

The yield of grain is influenced significantly by the application of NPK. The grain yield increased steadily with increase in the levels of NPK, and the mean yield obtained at the zero, half and full dose of NPK are 1322.8, 1638.4 and 1830.8 kg/ha respectively.

The grain yield is increased significantly by the application of Sagar, at all levels of NPK. The increases were from 1264.6, 1602.6 and 1704.4 kg/ha to 1381.0, 1674.2 and 1957.2 kg/ha respectively by the application of Sagar along with the zero, half and full doses of NPK. The interaction between NPK and Sagar was not significant. Out of the six combinations of treatments, the treatment in which NPK was applied at the highest level in conjunction with Sagar has given the highest yield. It has given 14.9 per cent increase in grain yield over the treatment in which NPK was applied at the highest level without Sagar. The percentage of increase obtained due to application of Sagar along with the zero and half dose of NPK are 9.2 and 4.5 per cent

Table No.IV

Effect of different levels of NPK and Sagar on yield characters of rice, variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	Weight of grain kg/ha	Weight of straw kg/ha	Grain-straw ratio	Weight of 1000 grain g	Percentage of chaff
	0	1264.6	1317.6	0.96	21.57	13.70
0	250	1381.0	1371.6	1.04	22.04	7.70
	Mean	1322.8	1344.6	1.00	21.80	10.70
	0	1602.6	1483.6	1.08	21.90	12.20
30:15:15	250	1674.2	1626.0	1.03	21.90	10.90
	Mean	1638.4	1554.8	1.05	21.90	11.55
	0	1704.4	2142.4	0.80	22.30	9.70
60:30:30	250	1957.2	2336.4	0.85	22.60	7.80
	Mean	1830.8	2239.4	0.83	22.45	8.75
	0	1523.9	1647.9	0.95	21.92	11.87
Mean	250	1670.8	1778.0	0.97	22.18	8.80

C.D. at 0.05 level for comparison between levels of NPK	82.4	99.5	0.05	0.10	N.S
,, Sagar	67.4	81.4	N.S	0.08	2.75
,, between combinations of treatments	116.5	155.2	0.08	0.15	4.80

respectively. At the same time, there is a yield increase of 6.3 per cent only when the NPK application is increased from half dose to full dose. But full dose of NPK with Sagar has recorded an increase of 14.9 per cent over NPK full dose alone. Thus considerable increase in yield can be obtained by the application of Sagar in conjunction with the full dose of NPK as seen from the figures above.

4. Yield of straw

Straw yield is significantly increased due to the application of NPK. The yield of straw at the zero, half and full dose of NPK are 1344.6, 1554.8 and 2239.4 kg/ha respectively.

Application of Sagar has significantly increased the mean yield of straw from 1647.9 kg/ha to 1778.0 kg/ha. The highest straw yield is recorded by the treatment in which Sagar is applied in combination with NPK at the highest level and this treatment has produced 8.1 per cent increase in straw yield over the treatment in which NPK was applied in full dose without Sagar. The interaction between NPK and Sagar was not significant.

5. Grain-straw ratio

Application of NPK has significantly influenced the grain-straw ratio. Application of N, P and K at the

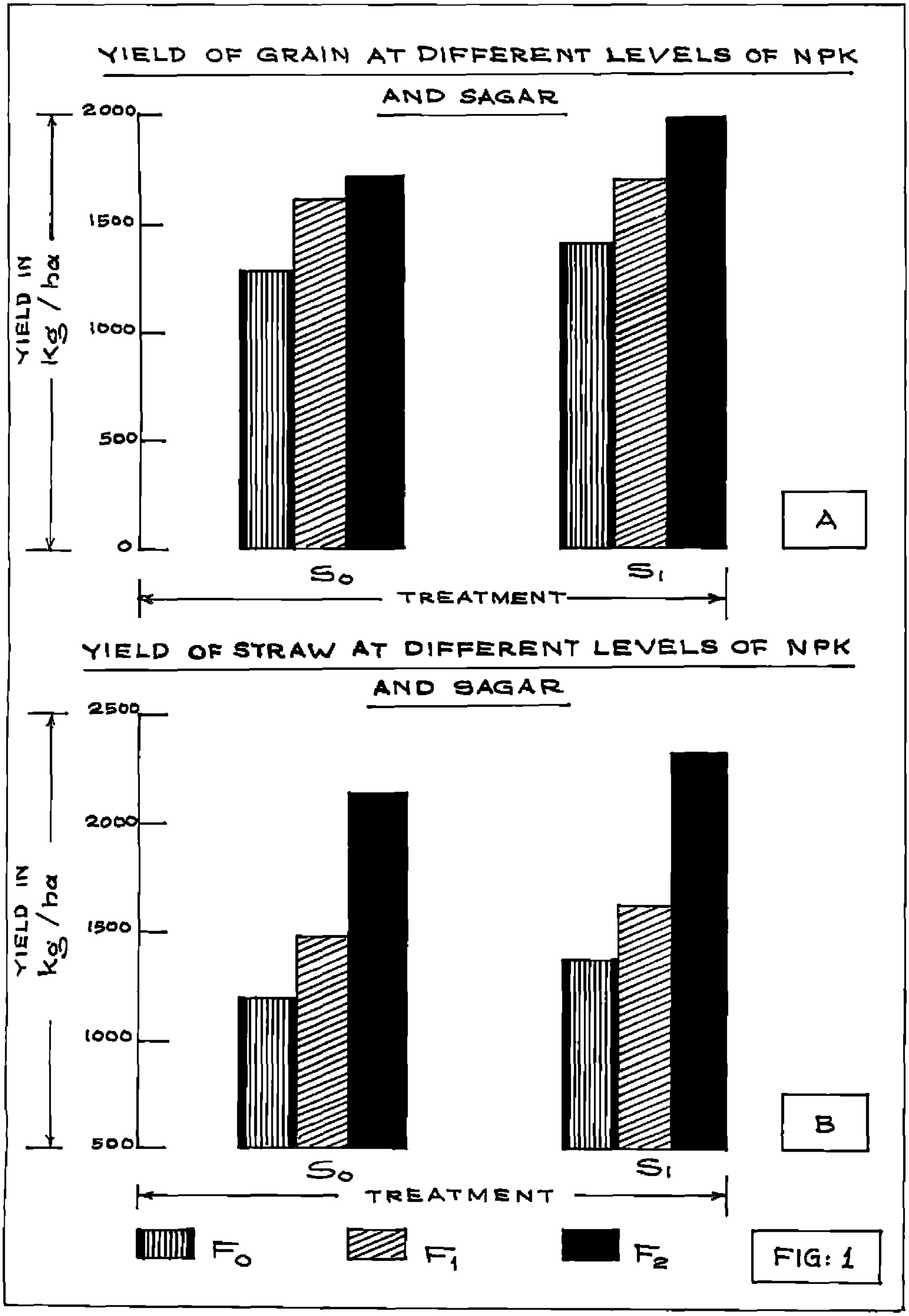

YIELD OF GRAIN AT DIFFERENT LEVELS OF NPK AND SAGAR
YIELD IN Kg / ha
2000
1500
1000
500
0
S0
S1
TREATMENT
A
YIELD OF STRAW AT DIFFERENT LEVELS OF NPK AND SAGAR
YIELD IN Kg / ha
2500
2000
1500
1000
500
S0
S1
TREATMENT
B
F0
F1
F2

FIG: 1

rate of 30:15:15 kg/ha has increased the grain-straw ratio to 1.05 from 1.00 in the zero level of NPK, while there was a decrease in the grain-straw ratio at the highest level of NPK (0.83).

Application of Sagar has not influenced the grain-straw ratio significantly. However, the mean grain-straw ratio has been increased from 0.95 to 0.97 due to application of Sagar. The interaction between the treatments was also not significant.

6. Weight of 1000 grains

As regards this character, the NPK levels tried were significantly effective. The weight of 1000 grains increased steadily with increase in the levels of NPK applied.

Application of Sagar has increased the 1000 grain weight significantly and the mean weight of 1000 grains increased from 21.92 g to 22.18 g due to the application of this material. The interaction between the treatments was also significant. The maximum weight of 1000 grains (22.60 g) is given by the treatment in which NPK full dose and Sagar are applied in combination. This treatment has given significantly increased weight of 1000 grains as compared to the other treatments.

7. Percentage of chaff

Application of Sagar has significantly decreased the percentage of chaff and the mean chaff percentage has been reduced from 11.87 to 8.80. The effect of fertilizers on the percentage of chaff was not significant.

C. Chemical composition of plant

Data relating to the chemical composition of plants (N, P_2O_5, K_2O, CaO and MgO) for the various treatments of NPK and Sagar are given in Tables V and VI.

Grain

1. Nitrogen

The percentage of nitrogen in grain was found to be significantly influenced by the application of NPK. The nitrogen content of grain tended to increase with increase in the rate of NPK application. The difference in the nitrogen percentage of grain due to Sagar was statistically non-significant. However, the trend was for Sagar to increase the nitrogen content of grain in the absence of fertilizers and the decrease the nitrogen content when applied along with the fertilizers. The interaction between NPK and Sagar was also significant.

Table No.V

Effect of different levels of NPK and Sagar on the composition of rice-grain, variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	N %	P_2O_5 %	K_2O %	CaO %	MgO %
	0	1.12	0.32	0.30	0.23	0.09
0	250	1.21	0.37	0.31	0.17	0.16
	Mean	1.17	0.35	0.31	0.20	0.13
	0	1.33	0.39	0.32	0.23	0.10
30:15:15	250	1.32	0.35	0.33	0.20	0.12
	Mean	1.33	0.37	0.33	0.22	0.11
	0	1.43	0.46	0.33	0.26	0.13
60:30:30	250	1.40	0.39	0.33	0.22	0.14
	Mean	1.42	0.43	0.33	0.24	0.14
Mean	0	1.29	0.39	0.32	0.24	0.11
	250	1.31	0.37	0.32	0.19	0.14
C.D. at 0.05 level for comparison between levels of NPK		0.03	0.04	N.S	0.01	0.01
,,	Sagar	N.S	N.S	N.S	0.01	0.01
,, between combinations of treatments		0.04	0.05	N.S	0.02	0.02

2. Phosphorus

In this case also the trend was similar to that of nitrogen. The P_2O_5 content of grain was influenced significantly by the application of NPK. As the fertilizer treatment was increased from zero to half and full dose of NPK, the content of P_2O_5 in the grain increased from 0.35 to 0.37 and 0.43 respectively.

The percentage of P_2O_5 was not affected significantly by the application of Sagar. However, the percentage of P_2O_5 in the grain was found to decrease slightly when Sagar was applied along with the fertilizers while there was an increase in the P_2O_5 content of the grain when Sagar alone was applied. This interaction between the treatments was significant.

3. Potassium

The different treatments were found to have no significant influence on the K_2O content of grain.

4. Calcium

The calcium content of the grain increased significantly due to the application of NPK. The application of Sagar, however, decreased the calcium content of grain and the effect was statistically significant. The interaction between the treatments was also significant.

5. Magnesium

The magnesium content of grain was significantly influenced by fertilizer application. No regularity was noted for the effect of fertilizer on the magnesium content of the grain. The MgO content at the zero, half and full dose of NPK were 0.13, 0.11 and 0.14 respectively.

Application of Sagar has significantly increased the percentage of MgO in the grain at all levels of NPK. The mean percentage of MgO has been increased from 0.11 to 0.14 by the application of Sagar. The highest percentage for MgO was recorded by the treatment in which Sagar was applied without NPK. The interaction between the treatments was also significant.

Straw

1. Nitrogen

The percentage of nitrogen in the straw increased with increase in the levels of NPK and the results were significant.

Application of Sagar at the zero level of NPK increased the nitrogen content of the straw, while at the other two levels of NPK, the application of Sagar slightly decreased the nitrogen content. However, the effect due to Sagar was not statistically significant. The interaction

Table No.VI

Effect of different levels of NPK and Sagar on the composition of rice-straw, variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	N %	P_2O_5 %	K_2O %	CaO %	MgO %
	0	0.87	0.22	1.20	0.40	0.33
0	250	0.91	0.25	1.33	0.38	0.42
	Mean	0.89	0.24	1.27	0.39	0.38
	0	1.01	0.28	1.51	0.42	0.40
30:15:15	250	0.98	0.26	1.61	0.40	0.40
	Mean	1.00	0.27	1.56	0.41	0.40
	0	1.17	0.33	1.97	0.42	0.40
60:30:30	250	1.11	0.31	1.96	0.41	0.44
	Mean	1.14	0.32	1.97	0.42	0.42
Mean	0	1.02	0.28	1.56	0.41	0.38
	250	1.00	0.28	1.63	0.40	0.42
C.D. at 0.05 level for comparison between levels of NPK		0.07	0.02	0.07	0.01	0.02
,, Sagar		N.S	N.S	0.06	0.01	0.01
,, between combinations of treatments		0.10	0.03	0.10	0.02	0.02

was also not significant.

2. Phosphorus

The percentage of P_2O_5 in the straw is increased significantly as higher levels of NPK are applied.

The P_2O_5 content is increased by the application of Sagar at the zero level of NPK, while at the higher levels of NPK, the P_2O_5 content is found to decrease slightly. This interaction between the treatments was significant. However, the effect of Sagar alone on the P_2O_5 content of the straw was not significant.

3. Potassium

The different treatments were found to have significant influence on the K_2O content of straw. The K_2O content increased with increase in the levels of NPK.

Application of Sagar also increased the mean K_2O percentage of the straw from 1.56 to 1.63 and this was statistically significant. The interaction between the treatments was not significant.

4. Calcium

The different treatments were found to have a significant influence on the calcium content of straw. Application of NPK increased the percentage of calcium, the CaO content at the zero, half and full dose of NPK being

0.39, 0.41 and 0.42 respectively.

The mean percentage of CaO has decreased from 0.41 to 0.40 by the application of Sagar and the difference is significant.

5. Magnesium

The magnesium content of the straw is influenced significantly by the application of NPK and it increased with increase in the quantity of fertilizer applied. The MgO content at the zero, half and full dose of NPK are 0.38, 0.40 and 0.42 respectively. Application of Sagar also significantly increased the magnesium content of straw. The maximum percentage of MgO (0.44) is recorded by the treatment in which NPK is applied at the highest level along with Sagar while the minimum is recorded by the control (0.33). The interaction between the treatments was significant.

D. Uptake of nutrients

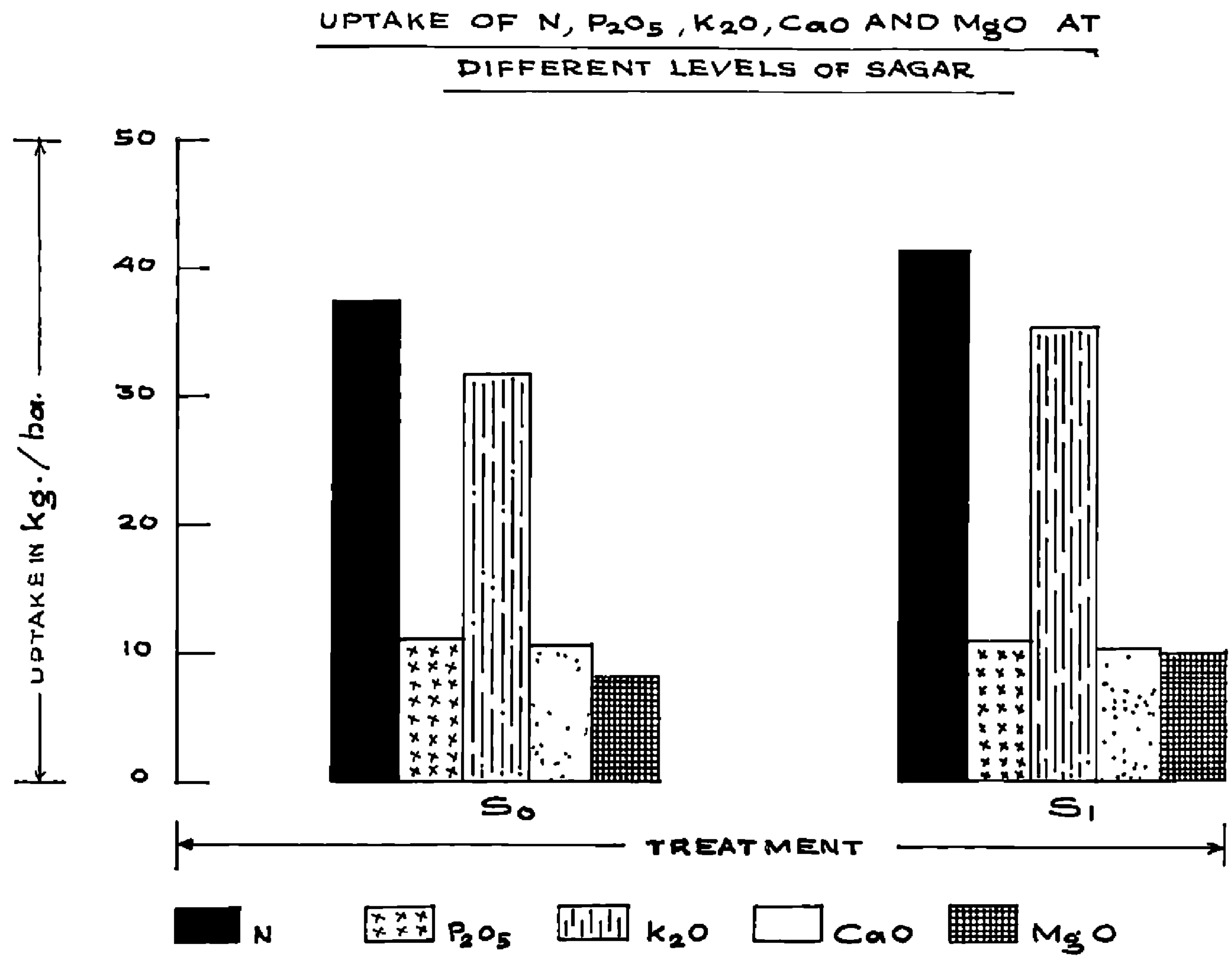
The data for the total uptake of different nutrients by rice, calculated as so many kg/ha as influenced by the various treatments are furnished in Table VII.

The uptake of all the nutrients was influenced significantly by the application of NPK, and it increased as the levels of NPK increased.

Table VII

Effect of different levels of NPK and Sagar on the uptake of nutrients by rice, Variety Annapurna

Levels of N, P_2O_5 and K_2O kg/ha	Levels of sagar kg/ha	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	CaO kg/ha	MgO kg/ha
	0	25.70	6.92	19.60	8.21	5.43
0	250	29.21	8.45	22.52	7.69	8.04
	Mean	27.45	7.68	21.06	7.95	6.73
	0	36.25	10.33	27.65	9.78	7.34
30:15:15	250	37.93	9.99	31.68	9.80	8.88
	Mean	37.09	10.16	29.66	9.79	8.11
	0	49.26	15.86	47.84	13.29	11.20
60:30:30	250	53.28	14.66	52.34	13.82	13.19
	Mean	51.27	15.26	50.09	13.55	12.20
Mean	0	37.07	11.04	31.70	10.42	7.99
	250	40.14	11.03	35.51	10.43	10.04
C.D. at 0.05 level for comparison between levels of	NPK	1.98	0.88	2.61	1.43	3.13
,,	Sagar	1.60	N.S	2.08	N.S	2.54
,, between combinations of treatments		2.80	1.25	3.69	2.04	4.42



UPTAKE OF N, P2O5, K2O, CaO AND MgO AT DIFFERENT LEVELS OF SAGAR
UPTAKE IN Kg./ha.
50
40
30
20
10
0
S0
S1
TREATMENT
N
P2O5
K2O
CaO
MgO

FIG: 2

Uptake of nitrogen, K_2O and MgO has been significantly increased due to the application of Sagar. The difference in the uptake of phosphorus and calcium due to Sagar is negligible and non-significant. The interaction between the treatments was significant only in the case of phosphorus. The maximum uptake of all nutrients except phosphorus is recorded for the treatment in which Sagar is applied in conjunction with NPK at the highest level.

F. Chemical composition of soil

The influence of the different levels of NPK and Sagar on the variation in pH and availability of nutrients was studied and the results obtained are presented in Table VIII.

1. Variation in soil. pH

As a result of the application of Sagar, there was a slight increase in the pH of the soil. The application of this material resulted in an increase of the pH from 4.8 to 4.9 one month after planting and from 4.5 to 4.7 by the time of harvest.

2. Availability of nutrients

The availability of N, P and K increased as the levels of NPK applied to the soil increased. No definite

Table No. VIII

Effect of different levels of NPK and Sagar on the variation in pH and availability of nutrients

Levels of N, P_2O_5 and K_2O kg/ha	Levels of Sagar kg/ha	pH of the soil		Available N % after harvest	Available P_2O_5 % after harvest	Available K_2O % after harvest	Total CaO % After harvest	Total MgO % after harvest
		After one month	After harvest					
0	0	4.70	4.40	0.0040	0.00010	0.0024	0.123	0.0064
	250	4.80	4.60	0.0042	0.00008	0.0027	0.133	0.0096
	Mean	4.75	4.50	0.0041	0.00009	0.0026	0.128	0.0080
	0	4.80	4.60	0.0048	0.00012	0.0030	0.154	0.0096
30:15:15	250	4.90	4.80	0.0048	0.00012	0.0033	0.140	0.0112
	Mean	4.85	4.70	0.0048	0.00012	0.0032	0.147	0.0104
	0	4.80	4.50	0.0051	0.00014	0.0032	0.130	0.0064
60:30:30	250	5.00	4.70	0.0054	0.00016	0.0035	0.123	0.0096
	Mean	4.90	4.60	0.0053	0.00015	0.0034	0.126	0.0080
Mean	0	4.80	4.50	0.0046	0.00012	0.0029	0.136	0.0075
	250	4.90	4.70	0.0048	0.00012	0.0032	0.132	0.0101
Before planting		4.50		0.0042	0.00010	0.0020	0.123	0.0070

nd is noticed for the content of magnesium and calcium in the soil due to the effect of NPK.

The results obtained reveal that there was substantial increase in the availability of potassium due to the application of Sagar. The total magnesium content of the soil also increased considerably, while the difference in the availability of nitrogen, phosphorus and calcium was negligible.

DISCUSSION

DISCUSSION

The results of the present study have shown that all the growth characters of rice were significantly influenced by the application of NPK. The influence of nitrogen on the various growth characteristics and yield of rice is a well recognised phenomenon (Black, 1957). The response of rice to P and K applications under Kerala conditions is comparatively less than that for nitrogen based on several experiments conducted in the State. This shows that the response obtained in the growth characteristics and yield of rice in the experiment due to the application of NPK may be mainly due to the effect of nitrogen.

Application of Sagar increased considerably the number of tillers and the number of productive tillers which is in conformity with the findings of Singh and Singh (1974) who had obtained significant increases in growth and productive tillers in wheat due to the combined application of different micronutrient cations.

The application of Sagar resulted in a significant increase in the length of panicle and the number of grains per panicle. The interaction between the treatments was significant for the number of grains per panicle and not for the length of panicle. These characters were found to increase with the application of Sagar. The beneficial effects on the number of grains per panicle due to application of magnesium has been reported for wheat by Sadapal and Das (1961). Kuriakose (1962) has reported an increase in the number of grains per panicle due to application of manganese in rice. Varghese and Money (1965) have also reported increase in the panicle length and the number of grains per panicle of rice due to the application of magnesium. The results of the present work are in agreement with the results obtained by the above workers.

The grain and straw yield increased significantly due to NPK and Sagar application and the interaction between NPK and Sagar was not significant as far as these characters were concerned. Maximum grain yield was obtained for the highest level of NPK with Sagar. The beneficial effect of magnesium application on grain yield was reported by Narayan and Vasudevan (1957) and Nair and Koshy (1966). The beneficial effect of combined application of micronutrients on yield was reported by Mahrotra (1968) and Chimania <u>et al</u> (1972) in rice and Singh and Singh (1974) in wheat. The results obtained in the present investigation agree with those obtained by the above workers.

The results on grain yield obtained show that the percentage of increases obtained due to application of Sagar at the zero, half and full dose of NPK are 9.2, 4.5 and 14.9 per cent respectively. At the same time the increase in yield obtained due to application of full dose of NPK over half dose of NPK is only 6.3 per cent. This shows that the efficiency of NPK can be increased by application of Sagar. At higher levels of application of major nutrients, the uptake and utilisation of secondary elements and micronutrients are well known to be enhanced. At such higher levels of application of NPK unless secondary and micronutrients are also adequately supplied and or made available in the soil the latter becomes a limiting factor in yield. The observation that application of Sagar containing magnesium and micronutrients increase the yield to the extent of 14.9 per-cent at the highest level of NPK confirm these generalisations. The beneficial effect of micronutrient application is more likely to be obtained with higher levels of fertilizer application. At lower levels of fertility, the major nutrients may be having more influence on yield than micronutrients.

The grain-straw ratio was influenced significantly by the levels of NPK. There was no difference in the grain-straw ratio at the zero and half dose of NPK. When the application of fertilizers was increased to full dose the grain-straw ratio was adversely affected. This may be due to the increase in the vegetative growth at high levels of nitrogen as compared to that at the lower level.

Application of Sagar has not influenced the grain-straw ratio significantly. For this character the trend was to increase with the application of Sagar. This is in accordance with the findings of Singh and Singh (1974) in wheat who have reported increase in the grain-straw ratio by the application of micronutrients.

The levels of NPK and Sagar have significantly influenced the 1000 grain weight and the interaction between the treatments was also significant. The maximum 1000 grain weight was recorded by the treatment in which Sagar applied with NPK at full dose. Carbohydrate accumulation might have been a maximum at the highest level of fertilizer application which might explain the highest value for 1000 grain weight at this level of fertilization.

Beneficial effects on the 1000 grain weight due to application of magnesium has been reported by Sadapal and Das (1961) and Nair and Koshy (1966). Misra and Bhattacharya (1967) noted an increase in the 1000 kernal weight of *Pennisetum typhoides* due to the combined application of all the trace elements. This increase in the 1000 kernal weight was reported to be due to the enhanced rate of metabolism resulting from the uptake of micronutrients which was condusive to various stages of development. The interaction between the NPK and Sagar has also increased the 1000 grain weight.

Percentage of chaff is not influenced significantly by the application of NPK, but the effect of Sagar is significant in reducing the percentage of unfilled grains. Reduction in the percentage of chaff have been reported in wheat by Sadapal and Das (1961) and by Varghese and Money (1965) in rice, due to application of magnesium.

Application of NPK has increased significantly the content of N, P_2O_5 and CaO in the grain and N, P_2O_5, K_2O, CaO and MgO in the straw. This observation is in partial agreement with the findings of Swell and Heih (1924) who have shown that fertilisers applied to poor soils usually result in an increase in the nutrient content in the plants, supplied by the fertilizers.

The effect of Sagar on the nitrogen and phosphorus content in the grain and straw was not significant. But the results show that Sagar applied at the O level of NPK has resulted in higher contents of nitrogen and phosphorus in the grain and straw, while at the higher levels of NPK, there is a slight decrease in the nitrogen and phosphorus content in the grain and straw. This may be due to the various interactions between the micronutrients and between micro and macro nutrients at higher levels of fertilizers applied, taking place in the soil and plant.

As for the K_2O content, Sagar had significant response for straw only.

The effect of Sagar on the CaO content of both grain and straw was significant with a reciprocal relationship between them. This is in conformity with the findings of Blair et al (1939) who reported that the addition of magnesium compounds resulted in a decrease in the calcium content of plants.

Application of Sagar increased the magnesium content of grain and straw significantly. The increase in the magnesium content of plants due to application of magnesium compounds has been reported by Dewan and Hunter (1945), Schachtsehabel and Hoffman (1958) and Padmaja and Varghese (1972). The inverse relationship between magnesium and calcium in plant nutrition is generally well accepted and this has been borne out by the present study also.

The uptake of all the nutrients increased significantly due to the application of NPK. The increased uptake of nutrients for increased rate of NPK application is only to be expected.

Application of Sagar increased significantly the uptake of nitrogen, K_2O and MgO. The difference in the P_2O_5 and CaO uptake due to application of Sagar was negligible. Greater production of dry matter with Sagar application may be the reason for the significant increase in the uptake of N, K_2O and MgO. Various interactions taking place between phosphorus and micronutrients and the inverse relationship between calcium and magnesium may be the reason for the non-significant difference in the uptake of P_2O_5 and K_2O.

Availability of K_2O and the total content of MgO in the soils were also increased by the application of Sagar. Chambers (1953) indicated that magnesium increased crop yield by increasing the potassium supply. Kemp and Geurink (1970) reported favourable effects in the magnesium content of the soil due to application of magnesium compounds. The results obtained in the present investigation agree with those obtained by the above workers.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A field experiment was conducted to assess the effect of application of Sagar, a manure supplement prepared from the sea water on the growth, yield and quality of rice and absorption of nutrients from soil. The results obtained are summarised below.

1. Application of NPK increased significantly all the growth characters and these characters were increased steadily with increase in the levels of NPK.

Sagar application increased considerably the number of tillers and the number of productive tillers per plant.

2 The length of panicle and the number of grains per panicle increased significantly by the application of both NPK and Sagar. The highest value for the length of panicle and the number of grains per panicle was produced by the treatment in which Sagar was applied in combination with NPK at full dose.

3. NPK and Sagar influenced significantly the yield of grain and straw and the yields were increased steadily with increase in the levels of NPK and Sagar.

The treatment in which NPK was applied at the highest level in conjunction with Sagar has given the highest yield. It has given 14.9 per cent increase in grain yield over the treatment in which NPK was applied at the highest level without Sagar.

4. Grain-straw ratio is influenced significantly, only by the application of NPK.

5. The maximum weight of 1000 grains was given by the treatment in which the full dose of NPK was applied in conjunction with Sagar. This treatment gave significantly increased weight of 1000 grains as compared to the other treatments.

6. Application of Sagar significantly decreased the percentage of chaff while the effect of fertilizers on this character was not significant.

7. As regards the chemical composition of plants all the contents studied except potassium and magnesium in the grain were significantly increased by the application of NPK. The content of nitrogen and P_2O_5 in the grain and straw and content of K_2O in the grain were not influenced significantly by the application of Sagar. The K_2O content in the straw and the percentage of MgO in the grain and straw were significantly increased by the application of Sagar,

while the CaO content in the grain and straw decreased due to the application of this material.

8. The uptake of all the nutrients was influenced significantly by the application of NPK and it increased as the levels of NPK increased.

Uptake of N, K_2O and MgO were significantly increased by the application of Sagar. The difference in the uptake of phosphorus and calcium due to Sagar was negligible and non-significant. The maximum uptake of all nutrients except phosphorus was recorded for the treatment in which Sagar was applied in conjunction with NPK at the highest level.

9. As a result of the application of Sagar there was a slight increase in the pH of the soil.

10. The availability of N, P_2O_5 and K_2O was increased as the levels of NPK applied to the soil increased.

There was substantial increase in the availability of potassium due to the application of Sagar. The total MgO content of the soil also increased considerably, while the difference, in the N, P_2O_5 and CaO contents were negligible.

From the above, it is seen that the rice crop has responded favourably to the application of Sagar.

The effect of Sagar in increasing the yield of rice may be partly due to its direct effect and partly due to its influcnce in increasing the availability of other nutrients. Results of the present study, therefore suggest that the manure supplement 'Sagar' has definitely a role in increasing the efficiency of NPK fertilisers for rice in the acid soils of Kerala and it is advisable to include it also in the preparation of manurial schedule for rice.

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APPENDICES

APPENDIX I

Summary of statistical analysis, growth characters of rice

Source	Degree of freedom	Number of tillers per plant M.S.	Number of productive tillers per plant M.S.	Height of plant cm M.S.
Total	29			
Replication	4	0.42	0.39	20.72*
Treatment	5	24.10**	24.85**	48.59**
F	2	59.35**	55.98**	110.80**
S	1	1.42	9.14	4.03
F x S	2	0.14	1.58	8.62
Error	20	5.16	3.83	5.78

*Significant at 5% level

**Significant at 1% level

APPENDIX II

Summary of statistical analysis, yield characters of rice

Source	Degree of freedom	Length of panicle cm M.S	Number of grains per panicle MS.
Total	29		
Replication	4	2.00	46.13*
Treatment	5	4.86**	437.00**
F	2	8.40**	811.20**
S	1	5.60*	441.60**
F x S	2	0.95	60.45*
Error	20	0.76	14.83

*Significant at 5% level

**Significant at 1% level

APPENDIX III

Summary of statistical analysis, yield characters of rice

Source	Degree of freedom	Yield of grain kg/ha M.S.	Yield of straw kg/ha M.S.	Grain straw ratio M.S.	Weight of 1000 grain g M.S.	Percentage of chaff M.S.
Total	29					
Block	4	7848.9	35267.0	0.0034	0.0053	35.71
Treatment	5	305532.8**	806100.4**	0.5970**	0.6488**	39.24*
F	2	657818.7**	2189213.8**	0.1407**	1.0740**	20.12
S	1	161920.9**	113677.0**	0.0012	0.2610**	72.39*
F x S	2	25052.7	19198.7	0.0078	0.4170**	41.82
Error	20	7801.2	11385.0	0.0033	0.0125	13.20

*Significant at 5% level

**Significant at 1% level

APPENDIX IV

Summary of statistical analysis - Chemical composition of rice - Grain

Source	Degree of freedom	N % M.S.	P_2O_5 % M.S.	K_2O % M.S.	CaO % M.S.	MgO % M.S
Total	29					
Replication	4	0.0118**	0.0010	0.0003	0.0002	0.0001
Treatment	5	0.0650**	0.0016**	0.0010	0.0050**	0.0038**
F	2	0.1521**	0.0177**	0.0021	0.0036**	0.0016**
S	1	0.0018	0.0038	0.0004	0.0155**	0.0101**
F x S	2	0.0094**	0.0093**	0.0003	0.0011*	0.0028**
Error	20	0.0010	0.0016	0.0108	0.0002	0.0002

*Significant at 5% level

**Significant at 1% level

APPENDIX V

Summary of statistical analysis - Chemical composition of rice - straw

Source	Degree of freedom	N % M.S	P_2O_5 % M.S	K_2O % M.S	CaO % M.S	MgO % M.S
Total	29					
Replication	4	0.0155*	0.0003	0.0038	0.0005	0.0005
Treatment	5	0.0635**	0.0082**	0.5020**	0.0010**	0.0083**
F	2	0.1520**	0.0166**	1.2258**	0.0016**	0.0084**
S	1	0.0016	0.0002	0.0329*	0.0016**	0.0168**
F x S	2	0.0058	0.0038**	0.0129	0.0001	0.0040**
Error	20	0.0054	0.0005	0.0055	0.0002	0.0003

*Significant at 5% level

**Significant at 1% level

APPENDIX VI

Summary of statistical analysis - uptake of nutrients by rice

Source	Degree of freedom	N kg/ha M S	P_2O_5 kg/ha M S	K_2O kg/ha M S	CaO kg/ha M S	MgO kg/ha M S
Total	29					
Replication	4	3.73	1.59	15.71	1.20	14.10
Treatment	5	589.50**	61.75**	911.66**	32.97**	388.10**
F	2	1434.99**	149.50**	2222.79**	81.72**	806.70**
S	1	70.80**	0.01	109.44**	0.40	313.00**
F x S	2	3.33	4.86*	1.61	0.50	6.90
Error	20	4.50	0.90	7.78	2.37	11.26

*Significant at 5% level

**Significant at 1% level

PLATE

PLATE

Influence of NPK and Sagar on the growth
of rice, variety Annapurna

Plant No.1. 0 kg N, P_2O_5, K_2O and Sagar/ha

,, 2. 30:15:15 kg/ha N, P_2O_5 and K_2O respectively

,, 3. 60:30:30 kg/ha N, P_2O_5 and K_2O respectively

,, 4. 30:15:15 kg/ha N, P_2O_5 and K_2O respectively
+ Sagar 250 kg/ha

,, 5. 60:30:30 kg/ha N, P_2O_5 and K_2O respectively
+ Sagar 250 kg/ha

,, 6. Sagar 250 kg/ha