STUDIES ON THE EFFECT OF VARYING LEVELS OF ZINC ON THE GROWTH AND YIELD OF RICE

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THESIS
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1980

DECLARATION

I hereby declare that this thesis entitled "Studies on the effect of varying levels of Zinc on the growth and yield of Rice" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Studies on the effect of varying levels of Zinc on the growth and yield of Rice" is a record of research work done independently by Shri. K. KRISHNAN NAMBOODIRI, under my guidance and supervision and that the thesis has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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C O N T E N T S

LIST OF TABLES

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INTRODUCTION

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Introduction of high yielding varieties of crops and adoption of intensive methods of cultivation in recent years have led to wide spread deficiencies of micronutrients, particularly zinc in Indian soils. The factors which govern the availability of these elements in soils include among others, soil texture, structure, soil reaction, nature of the parent material, organic matter, crop cultivated and cultural practices. Antagonism between the micro- and macro-elements or between the micro-elements themselves may also contribute to deficiency of these elements. The deficiency of these elements can invariably be detected through visual symptoms exhibited by plants. In such situations application of micro-nutrients either to the soil or to the foliage normally can correct the deficiency. "Hidden-hunger" in crops is also commonly observed. The plant may be in need of the element, but it is too early for the plant to exhibit visual symptoms of deficiency. In such a situation, which can be detected in advance by soil or tissue analysis, application of micronutrients will be helpful in bringing about increases in crop yield.

Among the micronutrients in Indian soils, zinc deficiency appears to be very common especially in alkali soils and in water-logged acid soils. In rice, the deficiency of zinc is exhibited by the appearance of rusty brown spots and discolouration of the older leaves starting from 2-3 weeks after transplanting. Tillering and growth are adversely affected. Interveinal chlorosis and light yellow coloration of the leaves are other symptoms observed and reported. "Khaira" disease observed in U.P. is reported to be caused by zinc deficiency (Nene, 1967).

Symptoms similar to those due to zinc deficiency reported earlier, appear in the water-logged acid rice soils in Kuttanad (Kerala) also. Zinc sulphate application, however, has proved helpful in alleviating such symptoms (Tomy et al., 1975). A preliminary survey carried out in Kuttanad soil has revealed that zinc is generally deficient in these soils (Aiyer et al., 1975). Detailed investigation on the effect of zinc in increasing the yield of rice in this area, which is the major rice growing tract in Kerala, has not been undertaken so far.

With a view to investigate the response of zinc to paddy in Kuttanad, a field experiment in Randomised Block Design was laid out in a cultivators' field at Edathua, where zinc deficiency was detected by soil analysis. Different methods of application of zinc were also tried. The observation on the growth parameters and yield characters made during the study as well as the nutrient interrelationships observed are discussed in the following pages.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The importance of zinc in plant nutrition has received much attention during the recent years. Maze (1919) furnished the first convincing evidence of the essentiality of zinc to higher plants. Its essential nature was in general accepted after Sommer and Lipman (1926) and Sommer (1928) who showed that zinc is indispensable for plant growth. Nene and Sharma (1969) observed that the 'Khaira' disease of paddy is due to zinc deficiency. According to Kanwar and Randhawa (1967) zinc deficiency is more wide spread in field and fruit crops in different parts of India.

1. Total zinc in soil.

Staker and Cummings (1942) found that the zinc content of peat soils of New York varies from traces to 23600 ppm. Thorne et al. (1942) reported that zinc content of a number of Utah soils ranges from 30-250 ppm. Swaine (1950) gave an average value of 10-300 ppm zinc in the lithosphere. The average zinc content of the lithosphere is 80 ppm (Goldschmidt, 1954). Nair and Mehta (1959) reported that Gujarat soils contain 2-95 ppm zinc. Lal et al. (1960) recorded that the total zinc content in the alluvial, black and laterite soils of India is in the range of 34-68 ppm, 69-76 ppm and 24-30 ppm respectively. Randhawa and Kanwar (1964) found that the total zinc content of Punjab soils varied from 18-97.5 ppm. Chatterjee and Das (1964) reported that the zinc content of

Indian soils varies from 21.5-88.7 ppm. According to Bandyopadhya and Adhikari (1968) the total zinc content of rice soils of Bengal ranged from 30.8-76.8 ppm. Zinc content of Onattukara and Kuttanad soils vary from 31-158 ppm and 59-93 ppm respectively (Balakrishnan Nair, 1970). In the alluvial soils of Kerala, the zinc content is in the range 15-92.5 ppm, as reported by George Varghese (1971). Gupta and Singh (1972) observed that the total zinc content of Indore soils ranges from 40-131 ppm. Valsaji (1972) found the total zinc content of Amaravila series of soils in Trivandrum District ranging from 12.6-100 ppm. Randhawa and Takkar (1975) reported that the total zinc content in Indian soils ranges from 2.0-1204 ppm.

2. Available zinc content of soils.

The value of available zinc content of soils varies depending upon the extractent used. Nair and Mehta (1959) found that available zinc content varied from 0.5-6.1 ppm in Gujarat soils. Lal et al. (1960) reported that the available zinc content in representative soils of India is in the range of 4.5 to 6.3 ppm in alluvial soils, 1.1 to 3.8 ppm in black soils and 1.2 to 7 ppm in laterite soils. Available zinc content of Maharashtra soils varied from traces to 0.5 ppm and that of Gujarat soils traces to 16 ppm (Durate et al., 1961). Bandyopadhya and Adhikari (1968) reported that the extractable zinc in rice soils of Bengal is in the range of 0.5 to 6.2 ppm. Grewal et al. (1969) observed that the soils of Haryana, Punjab and Himachal Pradesh have available zinc contents from 0.48 to 6.9 ppm. Sharma and Motiramani (1969) recorded that the available zinc in Madhya Pradesh varies from 2.4-5.58 ppm. Prasad and Singh (1969) reported that the dithizone extractable zinc in alluvial soils of Bihar is in the range 0.5 to 6.7 ppm. The available zinc content of Onattukara and Kuttanad soils, according to Balakrishnan Nair (1970), ranges from 0.5 to 5.01 and 0.52 to 2.4 ppm respectively. Ravikumar Praseedom (1970) observed that the available zinc content of Kerala soils ranges from 0.25 to 8 ppm. The alluvial soils of Kerala contain 1.2 to 6.48 ppm of available zinc (George Varghese, 1971). Valsaji (1972) found that the available zinc content of Amaravila soils in Trivandrum District ranges from 1.19 to 5.53 ppm. The variation in available zinc content of Tamil Nadu soils, as reported by Balasundaram et al. (1973) is in the range 0.7 to 2.6 ppm. Ravikumar Praseedom and Koshi (1975) observed that the available zinc in the surface soil varies from 0.3 ppm in the Kari profile of Vechoor to 77 ppm in the black soil of Kozhinjampara. Aiyer et al. (1975) observed that the available zinc content of Kuttanad soils varies from traces to 10.5 ppm. Available zinc content between traces to 22 ppm in Indian soils has been reported by Randhawa and Takkar (1975).

3. <u>Relation between total and available zinc.</u>

Nair and Mehta (1959) obtained a significant positive correlation between total and available zinc in Gujarat soils. Bandyopadhya and Adhikari (1968) reported that the value of total zinc is about 26 times that of extractable zinc and a positive correlation exists in West Bengal soils. Tripathi et al. (1969) observed a positive correlation between total and available zinc in U.P.soils. A positive correlation between the total and available zinc in Kerala soils was reported by Balakrishnan Nair (1970), Ravikumar Praseedom (1970) and George Varghese (1971). Katyal (1972) failed to establish any association between available and total zinc contents of rice soils. Balasundaram et al. (1973) observed a significant positive correlation between total and available zinc in Tamil Nadu soils.

Factors affecting availability of zinc.

Zinc deficiency in wet land rice generally occurs in soils having pH higher than 7, in soils with low total zinc content, such as sandy soils and in soils with higher content of organic matter.

A significant negative correlation between pH and extractable zinc content of Gujarat soils was observed by Nair and Mehta (1959). Chatterjee and Dass (1964) obtained more ammonium acetate extractable zinc in soils with pH below 6 and its content decreased with increase in pH above 7. Bandyopadhya and Adhikari (1968) reported significant negative correlation between pH and available zinc in West Bengal soils. Agarwala et al. (1970), however, obtained no definite trend in available zinc and pH in the eastern region soils of Uttar Pradesh. Rai et al. (1970), Valsaji (1972) and Balasundaram et al. (1973) reported significant negative correlations between available zinc and pH. Green house and laboratory study at IRRI on the relation between plant zinc and soil pH indicated that higher the soil pH, lower was the plant zinc content (IRRI, 1971). It was also reported by them that the solubility of zinc in water decreased 100 times with every unit increase in pH. McBride and Blasiak (1979) observed that zinc solubility in soils with pH 5.5 seemed to be determined by a nucleation or specific adsorption process, possibly involving iron and aluminium oxides.

Experiments at IRRI showed that zinc deficiency occurs regardless of pH in continuously wet soils. Air drying the soils from continuously wet blocks followed by flooding, produced a dramatic increase in rice yield and increase in the zinc content of straw (IRRI, 1971). The findings at IRRI, also indicate that zinc deficiency is possible even in acid soils if they are continuously waterlogged.

Nair and Mehta (1959) reported a positive significant relationship between organic matter and acid soluble zinc. De Romer and Smith (1964) found that decomposing plant tissues could immobilize zinc in an unavailable form. A high positive correlation between organic matter content and extractable zinc was observed by Sorenson et al. (1971), Sillanappa (1962), Dolar (1970) and Misra and Pande (1975). Sharma and Meelu (1975) recorded that the application of farm yard manure increased the available zinc status of the soils. However, studies at IRRI showed that excess organic matter appeared to inactivate soil zinc and retards zinc uptake by the rice plant (Yoshida et al., 1973).

Leeper (1952) postulated that calcium carbonate may act as a strong adsorbent for heavy metals. Thorne (1957) observed that liming the acid soils may produce zinc deficiency. Sen and Deb (1975) reported that the application of calcium carbonate resulted in a considerable decrease in the concentration of surface applied zinc. A linear decrease in rice yield with increasing rates of lime application was observed by Peterson et al (1975). Katyal et al. (1979) suggested that in soils of low available zinc, the presence of lime-bearing minerals may be an additional hazard to the proper zinc nutrition of crops.

The incidence of zinc deficiency increased consequent on the use of improved varieties of rice and the accompanying good cultural practices. Reports from AICRIP (1971) indicate that high doses of nitrogen contribute to zinc deficiency. The above effect of nitrogen on zinc deficiency was attributed to the build up of greater protein nitrogen which caused retention of zinc in roots as zinc-protein complex. Dev and Mann (1972b) observed that nitrogen applied in the form of ammonium sulphate decreased the soil pH and increased significantly the available zinc and manganese. Sharma and Meelu (1975) reported that available zinc in soil increased significantly with farm yard manure and decreased with phosphate applications. Potassium did not significantly affect the available zinc.

Antagonistic relationship between phosphorus and zinc in soil have been alluded to by Kalyanasundaram and Mehta (1970). Badanur and Venkatarao (1973) have concluded that the build up of phosphorus in an acid soil resulted in the decreased availability of zinc to the extent of 22 to 38 per cent. Takker et al. (1976) presented evidence to show that high phosphorus availability in the soil tends to reduce the rate of zinc entry into the roots inducing zinc deficiency. Patel and Wallace (1975), Prabha et al. (1975), Pathak et al. (1975), Singh (1976) and Chahal et al. (1976) reported decreased zinc content of maize, wheat, groundnut, tomato and rice with increasing application of phosphorus fertilizers.

Value of zinc in rice nutrition.

Tsui (1948) ascertained that zinc is required directly for the synthesis of Tryptophan and that auxin is produced from Tryptophan. Zinc has an important role in auxin formation and in the functioning of enzyme system (Thorne, 1957).

Lal and Subba Rao (1955) found that the efficiency of different plants to utilize zinc for dry matter production is of the order : rice-maize-barley and sugarcane. Kanwar and Dhingra (1962) reported that application of zinc increases the chlorophyll content. Naik and Asana (1961) found that zinc deficiency results in the reduced rate of protein synthesis and increased accumulation of non-protein intermediate in cotton plants. Sadaphal and Dass (1961) showed that soil as well as foliar application of zinc sulphate increases the protein content of wheat. Govindaraj and Gopal Rao (1964) reported a higher nitrogen content in sunhemp by zinc application during the first year but there was no response during the second year. According to Rao (1962) major portion of the zinc is needed by rice at the milk stage. Anand et al. (1969) showed that both zinc and copper increased chlorophyll content of citrus leaves. Chahal (1971) observed that the concentration of zinc in wheat plant was maximum at tillering stages and thereafter the concentration decreased progressively towards maturity. The influence of zinc on the growth, yield and other characters has been investigated. Tokuoka and Gyo (1938) observed that the addition of 1 ppm zinc in culture solution increased the yield of rice, while 5 ppm gave toxic effect. In different parts of India, substantial yield increase of rice by zinc application was reported by Singh and Jain (1964). Mahapatra et al. (1970) observed maximum increase in the yield of wheat by zinc application. Kanwar (1964) recorded that zinc sulphate application to acid soils of Bhadiarkar increased wheat yield significantly. Samboornaraman et al. (1969) found increased growth and dry weight of wheat by zinc application. Chanchal Singh and Grewal (1969) obtained five fold increase in wheat by the application of 10 ppm zinc in a Barewal soil. Significant increases in the yield of rice with different methods of zinc application have been reported by Abichandani (1955), Singh and Jain (1964), Kanwar (1964), Kanwar and Joshi (1964a), Mahapatra et al. (1970), Krishnamoorthy et al. (1976) and Bhadrachalam (1977). Mariam and Koshi (1977) observed a suppression of tiller numbers in rice with zinc application but reported increase in the number of grains/panicle and also height of plant. Tomy et al. (1975) observed increased yield of rice in Kuttanad with moderate dose of zinc sulphate application. Mahapatra and Gupta (1978) reported increased grain yield upto 21 per cent with zinc sulphate application. He also observed that there was more number of grains per panicle and more tiller per plant over control. Gill and Hardip Singh (1978) and Mahatim Singh et al. (1978) have reported that zinc application increased the values for all growth characters, such as tiller number, plant height, number of grains per panicle etc. and also grain yield. Singh et al. (1979) compiled the results of 13847 experiments on farmer's fields to evaluate the effect of zinc sulphate on cereals and groundnut. They observed that zinc treatment improved the yield of rice, wheat etc. and zinc significantly improved the response to N, P, K by these crops.

Methods of application.

Amongst the inorganic zinc carriers, zinc sulphate is the most efficient and cheapest for use in the correction of zinc deficiency in various crops. The kind of fertilizers as well as the time of application are important (Katyal et al., 1979). Abichandani (1955) reported that spraying of zinc sulphate increased rice yield beneficially. Bokde (1963), Singh and Jain (1964) and Nene (1967) observed increase in rice yield by foliar application of zinc. Samboornaraman et al. (1969) reported increase in wheat yield with foliar application of zinc. Sharma and associates (1968) showed response to both foliar and soil application of zinc by paddy. Lindsay (1972) reported that 1 kg zinc oxide applied to root as water suspension resulted in rice yield equivalent to 50 kg zinc sulphate per hectare as soil application. Increase in rice yield by coating the rice seed with zinc oxide at a rate of 1 lb ZnO per 100 lb seed has been reported by Thompson and Kasireddy (1975). Grewal and Singh (1975) found soil application as a better method to wheat and maize. Dipping the rice seedlings in a 2 per cent suspension of zinc oxide in water was recommended by IRRI (1973) for the correction of zinc deficiency. Castro (1976) found that zinc deficiency could be corrected by coating the germinated paddy seeds with zinc oxide at the rate of 1 per cent by weight of dry seed. Trehan and Sekhon (1977) provided a clear relationship between the method of application and efficiency of fertilizer zinc. He further reported that band placed zinc was superior to broadcasted zinc especially at lower levels.

Cox (1979) observed that zinc deficiency can be corrected by dipping rice seedlings in 1 to 2 per cent zinc oxide suspension in water. Ramakrishnan and Kaliappa (1976) and Singh et al. (1977) found soil application as a better method of zinc fertilisation to field crops. Shukla and associates (1971, 1972) and Mehta (1975) observed that the different methods of application did not significantly influence the yield when the level of applied zinc was 25 kg per hectare or more. Maskina and Randhawa (1979), Nijjar and Brar (1977) and Singh et al. (1977) evaluated zinc chelates also as a zinc source. Katyal et al. (1979) observed that for the correction of severe deficiency, zinc carriers as a rule should be applied prior to seeding or transplanting. Grewal and Singh (1975) in a trial with maize and wheat found that foliar application was not as beneficial as zinc sulphate broadcast on the soil at the time of sowing. Agarwala et al. (1977) reported that the effectiveness of foliar application of zinc would be reduced if sprayed at later growth stages. The results of the experiments conducted by the All India Co-ordinated Scheme for Micronutrients in 1977-78 on wheat crop indicated that soil application of sulphate, phosphate, carbonate and oxide of zinc were superior over foliar spray and seed soaking methods in increasing grain and straw yields.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment was laid out in a cultivators' field at Edathwa (Kuttanad) with a view to study the effect of different levels of zinc on the growth and yield of rice using paddy variety Jaya. The field was located as a zinc deficient area after analysis of soil samples from various locations in Kuttanad. The soil type at Edathwa was river alluvium surrounded by river.

Cropping history of the place.

A single crop in the punja season is the general pattern of cultivation prevailing in the area. The field will be flooded after harvest in March-April and will remain flooded till the commencement of the next cropping season in September. After strengthening the outer bunds, the field is drained and cultivation is started.

The physicochemical properties of the soil are given in Table 1(a).

Table 1(a). Physico-chemical properties of the soil from a cultivators' field at Edathwa.

A. Physical

Mechanical Analysis

Coarse sand	11.2%
Fine sand	18.7%
Silt	16.6%
Clay	44.0%

C.E.C. 32 me/100 g

Chemical

pH	4.5
Conductivity	0.212 m.mhos/cm
Organic carbon	4.7%
Total N	0.56%
Total P_2O_5	0.042%
Total K_2O	0.315%
Total Zn	78 ppm
Available Zn (EDTA)	1 ppm

Design and layout

The experiment was laid out in Randomised Block Design.

Treatment

The various treatments were as follows:

Zinc

Zn_0	- 0 kg $ZnSO_4$/ha
Zn_1	- 10 kg ,,
Zn_2	- 20 kg ,,
Zn_3	- 30 kg ,,
Zn_4 (F1)	- Foliar application of 0.25% $ZnSO_4$ solution
Zn_5 (F2)	- Foliar application of 0.5% ,,
Zn_6 (R1)	- Root dip of seedlings in 2% ZnO suspension

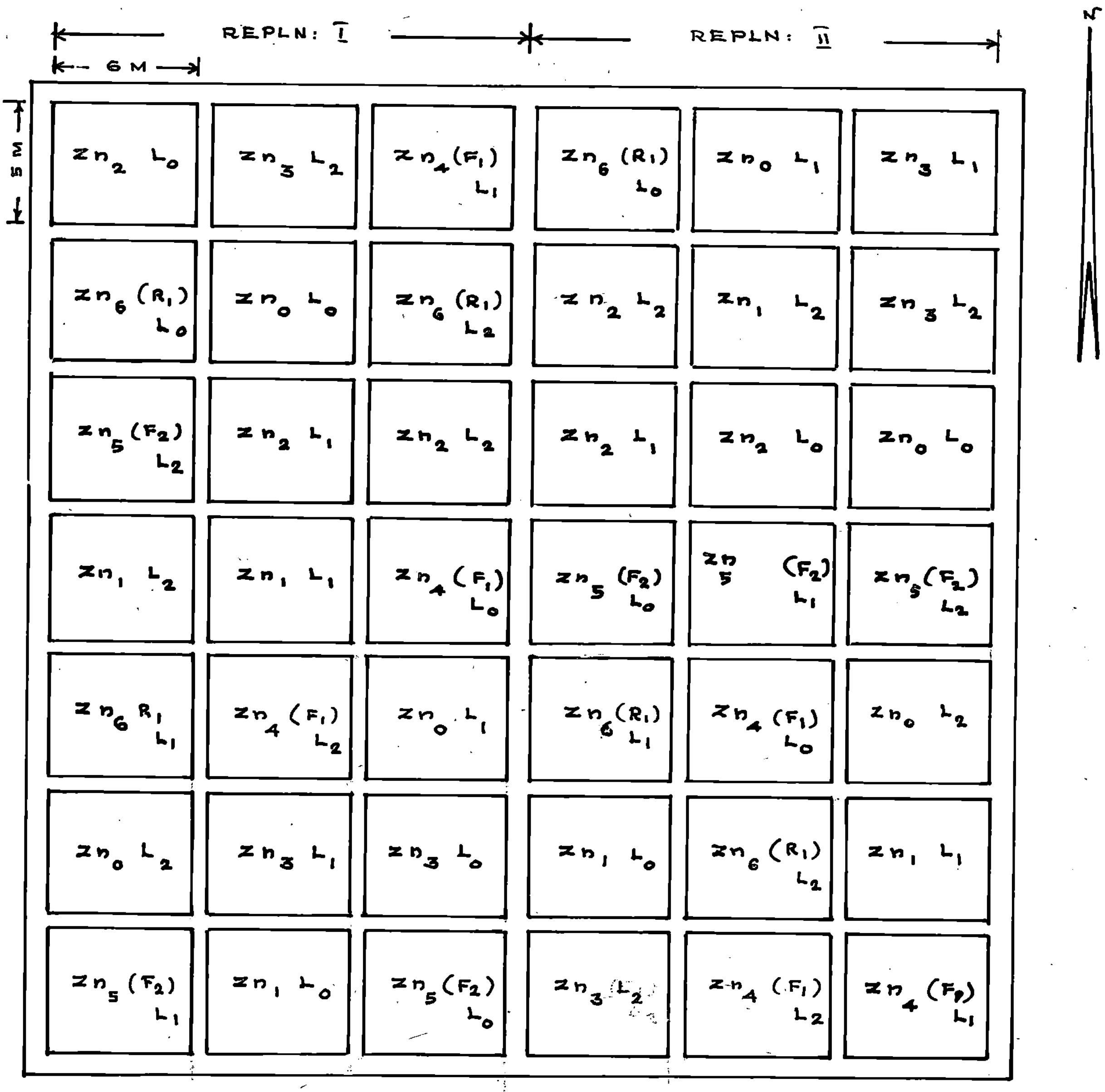
Replication - 2

Lime

L_0	- 150 kg CaO/ha	($\frac{1}{4}$ of the recommended dose of Package of Practices)
L_1	- 300 ,,	($\frac{1}{2}$ dose of Package of Practices)
L_2	- 600 ,,	(Full dose of Package of Practices)

Treatment combination

Zn_0L_0	- $ZnSO_4$ - 0 kg/ha + CaO - 150 kg/ha
Zn_0L_1	- ,, + CaO - 300 kg/ha
Zn_0L_2	- ,, + CaO - 600 kg/ha



NO. OF TREATMENTS :- 21 DESIGN :- R.B.D REPLICATION - 2

Zn_0L_0 - CONTROL
Zn_0L_1 - zinc 0 kg $ZnSO_4$/ha + 300 kg CaO/ha
Zn_0L_2 .. .. .. + 600 .. .. ..
Zn_1L_0 - 10 kg zinc sulphate + 150 .. .. ..
Zn_1L_1 - .. .. .. + 300 .. .. ..
Zn_1L_2 - .. .. .. + 600 .. .. ..
Zn_2L_0 - 20 kg .. .. + 150 .. .. ..
Zn_2L_1 - .. .. .. + 300 .. .. ..
Zn_2L_2 - .. .. .. + 600 .. .. ..
Zn_3L_0 - 30 kg .. .. + 150 .. .. ..
Zn_3L_1 - 30 kg. zinc sulphate + 300 kg CaO/ha
Zn_3L_2 - .. .. .. + 600 .. ..
Zn_4L_0 - Foliar apl: 0.25 % $SnSO_4$ + 150 .. ..
Zn_4L_1 - .. .. + 300 .. ..
Zn_4L_2 - .. .. + 600 .. ..
Zn_5L_0 - .. .. 0.5 % .. + 150 .. ..
Zn_5L_1 - .. .. + 300 .. ..
Zn_5L_2 - .. .. + 600 .. ..
Zn_6L_0 - Root dip 2% ZnO suspension + 150 .. ..
Zn_6L_1 - .. .. .. + 300 .. ..
Zn_6L_2 - .. .. .. + 600 .. ..

FIG: 1. LAY OUT PLAN – RANDOMISED BLOCK DESIGN

Zn_1L_0	-	$ZnSO_4$ - 10 kg/ha	+ CaO - 150 kg/ha
Zn_1L_1	-	"	+ CaO - 300 kg/ha
Zn_1L_2	-	"	+ CaO - 600 kg/ha
Zn_2L_0	-	$ZnSO_4$ - 20 kg/ha	+ CaO - 150 kg/ha
Zn_2L_1	-	"	+ CaO - 300 kg/ha
Zn_2L_2	-	"	+ CaO - 600 kg/ha
Zn_3L_0	-	$ZnSO_4$ - 30 kg/ha	+ Cao - 150 kg/ha
Zn_3L_1	-	"	+ CaO - 300 kg/ha
Zn_3L_2	-	"	+ CaO - 600 kg/ha
$Zn_4(F1)L_0$	-	$ZnSO_4$ - 0.25% spray	+ CaO - 150 kg/ha
$Zn_4(F1)L_1$	-	"	+ CaO - 300 kg/ha
Zn_4 $(F1)L_2$	-	"	+ CaO - 600 kg/ha
$Zn_5(F2)L_0$	-	$ZnSO_4$ - 0.5% spray	+ CaO - 150 kg/ha
$Zn_5(F2)L_1$	-	"	+ CaO - 300 kg/ha
$Zn_5(F2)L_2$	-	"	+ CaO - 600 kg/ha
$Zn_6(R1)L_0$	-	ZnO - 2% suspension (Root dip)	+ Cao - 150 kg/ha
$Zn_6(R1)L_1$	-	"	+ CaO - 300 kg/ha
$Zn_6(R1)L_2$	-	"	+ CaO - 600 kg/ha

Field culture

The field operations were carried out in the same manner as was done by the cultivators in the area who were following the Package of Practices recommendations for paddy prescribed by Kerala Agricultural University.

Nursery

Twenty kg good quality Jaya seeds were pre-germinated and sown in the seed beds. Growth in the nursery was good. Two sprayings with plant protection chemicals were given as a prophylatic measure against insects and pests.

Main field

Soon after the dewatering of the padasekharam, the area selected was ploughed, harrowed and levelled. The field was divided into 42 plots, each plot having an area of 6 m x 5 m (30 sq.m) and were separated by bunds of 30 cm width. The rows were given an outer bund of 60 cm width, with provision for irrigation and drainage. Lime at the required rates were applied to each plot, two days before planting the rice seedlings. N, P_2O_5 and K_2O in the form of urea, factomphos and muriate of potash respectively were applied at the uniform rate of 90:45:45 kg/ha as prescribed in the Package of Practices recommended by the Kerala Agricultural University. Half the nitrogen, full phosphate and half the potash were given as basal application, 50 per cent of the remaining nitrogen was applied as first top dress and the remaining nitrogen and half potash were applied as top dressing at the time of panicle initiation. For the soil application of zinc, zinc sulphate at the required levels were broadcasted just before transplanting. For the root dip of zinc, the seedling roots were dipped in 2% zinc oxide suspension in water before transplanting. Thirty days old healthy seedlings were used for transplanting. Two plants per hill with a spacing of 20 x 15 cm were transplanted. Irrigation and drainage were given according to necessity. Hand weeding was done twice to control weeds. Plant protection measures were taken as and when required. Foliar applications of 0.25% and 0.5% zinc sulphate in water were carried out on the third week of transplanting.

There was good rain during the early stages of the crop growth. The general stand of the crop was good throughout the period. It was noticed that the flowering was more uniform in zinc treated plots.

The field was harvested at full maturity. Each plot was harvested, threshed and dried separately. Wet weights and dry weights of grain and straw were recorded. Representative samples of the grain and straw from each plot were collected and preserved for analysis, after drying in an air oven at 70°C for 6 hr.

Biometric observations

Sampling was done as prescribed by Kwanchai A Gomez (1972). The following observations relating to the growth and yield characters of the plant were recorded from each treatment.

A. Observation on growth parameters

1. Height of the plant in cm at 30th day after transplanting
2. Height of the plant just before harvest
3. Tiller count on the 30th day and the number of productive tillers at harvest.

B. Yield attributes

(a) Percentage of productive tillers

(b) Number of grains per panicle

(c) Length of panicle

(d) Percentage of filled grains

(e) 1000 grain weight

C. Observations on yield

(a) Yield of grain

(b) Yield of straw

(c) Grain:straw ratio

D. Chemical analysis

(a) Nitrogen in the plant sample was determined by the Micro-kjeldahl method as outlined by Jackson (1958).

(b) Triple acid extract of the plant material was prepared and was used for the following estimations:-

(i) Phosphorus by Vanadomolybdate method using Klet-Summerson Photo-electric Colorimeter (Jackson, 1967).

(ii) Potassium using EEL Flame Photometer as outlined by Jackson (1967)

(iii) Calcium and magnesium by the Versenate titration method, as given by Jackson (1967), and

(iv) Zinc with the aid of Atomic Absorption Spectrophotometer as prescribed by Yoshida et al. (1976).

RESULTS

RESULTS

The data on the various growth characters of the rice plant as influenced by zinc and lime application in the field experiment are presented in Tables 1 to 25.

A. Growth characters.

Tables 1 and 2 present data on the influence of zinc and lime on the height of rice plant. The maximum plant height of 96.75 cm at harvest was recorded in the plot which received foliar application at 0.25 per cent zinc sulphate. This was followed by treatments 30 kg zinc sulphate per hectare and 20 kg zinc sulphate per hectare; which recorded 96.25 cm and 95.75 cm respectively. The control plots recorded at harvest a plant height of 91 cm. Increase in plant height was found to be significantly influenced by application of zinc except at the early stages of growth. The influence of root dip on plant height was not significant. Application of lime did not show any significant increase in plant height.

The tiller count and the percentage of productive tillers in plants under various treatments are given in Tables 3, 4 and 5. In the early stages of growth, the maximum tiller number of 22.15 was recorded in plots which received 20 kg zinc sulphate per hectare. Lime application also showed a slight increase in the number of tillers. At harvest stage, again there was significant increase in the tiller number in the treated plot. Tiller count of 23.1, 21.05 and 20.6 were

Table 1. Influence of zinc and lime on the height of rice plant at 30th day of transplantation (in cm).

	L_0	L_1	L_2	Mean
Zn_0	54.90	55.95	58.80	56.55
Zn_1	53.65	58.85	59.35	57.28
Zn_2	61.00	55.45	58.20	58.21
Zn_3	58.20	54.35	60.00	57.78
Zn_4	56.30	59.45	61.90	59.21
Zn_5	57.75	54.45	60.75	60.98
Zn_6	60.00	53.00	54.95	55.98
Mean	57.40	57.35	59.25	

C.D. for zinc Marginal means = 3.6874
C.D. for L ,, = 2.4140
Zn x L combination = 6.3860

Table 2. Influence of zinc and lime on the height of rice plant at harvest (in cm)

	L_0	L_1	L_2	Mean
Zn_0	91.00	91.00	90.85	90.95
Zn_1	93.75	95.75	94.50	94.66
Zn_2	92.25	93.75	95.75	93.92
Zn_3	96.25	91.50	91.75	93.16
Zn_4	96.75	95.50	90.75	94.33
Zn_5	91.25	93.95	91.80	92.33
Zn_6	90.85	93.60	92.00	92.15

C.D. for zinc Marginal means = 3.0162
,, L ,, = 1.9745
,, Zn x L combination = 5.2240

Table 3. Influence of zinc and lime on the tiller count of rice plant at 30th day

	L_0	L_1	L_2	Mean
Zn_0	19.35	17.00	17.25	17.86
Zn_1	18.90	18.05	18.15	18.36
Zn_2	21.50	21.90	22.15	21.85
Zn_3	21.10	20.25	19.35	20.23
Zn_4	15.40	20.40	18.90	18.23
Zn_5	16.50	20.00	19.50	18.66
Zn_6	18.30	18.20	20.00	18.33
Mean	18.72	19.40	19.33	

C.D. Zn Marginal means = 2.0319
L ,, = 1.3302
Zn x L combination = 3.5194

Table 4. Influence of zinc and lime on the tiller count at harvest

	L_0	L_1	L_2	Mean
Zn_0	19.00	17.20	16.75	17.65
Zn_1	18.75	17.95	17.55	18.08
Zn_2	21.40	22.55	23.10	22.35
Zn_3	21.05	20.20	19.90	20.38
Zn_4	15.80	20.60	18.70	18.36
Zn_5	17.35	18.30	19.70	18.45
Zn_6	18.40	20.40	20.10	19.63

C.D. Zn Marginal means = 2.684
L ,, = 1.757
Zn x L combination = 4.649

Table 5. Influence of zinc and lime on the percentage of productive tillers

	L_0	L_1	L_2	Mean
Zn_0	82.916	84.865	82.629	83.470
Zn_1	82.135	82.453	82.861	82.482
Zn_2	83.365	84.935	86.933	85.078
Zn_3	84.915	84.830	87.332	85.725
Zn_4	82.469	87.134	80.364	83.322
Zn_5	84.592	87.466	81.799	84.619
Zn_6	80.759	88.106	85.419	84.759
Mean	83.021	85.698	83.904	

C.D. Zn Marginal means = 4.4263
L " = 2.8977
Zn x L combinations = 7.6660

Table 6. Influence of zinc and lime on the length of panicle (in cm)

	L_0	L_1	L_2	Mean
Zn_0	22.70	23.85	21.85	22.80
Zn_1	24.15	23.35	22.00	23.16
Zn_2	24.50	22.30	23.30	23.36
Zn_3	24.35	23.20	24.00	23.85
Zn_4	25.00	23.15	22.50	23.55
Zn_5	23.15	24.15	23.00	23.43
Zn_6	23.30	22.00	22.50	22.60
Mean	23.88	23.14	22.73	

C.D. Zn Marginal means = 1.0881
L " = 0.7123
Zn x L " = 1.8346

recorded for treatments at 20 kg/ha, 30 kg/ha and 0.25 per cent foliar application of zinc sulphate respectively. Lime application did not show any influence on tiller count.

The data on the percentage of productive tillers as influenced by zinc and lime are given in Table 5. The maximum percentage of 87.4 was recorded in the plot which received 0.5 per cent zinc sulphate as foliar application compared to 82.6 per cent for the control plot.

B. Yield attributes.

1. The data on the length of panicle as influenced by zinc and lime are presented in Table 6.

Application of zinc recorded a significant increase in the length of panicle. Zinc sulphate applied as foliar spray resulted in the maximum length of 25 cm, followed by the soil application of 20 kg zinc sulphate per hectare, which resulted in 24.5 cm for length of panicle. In control plot the length of panicle was only 21.85 cm. The increased doses of lime recorded a decrease in the length of panicle.

2. Data on the number of grains per panicle as influenced by various treatments are presented in Table 7. The number of grains per panicle was influenced by zinc applied by different methods and at different levels. Maximum number of 192 grains per panicle could be recorded in plots which received 0.25 per cent of zinc sulphate as foliar spray.

s showing the general stand of the crop an
ifferent treatments at harvest

This was followed by 173 grains per panicle for soil application of 30 kg zinc sulphate per hectare as against 124.35 grains per panicle in the control plot.

3. The results on the percentage of filled grain as affected by zinc and lime treatments is presented in Table 8. It could be seen that the maximum percentage of 93.23 per cent filled grain resulted from the soil application of zinc sulphate at the rate of 10 kg per hectare. Foliar application of zinc also resulted in significant increase (92.2%) in the percentage of filled grains.

C. Yield of grain and straw

The results relating to the yield of grain and straw and grain:straw ratio from the different treatments are presented in Tables 9, 10 and 11 respectively and in Fig. 1a-1b.

The grain yield was significantly influenced by application of zinc. The maximum yield of 21.9 kg per plot was recorded from the plot which received foliar application of 0.5 per cent zinc sulphate, followed by 21.15 kg per plot which received 30 kg zinc sulphate per hectare. Maximum mean yield of 20.45 kg/plot and 20.13 kg/plot could be recorded for the foliar spray treatment of 0.5 per cent zinc sulphate and soil application of 20 kg zinc sulphate per hectare, respectively. Soil and foliar application were statistically on par. There was no significant increase in yield due to application of lime.

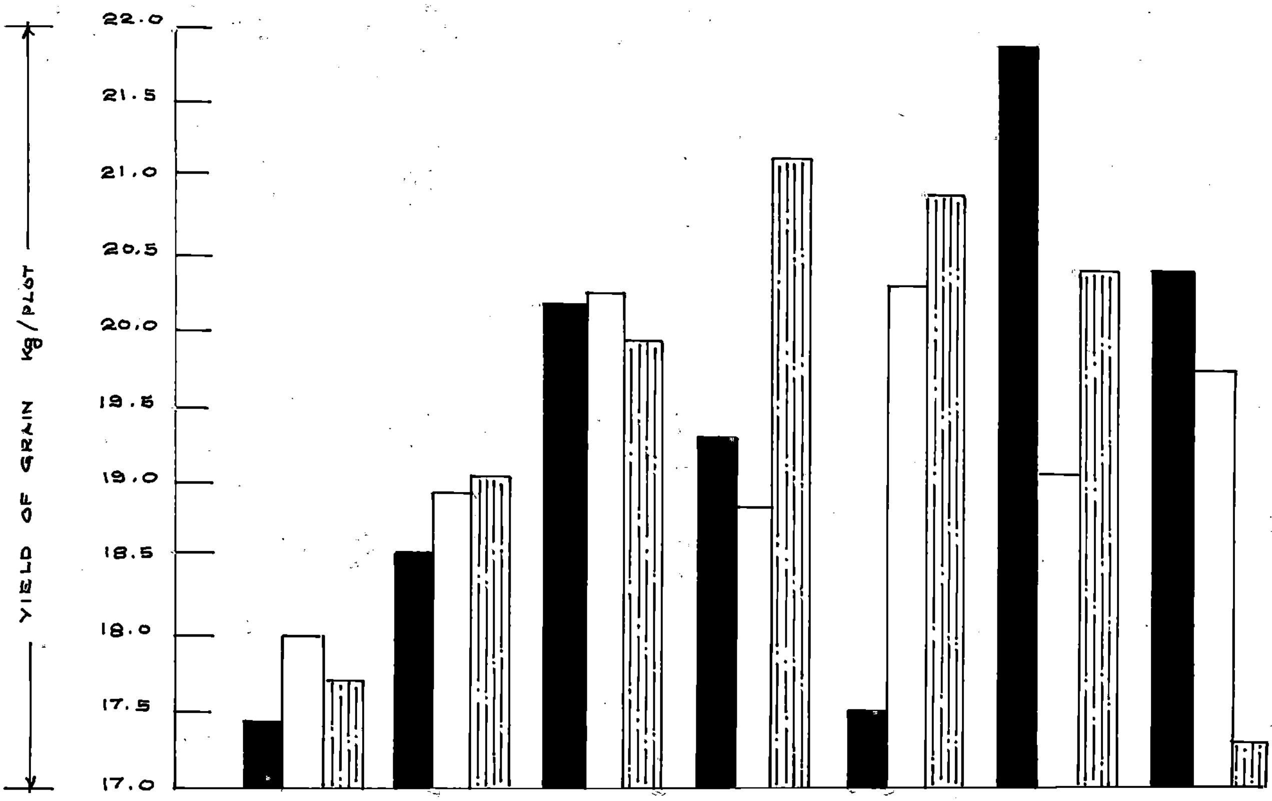


FIG: 1a. YIELD OF GRAIN Kg / PLOT

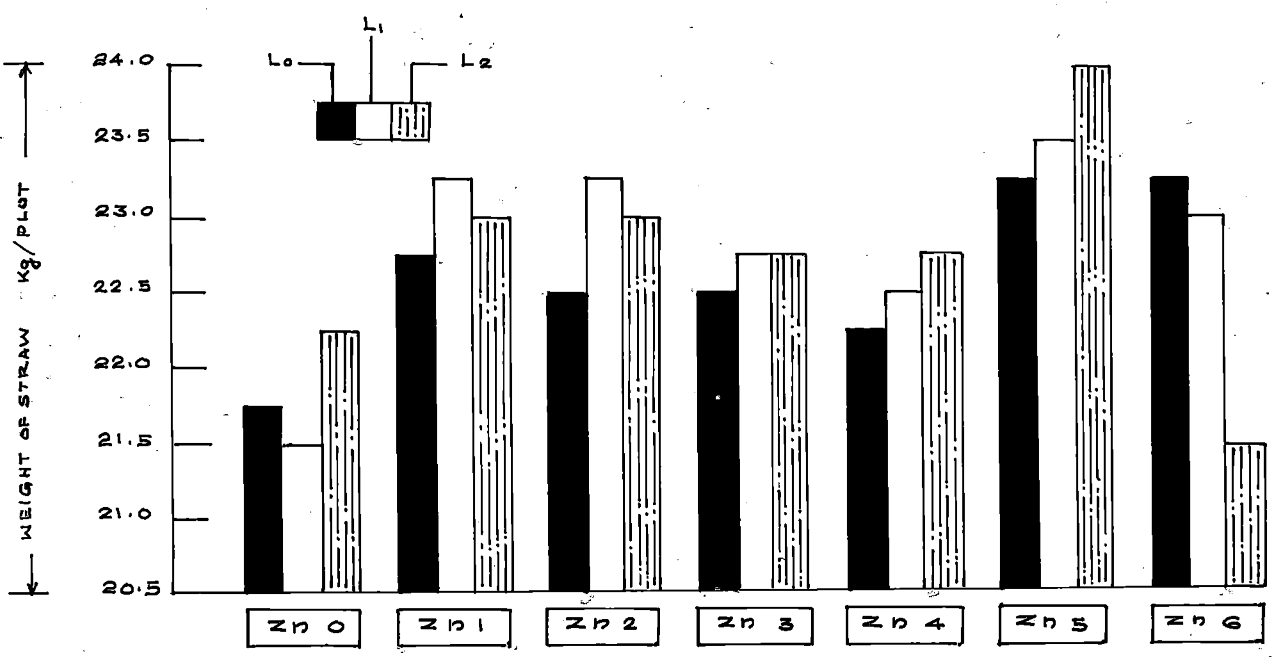


FIG: 1b. YIELD OF STRAW Kg / PLOT

Table 7. Influence of zinc and lime on the number of grains per panicle

	L_0	L_1	L_2	Mean
Zn_0	124.35	143.85	129.40	132.53
Zn_1	151.50	143.35	133.00	142.61
Zn_2	155.65	126.50	161.20	147.78
Zn_3	173.65	139.50	156.20	156.45
Zn_4	192.00	141.85	140.50	158.11
Zn_5	148.85	149.00	139.15	145.70
Zn_6	142.00	126.80	151.80	140.20
Mean	155.44	138.69	144.40	

C.D. Zn Marginal means = 5.86
L ,, = 2.51
Zn x L combination = 17.60

Table 8. Influence of zinc and lime on the percentage of filled grain

	L_0	L_1	L_2	Mean
Zn_0	86.66	90.95	87.37	88.32
Zn_1	93.22	88.91	87.50	89.88
Zn_2	91.66	88.32	88.77	89.58
Zn_3	92.63	91.63	90.85	91.70
Zn_4	92.22	90.32	90.89	91.14
Zn_5	87.42	91.47	87.38	88.76
Zn_6	87.98	89.17	90.15	89.10
Mean	90.25	90.11	88.99	

C.D. Zn Marginal means = 3.2996
L ,, = 2.1601
Zn x L combination = 5.7152

Table 9. Influence of zinc and lime on the yield of rice grain (kg/plot)

	L_0	L_1	L_2	Mean
Zn_0	17.45	18.00	17.70	17.71
Zn_1	18.55	18.95	19.05	18.85
Zn_2	20.20	20.25	19.95	20.13
Zn_3	19.30	18.85	21.15	19.76
Zn_4	17.50	20.55	20.90	19.65
Zn_5	21.90	19.05	20.40	20.45
Zn_6	20.40	19.75	17.30	19.15
Mean	19.33	19.34	19.49	

C.D. Zn Marginal means = 1.7135
L ,, = 1.1217
Zn x L combination = 2.9679

Table 10. Influence of zinc and lime on the yield of straw (kg/plot) in rice

	L_0	L_1	L_2	Mean
Zn_0	21.75	21.50	22.50	21.833
Zn_1	22.75	23.25	22.25	22.750
Zn_2	22.50	23.25	23.00	22.916
Zn_3	22.50	22.55	22.75	22.666
Zn_4	22.25	22.50	22.75	22.500
Zn_5	23.25	23.50	24.00	23.583
Zn_6	23.25	23.00	21.50	22.583
Mean	22.60	22.82	22.64	

C.D. Zn Marginal means = 0.8363
L ,, = 0.5802
Zn x L combination = 1.5350

Table 11. Influence of zinc and lime on the grain:straw ratio of rice

	L_0	L_1	L_2	Mean
Zn_0	0.802	0.836	0.795	0.8116
Zn_1	0.815	0.815	0.856	0.8288
Zn_2	0.897	0.874	0.863	0.8783
Zn_3	0.857	0.829	0.928	0.8716
Zn_4	0.786	0.904	0.920	0.8701
Zn_5	0.940	0.809	0.848	0.8661
Zn_6	0.878	0.858	0.804	0.8468
Mean	0.853	0.846	0.859	

C.D. Zn Marginal means = 0.0719
L " = 0.0470
Zn x L combination = 0.1246

Table 12. Influence of zinc and lime on the 1000 grain weight of rice (in g)

	L_0	L_1	L_2	Mean
Zn_0	27.205	27.950	28.320	27.825
Zn_1	27.780	27.150	27.850	27.593
Zn_2	26.955	27.100	27.140	27.065
Zn_3	27.375	27.250	26.445	27.023
Zn_4	27.275	27.550	27.125	27.316
Zn_5	27.685	26.575	27.175	27.145
Zn_6	27.350	27.250	26.500	27.033
Mean	27.375	27.260	27.222	

C.D. Zn Marginal means = 0.8423
L " = 0.5514
Zn x L combination = 1.4590

Weight of straw (Table 10) recorded an increasing trend with the application of zinc at all levels. Straw weight of 24 kg per plot and 23.25 kg per plot were recorded from the plots which received foliar application of 0.5 per cent zinc sulphate and soil application of 20 kg zinc sulphate per hectare, respectively.

Grain:straw ratio (Table 11) was also significantly influenced by the application of zinc. Foliar, soil and root dip treatments of zinc recorded grain:straw ratios 0.94, 0.92 and 0.88 respectively. Lime application failed to show any influence on the grain:straw ratio.

Data on the thousand grain weight as influenced by zinc application are presented in Table 12. The mean values for the control and treated plots indicated that there was no significant effect on thousand grain weight by zinc application. However, lime treated plots recorded a higher value of thousand grain weight. The value decreased with increase in the dose of zinc applied.

D. <u>Mineral composition of plant</u>

Data pertaining to the mineral composition of plants for the various treatments are presented in Tables 13 to 24.

(a) <u>Nitrogen</u>

The mean nitrogen content of straw in control was 0.747 per cent while that in the plot which received 20 kg zinc sulphate/ha was 0.820 per cent. No significant influence could be noticed on the nitrogen content of straw by the

Table 13. Influence of zinc and lime on the percentage of nitrogen in rice straw

	L_0	L_1	L_2	Mean
Zn_0	0.679	0.771	0.790	0.747
Zn_1	0.808	0.808	0.698	0.771
Zn_2	0.808	0.771	0.881	0.820
Zn_3	0.734	0.882	0.734	0.783
Zn_4	0.694	0.881	0.790	0.788
Zn_5	0.808	0.698	0.661	0.722
Zn_6	0.808	0.661	0.176	0.728
Mean	0.763	0.781	0.753	

C.D. Zn Marginal means = 0.1613
L ,, = 0.1056
Zn x L combination = 0.2795

Table 14. Influence of zinc and lime on the percentage of nitrogen in rice grain

	L_0	L_1	L_2	Mean
Zn_0	1.189	1.083	1.212	1.161
Zn_1	1.206	1.135	1.119	1.153
Zn_2	1.170	1.154	0.987	1.103
Zn_3	1.304	1.267	1.323	1.298
Zn_4	1.139	1.129	1.960	1.154
Zn_5	1.249	1.154	1.220	1.209
Zn_6	1.314	1.249	1.101	1.221
Mean	1.224	1.168	1.166	

C.D. Zn Marginal means = 0.1765
L ,, = 0.1168
Zn x L combination = 0.3092

application of zinc (Table 13).

In grain (Table 14) the nitrogen content increased with zinc application and it varied from 1.083 per cent in control to 1.323 per cent in the plot which received 30 kg zinc sulphate/ha.

(b) Phosphorus

Table 15 presents data on the phosphorus content in straw as influenced by zinc and lime. The phosphorus content was found to vary from 0.025 per cent to 0.07 per cent [illegible] with application of zinc. The phosphorus content of straw in the plot which was given root dip treatment of zinc was 0.07 per cent which was higher than those from soil or foliar applications of zinc.

The data on the phosphorus content of grain as affected by zinc and lime are presented in Table 16. The phosphorus content of grain by the application of 30 kg zinc sulphate/ha was 0.305 per cent. However, the mean phosphorus content of the grain by this treatment was 0.285 per cent while the mean value in the control plot was 0.2916 per cent. Table 16 also indicates a slight increase in the phosphorus content of grain by lime application. The mean value of phosphorus in the lime treated plots was found to vary from 0.266 per cent to 0.280 per cent.

(c) Potash

Data on the potash content of straw as influenced by zinc application are presented in Table 17. The mean value

Table 15. Influence of zinc and lime on the percentage of phosphorus in rice straw

	L_0	L_1	L_2	Mean
Zn_0	0.0250	0.0525	0.0675	0.0483
Zn_1	0.0575	0.0500	0.0475	0.0516
Zn_2	0.0575	0.0675	0.0500	0.0583
Zn_3	0.0500	0.0450	0.0400	0.0450
Zn_4	0.0575	0.0500	0.0700	0.0591
Zn_5	0.0625	0.0550	0.0600	0.0591
Zn_6	0.0625	0.0700	0.0475	0.0600
Mean	0.0532	0.0557	0.0546	

C.D. Zn Marginal means = 0.01671
L " = 0.01094
Zn x L combination = 0.02895

Table 16. Influence of zinc and lime on the percentage of phosphorus in rice grain

	L_0	L_1	L_2	Mean
Zn_0	0.290	0.295	0.290	0.292
Zn_1	0.235	0.255	0.245	0.245
Zn_2	0.295	0.270	0.300	0.288
Zn_3	0.270	0.295	0.290	0.285
Zn_4	0.280	0.305	0.300	0.295
Zn_5	0.240	0.240	0.260	0.246
Zn_6	0.245	0.290	0.275	0.270
Mean	0.266	0.278	0.280	

C.D. Zn Marginal means = 0.03789
L " = 0.02480
Zn x L combination = 0.06563

Table 17. Influence of zinc and lime on the percentage of potash in rice straw

	L_0	L_1	L_2	Mean
Zn_0	1.900	2.200	2.025	2.041
Zn_1	1.850	1.970	2.075	1.966
Zn_2	1.925	2.100	2.100	2.041
Zn_3	2.100	2.025	1.925	2.016
Zn_4	2.175	1.900	2.275	2.110
Zn_5	1.925	1.475	2.000	1.800
Zn_6	2.125	2.150	2.175	2.150
Mean	2.000	1.975	2.082	

C.D. Zn Marginal means = 0.2862
L " = 0.1873
Zn x L combination = 0.4957

Table 18. Influence of zinc and lime on the percentage of potash in rice grain

	L_0	L_1	L_2	Mean
Zn_0	0.400	0.425	0.525	0.417
Zn_1	0.413	0.475	0.413	0.433
Zn_2	0.488	0.513	0.413	0.481
Zn_3	0.500	0.450	0.513	0.488
Zn_4	0.475	0.488	0.438	0.466
Zn_5	0.425	0.475	0.500	0.466
Zn_6	0.438	0.413	0.488	0.446
Mean	0.448	0.462	0.455	

C.D. Zn Marginal means = 0.07584
L " = 0.04965
Zn x L combination = 0.13136

for potash content of straw in the control plot was 2.041 per cent while the mean values in the root dip treatment with 2 per cent zinc oxide suspension and foliar application of 0.25 per cent zinc sulphate per hectare were 2.15 per cent and 2.11 per cent respectively.

The data on the potash content in grain as influenced by zinc application are presented in Table 18. The potash content was found to vary from 0.4 per cent to 0.513 per cent, the maximum value could be obtained from the soil application of zinc at higher levels.

(d) Calcium

Table 19 and 20 give data on the calcium content of straw and grain respectively. The calcium content of grain and straw showed no significant difference by the application of zinc. The calcium content of straw varied from 0.374 to 0.551 per cent and that of grain from 0.11 to 0.154 per cent.

(e) Magnesium

Data on the magnesium content of straw and grain as influenced by zinc application are presented in Tables 21 and 22 respectively. No significant difference could be noticed by the application of zinc on the content of magnesium. The magnesium contents of straw and grain were found to vary from 0.1605 to 0.261 per cent and 0.082 to 0.15 per cent respectively.

(f) Zinc content

The values on the zinc content of straw and grain as influenced by the different levels of zinc are presented in

Table 19. Influence of zinc and lime on the percentage of calcium in rice straw

	L_0	L_1	L_2	Mean
Zn_0	0.5510	0.4610	0.4625	0.4915
Zn_1	0.4845	9.4405	0.5510	0.4920
Zn_2	0.5290	0.4450	0.5290	0.4995
Zn_3	0.4620	0.4240	0.3965	0.4275
Zn_4	0.5290	0.4845	0.4320	0.4815
Zn_5	0.5070	0.4400	0.3745	0.4405
Zn_6	0.4625	0.5290	0.4410	0.4775
Mean	0.5035	0.4599	0.4552	

C.D. Zn Marginal means = 0.6703
L ,, = 0.04398
Zn x L combination = 0.1161

Table 20. Influence of zinc and lime on the percentage of calcium in rice grain

	L_0	L_1	L_2	Mean
Zn_0	0.1100	0.1540	0.1980	0.1540
Zn_1	0.1302	0.1625	0.1660	0.1535
Zn_2	0.1100	0.1335	0.0910	0.1115
Zn_3	0.1100	0.1100	0.1320	0.1173
Zn_4	0.1129	0.0880	0.1455	0.1151
Zn_5	0.1405	0.0875	0.1100	0.1126
Zn_6	0.1185	0.1320	0.1540	0.1348
Mean	0.1190	0.1239	0.1423	

C.D. Zn Marginal means = 0.0580
L ,, = 0.0366
Zn x L combination = 0.0966

Table 21. Influence of zinc and lime on the magnesium content of rice straw

	L_0	L_1	L_2	Mean
Zn_0	0.1740	0.1605	0.2810	0.2051
Zn_1	0.2275	0.1470	0.2005	0.1916
Zn_2	0.2140	0.2140	0.1605	0.1961
Zn_3	0.1605	0.1470	0.2675	0.1916
Zn_4	0.1335	0.1335	0.1335	0.1335
Zn_5	0.1740	0.1465	0.2000	0.1735
Zn_6	0.2805	0.1335	0.1340	0.1826
Mean	0.1948	0.1545	0.1967	

C.D. Zn Marginal means = 0.08416
L ,, = 0.05509
Zn x L combination = 0.14570

Table 22. Influence of zinc and lime on the percentage of magnesium in rice grain

	L_0	L_1	L_2	Mean
Zn_0	0.0995	0.1500	0.1065	0.1186
Zn_1	0.1065	0.1205	0.0950	0.1068
Zn_2	0.1095	0.1300	0.1500	0.1298
Zn_3	0.1235	0.1200	0.1125	0.1186
Zn_4	0.0820	0.1255	0.1200	0.1091
Zn_5	0.1330	0.1205	0.1290	0.1275
Zn_6	0.1025	0.1065	0.1265	0.1098
Mean	0.1080	0.1246	0.1188	

Tables 23 and 24 respectively and in Fig.2a-2b. There was significant increase in the zinc content of straw and grain with increasing doses of zinc. The zinc content in straw varied from 26.5 ppm for control to 53 ppm for the foliar application with 0.5 per cent zinc sulphate. In the soil application of zinc, the zinc content in straw progressively increased with increasing levels of zinc applied. However, the root dip treatment recorded a lesser content of zinc than in other treatments, but higher than control. The content of zinc in grain varied from 27 ppm in the control plot to 61.5 ppm for the foliar application with 0.5 per cent zinc sulphate, followed by 60 ppm for soil application of 30 kg zinc sulphate per hectare.

The application of lime recorded significant difference in the zinc content of the plant. The zinc content in both straw and grain progressively decreased with increasing levels of lime. Table 25 reveals the uptake of zinc by rice plant. The zinc uptake by plant increased significantly with the application of zinc. The uptake by plants in the control plot was 1.087 g only. This value increased to 2.058 g per plot and 2.0916 g per plot which received 30 kg zinc sulphate per hectare as soil application and 0.5 per cent as foliar applications, respectively. Foliar application of zinc recorded the highest uptake of zinc by plants.

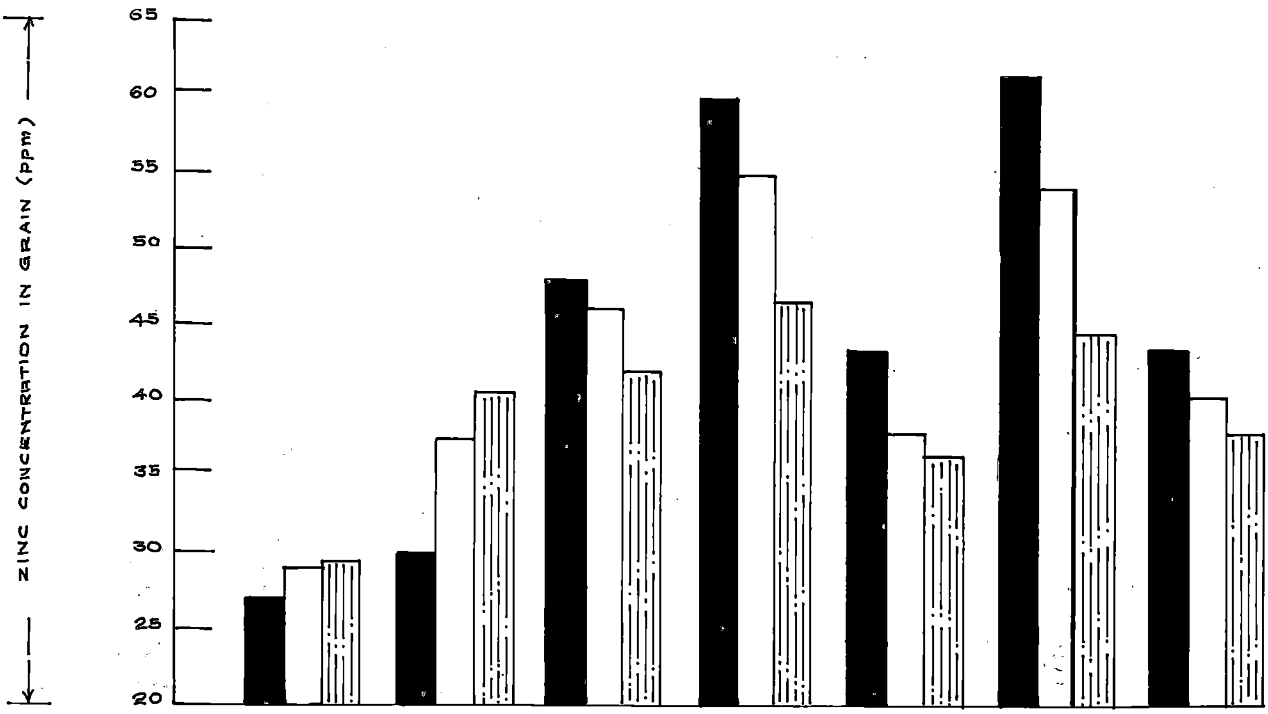


FIG: 2a. ZINC CONCENTRATION IN GRAIN IN ppm

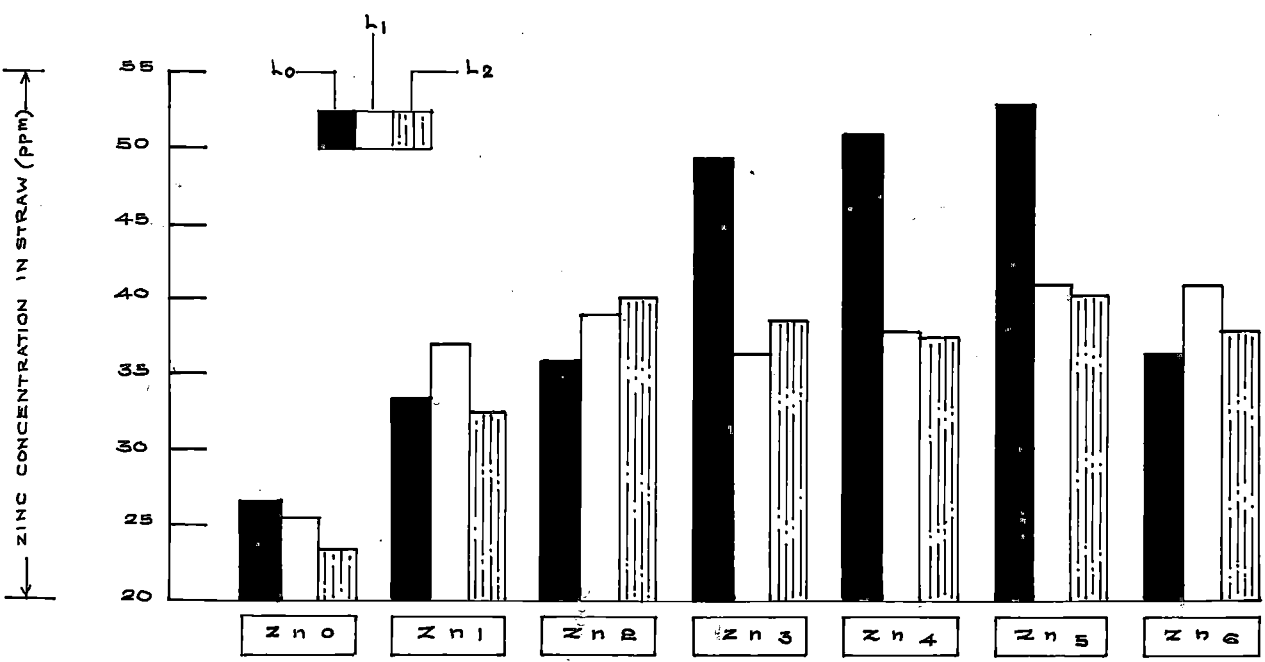


FIG: 2 b. ZINC CONCENTRATION IN STRAW IN ppm

Table 23. Influence of zinc and lime on the zinc content of straw (in ppm)

	L_0	L_1	L_2	Mean
Zn_0	26.50	25.50	23.50	25.16
Zn_1	33.50	37.00	32.50	34.33
Zn_2	36.00	39.00	40.00	38.38
Zn_3	49.50	36.50	38.50	41.50
Zn_4	51.00	38.00	37.50	42.16
Zn_5	53.00	41.00	40.50	44.83
Zn_6	36.50	41.00	38.00	38.50
Mean	40.86	36.86	35.78	

C.D. Zn Marginal means = 3.622
L " = 2.3712
Zn x L combination = 6.273

Table 24. Influence of zinc and lime on the zinc content in grain (in ppm)

	L_0	L_1	L_2	Mean
Zn_0	27.0	29.0	29.5	28.50
Zn_1	30.0	37.5	40.5	36.00
Zn_2	48.0	46.0	42.0	45.33
Zn_3	60.0	55.0	46.5	53.83
Zn_4	43.5	38.0	36.5	39.33
Zn_5	61.5	54.0	44.5	53.33
Zn_6	43.5	40.5	38.0	34.33
Mean	44.79	42.86	36.93	

C.D. Zn Marginal means = 8.422
L " = 4.513
Zn x L combination =14.588

Table 25. Influence of zinc and lime on the zinc uptake by plant (g/plot)

	L_0	L_1	L_2	Mean
Zn_0	1.132	1.064	1.062	1.088
Zn_1	1.318	1.571	1.490	1.461
Zn_2	1.776	1.837	1.798	1.790
Zn_3	2.269	1.864	2.042	2.058
Zn_4	1.952	1.630	1.595	1.725
Zn_5	2.193	2.171	1.910	2.092
Zn_6	1.782	1.722	1.485	1.660
Mean	1.774	1.695	1.621	

C.D. Zn Marginal means = 0.1462
L ,, = 0.2235
Zn x L combination = 0.3868

DISCUSSION

DISCUSSION

The broad objective of the present investigation was aimed at studying the effect of different levels of zinc on the growth and yield of rice in the submerged wet lands of Kuttanad. The result of a field experiment conducted in a cultivators' field at Edathua (Upper Kuttanad) where zinc deficiency was confirmed by soil analysis are discussed in the following pages.

It has been observed that the plant height was significantly influenced by soil and foliar applications of zinc. Similar results have been recorded by Chao and Tsui (1963), Balakrishnan Nair (1970) and Mariam and Koshi (1977). Foliar application recorded the maximum height of 96.75 cm.

The present data show that zinc application increased the number of tillers. However, the increase in the percentage of productive tillers was not significant. Soil application of zinc sulphate was more effective in increasing the tiller number. Balakrishnan Nair (1970), Gill and Hardip Singh (1978), Mahatim Singh et al. (1978) and Mahapatra and Gupta (1978) have also obtained significant increase in the number of tillers with the application of zinc.

Panicle length increased significantly with application of zinc. This result is in conformity with the findings of Mahatim Singh et al. (1978) and Gill and Hardip Singh (1978).

Number of grains per panicle and the percentage of filled grains recorded a significant increase by zinc application. Mariam and Koshi (1977) and Gill and Hardip Singh (1978) have also reported a similar trend by the application of zinc.

The grain and straw yields significantly increased with zinc application. Foliar application of 0.5% zinc sulphate followed by soil application of 20 kg zinc sulphate per hectare, recorded the maximum yield. Soil and foliar applications were superior over control and root dip treatment. Root dip treatment of zinc resulted in higher yield than control. An increase of 25% yield over control was obtained by foliar application of 0.5% zinc sulphate. Soil application of 20 kg zinc sulphate per hectare recorded more than 20% increase in yield over control. Soil and foliar applications of zinc sulphate were statistically on par. Similar response to zinc by rice has been reported by Kanwar (1964), Kanwar and Joshi (1964a) in the acid soils of Punjab. Grewal et al. (1969) observed that foliar application of 0.6% zinc sulphate increased the yield of paddy. According to Abichandani (1955), spraying of paddy plant with zinc sulphate and seed treatment with zinc increased the yield markedly. Similar results have also been reported by Singh and Jain (1964), Pillai (1967) and Mahapatra et al. (1970). Sharma and associates (1968) in a field experiment found that both soil and foliar applications of zinc increased the yield of grain and straw in the alluvial soils of Lucknow District. The results obtained by Venkateswaralu (1964), Venkateswaralu and associates (1971) and Mehta et al. (1975) are also in conformity with the findings of the present study, which is further supported by Bokde (1963) Randhawa and Dev (1972), Ramanadhan et al. (1973), Prabha et al. (1975), Tomy et al. (1975), Thompson and Kasireddy (1976), Krishnamurthy et al. (1976), Singh et al. (1979), Mikkelson and Brandson (1975) and Pathak et al. (1975). Application of lime showed a slight increase in grain yield. This is supported by the findings of Mariam and Koshy (1977).

Among the different methods of application of zinc tried, foliar application with 0.5% zinc sulphate recorded the maximum yield of rice which was followed by soil application of 20 kg/ha. Soil and foliar applications of zinc were statistically on par. Root dip method gave an increase in yield over control. In Moncompu (Kuttanad) soil Tomy et al. (1975) obtained similar results. Flor et al. (1974) found that application of zinc is most effective if done immediately before sowing. Samboornaraman et al. (1969) reported similar results to show that both foliar application of zinc at the tillering stage and soil application are equally effective in increasing the rice yield. The results of the present study receive ample support from the findings of Singh and Jain (1964), Lindsay (1972), IRRI (1973), Grewal and Singh (1975), Bhadrachalam (1977), Krishnamoorthy et al. (1976), Trehan and Sekhon (1977).

Mahapatra and Gupta (1978), and Katyal (1979). Trehan and Sekhon (1977) and Gill and Hardip Singh (1978) observed that application of zinc sulphate upto 20 kg/ha significantly increased grain yield but increasing the dose beyond 20 kg showed no increase in growth and yield. This finding also supports the results of the present investigation.

The grain:straw ratio was significantly influenced by the application of zinc. Highest mean value of 0.873 for grain:straw ratio was recorded for the soil application with 20 kg zinc sulphate per hectare.

The different treatments of zinc showed no significant influence on thousand grain weight. This is in conformity with the results obtained by Balakrishnan Nair (1970).

Mineral composition of plant

The nitrogen content of straw was not influenced by zinc application. However, in grain the nitrogen content appeared to increase with the soil application of zinc. Similar results have been recorded by Balakrishnan Nair (1970). Lime application failed to show any significant effect on the nitrogen content of grain and straw.

The phosphorus contents in both grain and straw were found to be affected by the application of zinc. The mean value for the phosphorus content in straw varied from 0.0483 per cent for control to 0.06 per cent for zinc treated plots. The phosphorus content in straw increased with increase in zinc application upto 20 kg zinc sulphate per hectare. However, the phosphorus content decreased with the soil application of 30 kg zinc sulphate/ha. This may be due to the antagonistic effect of excess zinc on phosphate. The phosphorus content of grain varied from 0.23 per cent to 0.305 per cent. The phosphorus in grain slightly decreased with higher doses of zinc. Similar results have been recorded by Balakrishnan Nair (1970).

The different zinc treatments did not show any significant effect on the potash content of straw or grain. Similar results have also been reported by Balakrishnan Nair (1970). The potash content of straw was found to range from 1.85 per cent to 2.275 per cent and that of grain from 0.4 per cent to 0.512 per cent.

Calcium and Magnesium

The concentration of calcium in straw ranged between 0.374 per cent to 0.551 per cent, and in grain 0.11 per cent to 0.198 per cent. The calcium content slightly decreased with increasing dose of zinc. The magnesium content in straw ranged from 0.133 per cent to 0.267 per cent and that in grain ranged from 0.082 per cent to 0.15 per cent. No significant variation in the magnesium content with the application of zinc could be noticed.

Zinc concentration of grain and straw

The concentration of zinc in grain and straw showed a significant increase with increasing levels of zinc applied. The zinc content in straw varied from 23.5 ppm to 53 ppm and that of grain from 27 ppm to 61.5 ppm. The uptake of zinc was also influenced significantly by the levels of zinc. The uptake of zinc ranged from 1.062 g in control plot to 2.269 g in the plot which received 30 kg zinc sulphate/ha. Balakrishnan Nair (1970) also found an increase in plant concentration of zinc with increased doses of zinc applied. Pathak et al. (1975) reported similar response of applied zinc on the concentration of zinc in plant. Cottenie (1979) reported that the concentration of zinc in plant tissue increased with increase in the soil content of available zinc. Shukla et al. (1972), however, found no difference among the different levels of applied zinc. Zinc concentration and the zinc uptake increased with increase in the levels of zinc. Takkar et al. (1977) reported an increase in the uptake of zinc with increase in the level of zinc applied. These results are in conformity with the findings of the present study.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

A field experiment was conducted in a cultivators' field at Edathua (Kuttanad) with a view to study the effect of different levels of zinc on the growth and yield of rice using paddy variety Jaya. The treatment included soil application of 0, 10, 20 and 30 kg zinc sulphate per hectare, foliar application of 0.25 per cent and 0.5 per cent zinc sulphate, root dip in 2 per cent zinc oxide, three levels of lime - 150, 300 and 600 kg CaO/ha and their combinations.

The cultural operations were carried out in the same manner as were done by the neighbouring cultivators. Manure, fertilizer and lime were applied as per the Package of Practices recommended by the Kerala Agricultural University. Observations on the growth parameters and yield characters were made. Chemical analysis of the plant material for N, P, K, Ca, Mg and Zn at harvest were also carried out. The results are summarised below:

1. Increase in plant height at harvest was found to be significantly increased by the application of zinc.

2. Significant increase in the number of tillers by the application of zinc was noticed.

3. Increase in the percentage of productive tillers could be recorded but was not significant.

4. Length of panicle increased significantly with application of zinc.

5. Application of zinc recorded a significant increase in the number of grains per panicle.

6. The increase in the percentage of filled grains by zinc application was significant.

7. Significant increase in the yield of grain could be obtained by the application of zinc. Foliar application of 0.5 per cent zinc sulphate and soil application of 20 kg zinc sulphate per hectare recorded the maximum yield of grain. Both these treatments yielded more than 20 per cent grain over control and were statistically on par.

8. Significant increase in the weight of straw could also be obtained by zinc application at different levels. Maximum straw yield was obtained from foliar application of 0.5 per cent zinc sulphate and soil application of 20 kg zinc sulphate per hectare.

9. Grain:straw ratio was significantly influenced by the application of zinc.

10. Thousand grain weight was not influenced by the application of zinc.

11. The percentage of nitrogen in straw was not significantly influenced by zinc application. In grain, however, the nitrogen content increased with increasing doses of zinc.

12. The phosphorus content of straw and grain increased with increasing application of zinc up to 20 kg zinc sulphate per hectare. A decreasing trend could be noted

with higher doses of zinc applied.

13. The different levels of zinc did not indicate any significant influence on the potash content of straw or grain.

14. The calcium content in straw and grain recorded no significant difference by the application of zinc.

15. No significant difference in the content of magnesium in straw and grain could be obtained by zinc application.

16. Significant increase in the plant concentration of zinc in straw and grain could be obtained with increasing levels of zinc applied. The uptake of zinc by plant also increased with increasing levels of zinc applied.

17. Significant reduction in the zinc content of straw and grain could be observed with increasing levels of lime applied. This may be due to the increase in the soil pH brought about by lime application with consequent reduced availability of zinc to the plant.

Application of zinc has resulted in a significant increase in the grain and straw yields of paddy. Soil application of 20 kg zinc sulphate per hectare and foliar application of 0.5 per cent zinc sulphate were found to be equally beneficial in obtaining maximum yield of paddy. The present study indicates the beneficial role of zinc when applied to acid rice soils of Kuttanad.

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* Original not seen

APPENDIX I

ANALYSIS OF VARIANCE TABLE
Growth characters of rice

Source	Degrees of freedom	Mean squares				
		Length of plant at	Length of plant at	Tiller count at 30th day	Tiller count at harvest	Percentage of productive tillers
Zn	6	17.1570	10.7549	11.8980**	16.3780*	7.8380
Soils (S)	3	9.2183	46.3550**	59.9240**	85.6660**	39.4780
Foliar (F)	2	89.6600**	52.0810**	4.2866	3.4810	9.0700
Soil Vs.Foliar	1	118.1607**	7.3500	56.4540**	75.0400**	4.5230
Soil Vs.Root	1	42.6660*	42.1350*	29.7037**	5.5104	1.4780
Foliar Vs.Root	1	203.3630**	16.8030	0.2133	18.0070	7.4600
Lime (L)	2	16.3500	4.2530	1.9464	2.2880	26.0440
Zn x L	12	18.7620	7.6980	4.3239	3.3860	9.1890
Error	20	9.3740	6.2720	2.8466	4.9644	13.5080

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX II

ANALYSIS OF VARIANCE TABLE

Effect of zinc and lime on the yield attributes of rice

Source	Df.	Mean squares					
		Length of panicle	Percentage of filled grain	Yield of grain	Yield of straw	Grain:Straw ratio	1000 grain weight
Zn	6	1.1291	9.2270	5.0340	1.6349	0.0038	0.5874
Soils (S)	3	3.4479*	34.9970*	20.9233*	4.2083**	0.0191*	2.8195**
Foliar (F)	2	2.9316*	41.4609	35.5466**	14.0416**	0.0754**	2.5790*
Soil Vs.Foliar	1	0.2010	4.1417	4.7040	1.5041	0.7330**	0.0150
Soils Vs.Root	1	10.0104**	22.2870	2.5350	0.5041	2.2386**	0.5075
Foliar Vs.Root	1	9.5408**	8.6080	9.7200*	2.5208*	0.0669**	0.3366
Lime (L)	2	4.6973*	6.7250	0.1159	0.1845	0.0006	0.0885
Zn x L	12	1.3012	7.4910	3.2670	0.5248	0.0050	0.4207
Error	20	0.8162	7.5060	2.0243	0.5461	0.0036	0.4892

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX III

ANALYSIS OF VARIANCE TABLE
Effect of zinc and lime on the chemical composition of rice straw

Source	Df.	Mean squares					
		N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Zn (ppm)
Zn	6	0.0746	0.000224	0.0784	0.00463	0.00334	254.61**
Soils	3	0.0168	0.000583	0.0225	0.02034**	0.00073	902.33**
Foliar	2	0.0201	0.001170**	0.4387**	0.01741*	0.02322*	2048.66**
Soils Vs.Foliar	1	0.0288	0.002160**	0.0375	0.00041	0.03398*	640.27**
Soils Vs Root	1	0.0546	0.000938*	0.2709*	0.00027	0.00996	2.66
Foliar Vs.Root	1	0.0088	0.000053	0.4033*	0.00094	0.00187	300.00**
Lime	2	0.0030	0.000276	0.0439	0.00995	0.00794	100.02**
Zn x L	12	0.0121	0.000193	0.0501	0.00443	0.00509	41.72**
Error	20	0.0179		0.0565	0.00309	0.00488	9.05

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX IV

ANALYSIS OF VARIANCE TABLE
Effect of zinc and lime on the chemical composition of grain

Source	Df.	Mean squares					
		N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Zn (ppm)
Zn	6	0.02381	0.002680*	0.003601	0.001574	0.000496	562.134**
Soils	3	0.12490**	0.012930**	0.019270*	0.009385*	0.001587	2188.166**
Foliar	2	0.01607	0.131000**	0.015000*	0.009246**	0.001513	2790.166**
Soils Vs.Foliar	1	0.00018	0.000041	0.000166	0.004800	0.000003	35.266
Soils Vs.Root	1	0.18150	0.000004	0.004400	0.000730	0.001000	222.070
Foliar Vs.Root	1	0.01880	0.000008	0.005208	0.004840	0.000867	341.333*
Lime (L)	2	0.01546	0.000963	0.000714	0.002120	0.000997	234.730*
Zn x L	12	0.00856	0.000298	0.002849	0.000923	0.000522	78.099
Error	20	0.02197	0.000990	0.003965	0.002140	0.001045	48.907

*Significant at 5 per cent level
**Significant at 1 per cent level

ABSTRACT

A field experiment was conducted in a cultivators' field at Edathua (Kuttanad) to study the effect of different levels and methods of zinc application on the growth and yield of rice (var. Jaya). Soil application of 0, 10, 20 and 30 kg zinc sulphate per hectare; foliar application of 0.25 per cent and 0.5 per cent zinc sulphate, root dip in 2 per cent zinc oxide suspension, lime at 150, 300 and 600 kg CaO per hectare and their combinations were included in the treatments. The field was selected on the basis of a low content of available zinc (EDTA extractable).

Observations were recorded on the growth parameters and yield characters. The chemical analysis of the plant material for N, P, K, Ca, Mg and Zn at harvest were also carried out. The different growth parameters studied, recorded a significant increase by the application of zinc. Significant increase in the grain yield could be obtained by zinc application. Foliar application of 0.5 per cent zinc sulphate and soil application of 20 kg zinc sulphate per hectare recorded the maximum yield of grain. These treatment yielded more than 20 per cent grain over control and were statistically on par. There was no significant increase in the mineral contents in the plant by zinc application, except zinc and phosphorus. Increased application of lime resulted in a

significant reduction in the zinc content of straw and grain. The study indicates the importance of zinc in rice nutrition in the acid soils of Kuttanad. In soils with available zinc concentration below critical levels it is possible to get significant response to application of zinc based on economics of method of application and cost of chemical soil application appears to be cheaper.