AVAILABILITY OF ZINC IN ALLUVIAL AND LATERITIC SOILS OF ORISSA FOR RICE

THESIS PRESENTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE
OF

MASTER OF SCIENCE

IN AGRICULTURE (CHEMISTRY)

BY

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BHUBANESWAR

1972

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This is to certify that the research work entitled " Availability of zinc in alluvial and lateritic soils of Orissa for rice " has been carried out by Sri Jiban Sankhali Mohapatra, in partial fulfillment of the M. Sc. Ag. (Chemistry) degree of the Orissa University of Agriculture and Technology under my guidance and supervision during the session 1971 - 72.

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ACKNOWLEDGEMENT

The author avails the opportunity to express his profound sense of gratitude to Dr. N. Panda, B. Sc. Ag. (B. H. U.); M. Sc. (Allahabad), Ph. D. (Missouri), Reader and Head of the Department, Soils and Agricultural Chemistry, College of Agriculture, Orissa University of Agriculture and Technology for suggesting the problem and guiding throughout the investigation.

The author is very much grateful to Dr. G. N. Mitra, M. Sc. Assoc. I. A. R. I., Ph. D., Reader in Agricultural Chemistry for his valuable advice.

The author is highly indebted to Sri S. N. Mishra, Extension Soil Chemist for his manifold help throughout the period of investigation.

The author is also grateful to Sri P. K. Das, Lecturer in Agril. Chemistry for his valuable help during the research work.

He is further thankful to Sri K. C. Nayak and Sri P. K. Dash for their constant encouragement during the period of investigation.

Financial assistance in the form of a Junior Fellowship from I. C. A. R. is greatfully acknowledged.

Lastly, the author is deeply indebted to his parents for their blessings.

(Jiban Sankhali Mohapatra)

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INTRODUCTION

In India, where agriculture is the mainstay of people, soil fertility and fertilizer research was considered of vital importance for increasing crop production. Soil is the backbone of Agriculture and soil research acquired due recognition and was very much intensified in the present era of "Green revolution". There exists a great varieties of soils and greater complexity of problems depending on the diversity of climate, geology, and the net work of rivers and streams. In Orissa, the lateritic soils and the alluvial soils are the predominant soil types found in the thickly populated and intensively cultivated areas which add to the complexity and diversity of soil problems.

Exploitive agriculture leads to serious depletion of micronutrients. Wide adoption of high yielding varieties of crops as rice, wheat, maize, jowar, and bajra not only brought about nutritional problems of major elements but also proportionately brought to light the paramount importance of micronutrient cations like zinc. The bonafide researches conducted recently by Indian soil scientists revealed very wide spread deficiency of zinc and significant responses to application of zinc sulphate. In soils deficient in zinc, the full responses to NPK will not show up unless zinc is supplied. It is also reported that apart from wheat areas of Punjab, Haryana, Tarai area and some parts of U.P. extensive areas growing rice and maize in Orissa, Andhra Pradesh, Tamilnadu, Bihar and Assam have shown zinc deficiency with a significant response to zinc application and as such locating these areas is of prime need to our nation today. The micronutrient research has also led to interesting results on interactions of zinc and phosphates. In some soils, zinc deficiency becomes evident after heavy application of phosphates due to the phosphate zinc interaction in the soil as well as in the plant. Since soils of Orissa have high capacity for phosphate fixation, the negative phosphate zinc interaction in such soils may not be suspected. According to Kanwar the application of zinc shows responses upto a certain limit beyond which they depress yields. There are interesting varietal differences to crop response to micronutrient deficiencies and an intensive screening programme has been undertaken to categorise crop varieties according to susceptibility to micronutrients. Some of the high yielding varieties of wheat, rice, sorghum and maize are more susceptible to zinc deficiencies than are others. On soils low in available zinc, the non-susceptible variety may not respond to application of zinc whereas the susceptible variety will not grow successfully unless zinc is applied. It is also of much importance that the multiple cropping with high yielding varieties and heavy doses of NPK are producing more wide-spread deficiency of micronutrients. Farmers may obtain very high yields under multiple cropping for 2 - 3 years but zinc deficiency then becomes so acute as to cause virtual failure of the crop. It has also been reported that a farmer producing 13.9 tonnes of wheat and rice per annum per hectare is removing annually 274, 312, 574, 17, 4290 and 1225 gm / ha of boron, copper, zinc, molybdenum, iron and manganese respectively. Since the amount of available micronutrients in the soil is only a few kg/ ha, it can be appreciated that these must be replenished through some artificial sources. Because of the antagonistic effect of micronutrients, no 'shot-gun' method for correction of deficiencies by using adhoc mixtures of micronutrients can produce satisfactory results. In India there is evidence that many diseases of wheat and rice are related to nutritional disorders caused by micronutrient imbalances.

The look out of the fertilizer technology for manufacture of micro-nutrient fertilizers is of much importance considerably in the recent years as higher crop yields are placing greater demand on the land and resulting in deficiencies in soils in which the available supply of zinc is limited. Also, the use of high-analysis fertilizers that contain few impurities has reduced the amount of zinc added to soil. To replenish zinc in the soil, the common source is zinc sulphate applied either as a spray or a soil treatment. Zinc also is included with other micronutrients as a frit, however, zinc alone is not available in this form. Several zinc chelates have been developed which include ZnEDTA, ZnHEDTA and $Na_2ZnEDTA$ and ammonium lignin sulfonate chelated with zinc. A relatively new compound being offered is zinc-iron-ammonium sulphate containing 4 % zinc. This is produced by the manufacture of ammonium sulphate using spent sulfuric acid high in zinc and iron contaminants. A metallic ammonium phosphate containing 33.5 % zinc has been developed. Zinc oxide and carbonate are also used.

Since fertilizers are very costly and the future of Agriculture depends on them, improved techniques are needed to guide fertilizer applications. The farmer is interested in knowing not only what is deficient in his soil but also how much of a specific nutrient should be used to achieve a particular yield-level. Efforts to quantify this relationship are being made under this research project.

The recognition of zinc as essential to plants and animals is probably greater now due to many reasons, such as (i) it plays a great role in metabolism and is the activator of many enzymes like carbonic anhydrase and peptidase etc.; (ii) the wide-spread deficiency of zinc in plants at present days results in declining concentration of zinc in food and food crops.(iii) Plant proteins in human foods are coming into wider use as a means of alleviating protein deficiencies, especially in India and other underdeveloped countries. Zinc is less available to animals from diets containing plant protein than it is from diets based on animal proteins; (iv) increased levels of zinc in human diets may be beneficial in counteracting detrimental effects of cadmium; (v) zinc deficiencies in a number of species, including man, have been observed during the past years andimpaired healing of wounds in human body has also been attributed to zinc deficiency. Since the danger of toxicity from excess dietary zinc is minimal, it would seem evident that a general increase in the concentration of zinc in human and animal foods would be desirable . In regard to zinc nutrition of plants, the zinc concentration in plants often reflects the level of available zinc in the soil, the changes in zinc concentration in plants brought about by the use of zinc fertilizers are more evident in the leaves than in the seeds. As the seeds and fruits are major sources of plant materials in human diets, it may be that a very substantial increase in the levels of available zinc in soils would have only a slight effect upon the level of zinc in human diets. The low availability to animals of zinc in plants has been attributed to the presence of insoluble complexes of zinc with calcium and phytic acid in plants. In animal proteins, phytate is not present and the zinc in diets based on animal protein is more available and effective in meeting the zinc requirements in animals. The use of high levels of animal protein in human diets undoubtedly is of great value in protecting people from zinc deficiency in countries where adequate supplies of animal protein are available.

In Orissa, the laterite soils and alluvial soils which predominate in the thickly populated and intensively cultivated areas, mostly being acidic and principal crop being rice, not much work has yet been initiated on the problem of zinc. No systematic work has been done to delineate the areas of zinc deficiency in the soils of Orissa. Since reports are available from the neighbouring states Andhra Pradesh regarding response of rice to zinc application, it is hoped that rice soils of Orissa might show also response. This is quite probable because rice is grown under submergence creating reduced condition. Under reduced condition, decreased availability of zinc has been reported. So it is thought worthwhile to measure the available zinc status of soils of Orissa and see whether in such soils rice responses to zinc application.

Objectives of the Investigation

1) To measure the total and available zinc status of alluvial and lateritic soils of Orissa and investigate the relationship between the physical and chemical properties of soils with the availability of zinc by laboratory evaluation.

2) To assess the availability of zinc with particular reference to pH as influenced by liming.

3) To investigate the response of high yielding paddy variety to application of zinc in alluvial and lateritic soils of Orissa by pot culture studies and field experiments respectively.

4) To test and compare the applicability of two methods for determination of available zinc in Alluvial and lateritic soils of Orissa. (i) 0.1 N HCl Extraction method and (ii) Ammonium acetate and Dithizone extraction method.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Zinc Content of Soil

Sundara Rao (1937) who was the pioneer worker in India reported that the zinc content of west coastal soils varied from 0.03 to 0.66 %.

According to Hibbard (1940) surface soils contained more total zinc and extractable zinc than subsoils.

Thorne et al (1942) reported that in Utah States the soils formed on the lime stone contained more zinc than soils, formed from gneisses, quarotzites even though the composition of the parent material was same in both cases.

Holmes (1943) reported that the soils from Atlantic coastal plains contained relatively smaller amount of zinc than the others. The zinc content of alluvial soils of Mississippi river basin were found to vary considerably. This variation was attributed by him to the variation in the composition of parent materials.

Shiho (1951) showed that in Japan the total zinc content of soils examined averaged 82 ppm and that it was higher in alluvial soils developed from shale.

Black cotton soils of a few citrus growing tracts of Bombay contained 0.12 to 17.6 ppm zinc (Bondale et al 1951).

According to Healy (1952), at the concentration of 38.5 ppm total zinc in the surface soils of orange orchards in Cook Island the plants suffered from zinc deficiency.

As revealed by Weltz et al (1953) the soils of Appalachian province contained 100 ppm of total zinc, whereas those of coastal plain contained on an average only 41 ppm.

Tomboni (1954) reported that the viticultural and tobacco soils of Italy were found to contain 4 to 6 ppm of total zinc which was not influenced by pH, lime status and humus content.

By reviewing the data on zinc content of soils, Swaine (1955) reported that the average value for most of the mineral soils was between 10 and 300 ppm.

Mehta and Dakshinamurti (1955) found zinc upto 1000 ppm in Delhi soils.

As stated by Kerdo and Vasil (1958) , the total zinc content of Russian and Chernozems was approximately 72 ppm.

Satyanarayan (1959 a) reported the zinc content of cotton soils of Gujarat varies from 14.3 to 61.7 ppm.

According to Nair and Mehta (1959), the total zinc content of Western India soils of Gujrat and Saurashtra soils was 20 to 95 ppm.

Lal et al (1960) measured total zinc ranging from 34 to 68 in virgin red soils, 69 to 74 ppm in black soils and 24 to 30 ppm in laterite soils.

Harled et al (1960) revealed that application of zinc sulphate @ doze on the surface of Lakeland or Red Bay soil, increased the zinc concentration to a depth of 18 inches.

Agarwala (1963, 1964) studied zinc status of the soils of U.P. and found that the zinc content of Bondolkhand, upland alluvial, Vindhyan and Bhabhar were 5.5 to 1204.9 ppm , 31.4 to 109.2 ppm, 2.1 to 124.1 ppm and 13.1 to 151.6 ppm respectively. He also reported the zinc content of alkali soils of U.P. was within a range of 70 to 205 ppm.

Ranadive et al (1964) from a study on zinc status of Maharastra soils reported that the zinc content of red sandy loam and loam laterite , black clay, saline and alkali soils and costal allurium soils were in the ranges of 35 to 65 ppm, 64 ppm, 39 to 60 ppm, 25 to 30 ppm and 40 to 43 ppm respectively.

Kanehiro (1964) noted that very highly weathered and leached ferruginous oxisols, and ultisols showed relatively low total zinc contents throughout the profiles ranging from 69 to 142 ppm.

Randhawa and Kanwar (1964) found out by analysis of 41 soils representing 7 profiles from different agro-climatic zones of Punjab that the zinc content agreed the range of 18.00 to 97.50 ppm with an average value of 54.50 ppm.

Roychoudhuri and Dutta Biswas (1964)reported that sand stone, lime stone, shale and igneous rock contained 16,24,47 and 51 ppm zinc respectively.

Chatterjee and Dass (1964) studying on some Indian soils reported that the zinc content varied from 21.5 to 88.7 ppm.

Konohira et al (1967) reported that total zinc content of some Hawaiian profiles was between 91 and 280 ppm. They reported that for sandy loam and silty loam soils the total zinc values were not especially high indicating that high zinc figures were not necessarily associated with young soils.

Bandyopadhya and Adhikari (1968) indicated that the zinc status of rice soils of West Bengal was adequate to face the requirement. According to them the zinc status of the paddy soils in India was satisfactory and the total zinc content showed a significant relationship with rainfall where annual rainfall varied from 100 to 150 cm .

As revealed by Eswarappa et al (1969) total zinc content of red soils varied between 22 and 77 ppm. They also recorded more total zinc in laterite soil which was 40 to 114 ppm as compared with red soils. The total zinc content of black soil ranged from 30 to 106 ppm.

Tripathi et al (1969) reported that the total zinc content of typical soils of Uttar Pradesh ranged from 14.1 to 91.4 ppm.

Sharma and Motiramani (1969) working with soils of Madhya Pradesh showed that the total and available zinc content was higher in black soils and lowest in alluvial soils.

Prasad and Sinha (1969) reported that total zinc of Bihar soils ranged from 69 to 1010 ppm with the average value being 497 ppm.

By analysing the soils from 92 fields in California Brown et al (1971) found out that the total zinc content of those soils varied from 28 to 136 average being 86 ppm.

Mohapatra and Kibe (1971) on a comparative study between NH_4-acetate extracted zinc and plant uptake by Neubauer's Technique reported that probably the neutral ammonium acetate was a suitable extractant for determining the available zinc contents of Maharastra soils.

Gupta and Singh (1972) studying the soils of 4 blocks of Indore district reported that the total zinc content was within the range of 40 to 131 ppm.

Routray (1971) reported the total zinc content of lateritic soils of Orissa to be 38 to 88 ppm.

Methods of Soil Testing for Available Zinc

The biological extraction method using *Aspergillus niger* to predict response of zinc application to soil was not suitable for all types of soils or it could not give reliable results for the requirement of different crops. So for the assessment of the availability of zinc for all types of soils, it was desirable to take the help of chemical extraction methods. Several chemical methods have been suggested to determine the availability of zinc in soil. However, the chemical methods proved less successful than the bio-assay method.

Shaw and Dean (1952) obtained correlation between zinc deficiency and amount of zinc extracted by ammonium acetate and dithizone.

Tucker and Kurtz (1955) obtained a significant correlation between ammonium acetate dithizone extracted zinc and biologically extracted zinc from soil.

Massey (1957) reported a significant correlation between ammonium acetate dithizone extracted zinc and zinc uptake by maize plants (r = 0.694).

Shumble et al (1963) obtained significant responses in wheat, maize and paddy to the application of zinc on soils which contained less than 0.5 ppm of dithizone extractable zinc.

Martens and Chesters (1967) reported dithizone extractable zinc had a significant correlation with uptake of zinc by maize plants .

Grewal et al (1969) reported a good correlation between dithizone ammonium acetate extractable zinc and zinc uptake by wheat plant.

Meelu and Randhawa (1970) reported statistically significant relationship between the total zinc uptake by the second crop and the dithizone ammonium acetate extractable zinc in the soil after the first crop . They concluded that dithizone was the reliable extractant for the prediction of the responses to applied zinc.

Rai and Chimania (1971) on a comparative study of chemical extractants reported that range of zinc extracted from soils by N. NH_4OAc (pH 7.0) + 0.01 % dithizone was 0.15 to 3.97 ppm, the average being 1.67 ppm. This extractant did not give any correlation between zinc extracted from soils and zinc concentration of plants. They also reported that ammonium acetate, dithizone extractant and 0.1 N HCl extractant were useful.

A direct relationship between 0.1 N HCl extracted zinc and availability of soil zinc for slightly acid soils of similar structure was observed by Wear and Sommer (1947). Little or no relationship was indicated to exist between 0.1 N HCl extractable zinc and plant availability of soil zinc for 51 soils which differed in pH, texture, and organic matter content.

Barrows, Tucker and Kurtz observed that 0.1 N HCl extracted zinc was significantly correlated with bio-assay method and 0.1 N HCl is a good extractant in acid soils.

Morton (1967) observed a direct relationship between zinc extracted with 0.1 N HCl and the zinc supplying power of soils that varied widely in texture and pH.

Nair and Mehta (1959) working with Gujrat soils reported a significant correlation between pH and 0.1 N HCl soluble zinc.

A significant relationship between 0.1 N HCl extractable zinc and yield of maize and cauliflower grown on Bundelkhand soils of U.P. was obtained by Agarwala (1963, 1964).

Rai and Chimania (1971) observed by studying 25 black soils of Madhya Pradesh with 5 extractants for zinc evaluation, a non-significant positive correlation between 0.1 N HCl extractable zinc and zinc concentration of wheat plant.

The bio-assay technique was used as a standard for comparison as it was widely accepted as a good indicator of micronutrient availability and showed excellent correlation with actual crop responses in different soil types (Donald et al 1952 ; Henriksen and Jensen, 1958 ; Jensen and Lamm ,1961).

On an intensive study of 36 soils of Wisconsin, Dolar et al (1971) reported that the extractant normal ammonium acetate (pH 7.0), 0.01 M EDTA and 0.1 N HCl showed promise in soil tests for the simultaneous availability of Cu, Mn and Zn.

Martens et al (1966) concluded that the relative amount of zinc extracted by the zinc tests was in order of A. niger $>$ 0.1 N HCl $>$ Dithizone $>$ 0.2M $MgSO_4$ extractable zinc.

Eswarppa et al (1969) found a positive correlation between 0.023 EDTA extractable zinc with 0.1 N HCl extraction method. Also 0.023 EDTA extraction showed a good correlation with bio-assay method not in alkaline calcareous black soil.

A best relationship between uptake of zinc by soybean and zinc determined by bio-assay method was obtained by Prasad and Sinha (1969).

Murty and Mehta (1970) compared <u>Aspergillus niger</u> method and 7 chemical extractants for determining the available Zn^{++} in soils of Gujrat. They reported highest correlation with <u>Aspergillus</u> method followed by ammonium acetate and dithizone method.

Navrot and Gal (1971) reported that the quantities of zinc extracted EDTA- $(NH_4)_2$ CO_3 were higher in some mediterranean rendzina soils with a lower total zinc content.

Rai and Chimania (1971) on a study with maize crop in shallow black soils of Madhya Pradesh revealed that 2N $MgCl_2$ alone gave a significant correlation between extractable zinc in soil and plant zinc (of control pots).

Ranadive (1964) and Chatterjee and Dass (1964) used a number of extractants such as water, N KCl, ammonium acetate (pH 4.6 and pH 7.0), EDTA, 0.1 N HCl, dithizone and bio-assay for determining available zinc in some Indian soils but they did not find any one extractant as a good indicator of responses to zinc.

Rai and Chimania (1971) studying suitability of 5 chemical extractants for determination of zinc in 28 shallow black soils of Madhya Pradesh concluded that the normal NH_4- acetate (pH 4.6) was the only suitable extractant to predict response of wheat to application of zinc and also they obtained a highly significant correlation (r = 0.666) of this extractant between soil zinc and plant zinc content.

Available Zinc Contents of Soil

A good supply of a particular nutrient in a soil is known by the quantity of the nutrient retained by it in available form.

Berg (1947 a, b) gave a tentative limit of zinc deficiency and toxicity in case of available zinc were below 1 ppm and above 100 ppm respectively.

Wear and Sommer (1947) reported that the zinc deficient soils contained less than 1 ppm 0.1 N HCl extractable zinc.

Woltz et al (1953) reported that the extractable zinc contents for soils of Appalachian district was 4 ppm and that of coastal soil was only 1.8 ppm .

Tucker (1953) noted that soils giving <u>A.niger</u> available zinc test of 2.0 to 12.0 ppm showed no deficiency symptom.

Nair and Mehta (1959 a) reported the 0.1 N HCl extractable zinc of Hill (Shallow) soils of Gujrat varied from 0.5 to 6.1 ppm .

Lal et al (1960) found out that the 0.1 N HCl extractable zinc of Orissa was of 1.2 to 7.0 ppm.

Duarte et al (1961) reported that the available zinc extracted by ammonium acetate of some Gujrat and Maharastra soils varied even from traces to 48 ppm.

Rampel (1962) found out that zinc content of soils of white Russia varied from 0.60 to 1.95 mg / kg.

Agarwala (1963, 1964) studied the micronutrient status of U.P. soils and reported that the available zinc extracted by 0.1 N HCl of alluvial soil of U.P. falls within a range of 0.1 to 7.8 ppm and that of Bundelkhand soils 0.7 to 8.3, Bhabhor soil 0.4 to 8.6, and Vindhyan soil 1.2 to 10.5 ppm.

Brown et al (1962, 1964) gave a critical limit for Dithizone extractable zinc below which responses to added zinc could be expected was 0.5 ppm.

The available zinc of Maharastra soil was determined by Ranadive et al (1964) by several methods. He recorded available zinc as 0.35 to 3.44 ppm, 1.37 to 8.25, 0.3 to 9.7 when the extractants were Ammonium acetate (pH 7.0) Ammonium acetate (pH 4.6), and 0.1 N HCl respectively.

Ammonium acetate extractable zinc of some Punjab soils was 0.71 ppm (Bhumble and Dhingra ,1964).

As determined by Chatterjee and Bose (1964), the available zinc of some Indian soils extracted by Ammonium acetate (pH 7.0), Ammonium acetate (pH 5.0), Dithizone, 0.1 N HCl were 0.21 to 1.91, 1.0 to 5.6, 0.8 to 7.0 and 2.2 to 9.2 respectively.

Bhumble et al (1965) reported the Dithizone extractable zinc of Punjab soil was 0.39 to 0.75 ppm .

Rajani (1965) recorded the available zinc extracted by Ammonium acetate of sandy soils, Laterite soils medium black soils, deep black soils and alluvial soils of Gujrat were 20.2 ppm, 2.6 to 20.0 ppm, traces to 26.0 ppm, traces to 211.2 ppm and traces to 193.6 ppm respectively

Tripathi et al (1969) recorded that available zinc was constituted about 5 to 15 % of the total zinc content and varies from 0.9 to 8.8 ppm with a mean value of 4.4 ppm.

Rai andChimania (1971) determined the Ammonium acetate (pH 7.0) Dithizone extractable zinc of shallow black soils of Madhya Pradesh as 0.15 to 3.97 ppm with 1.67 ppm as the average value.

By studying some important soils of tropical and subtropical soils Prasad and Pagel (1971) concluded that a greater content of available zinc was found on the top layer as compared with deeper layers of soil.

Gupta and Singh (1972) reported that the available zinc of some soils of Indore district varied from 0.9 to 3.25 ppm.

Routray (1971) recorded the available zinc of some lateritic soils of Orissa varied from 2 to 9 ppm.

Factors Affecting Availability of Zinc

Soils differ widely in their zinc supplying power regardless of the amount of zinc present in non-replaceable form. Factors affecting the availability of zinc to the plants include soil reaction, $CaCO_3$, organic carbon, phosphorous replaceable bases, clay content, soil microorganisms and fixation etc.

Soil Reaction

pH

pH affects the availability of zinc by affecting activity of microorganisms or changing in the solubility of antagonistic ions or change in the ability of plant roots to absorb ions. Zinc deficiencies are usually observed on soils with pH greater than 6.0 and less than 8.0 but decreases as the pH goes down or up from these levels.

Camp (1945) reported that the deficiency of zinc would be expected if the pH of the soil exceeded 6.0 for citrus crop.

The reduction in zinc concentration by liming as reported by Wear (1956) was not due to calcium but due to the effect of pH.

According to Chatterjee and Dass (1964) more NH_4 acetate extractable zinc was found in soil at pH below 6.0 and its content decreased as pH rose above 7.0.

Sherman and Kanehiro (1967) obtained a correlation co-efficient of 0.062 between pH and available zinc. They also reported that a decrease in extractable zinc content was associated with an increase in soil pH.

A significant negative correlation was obtained between pH and extractable zinc (Bandyopadhya and Adhikari, 1967).

According to Yoshida and Tanaka (1969) soil reaction is one of the factors responsible for decreased availability of zinc in submerged soils.

Prasad and Pagel (1970)reported that the zinc content was decreased with increasing in soil pH.

Meuer et al (1971) working with Brazilian soils revealed that zinc deficiencies occured at soil pH 7 6.3 .

The increased availability of zinc by application of Zinc Sulphate was decreased with soil pH (Stanton and Burger, 1971). They also mentioned that NH_4NO_3 increased the availability of zinc only due to shift in soil pH. $CaCO_3$ and $MgCO_3$ decreased zinc availability owing to pH changes.

Liming

Rogers and Wu (1948) pointed out that zinc concentration in Oat plant was decreased with increasing rates of liming but they did not find any responce to added zinc.

Epstein and Stout (1951) reported the sharp decrease in solubilities of zinc by the addition of $Ca(OH)_2$.

Leeper (1952) postulated that $CaCO_3$ was a good absorbant for heavy metal ions.

Increased zinc deficiency was reported by Winter and Parks (1935) due to lime application.

Brown and Holmes (1956) reported the solubilities and plant availability of copper, zinc and iron generally are believed to decrease when soils are limed.

According to Wear (1956) , the uptake of zinc was increased by the application of $CaCO_3$ and

Na_2CO_3 but reduced on application of $CaSO_4$.

Jurinak and Bauer (1956) indicated that zinc was adsorbed in the crystal surfaces of dolomite and magnesite by replacing magnesium. They also reported that zinc was less strongly adsorbed on calcite than magnesite and dolomite.

Nair and Mehta (1959 a) observed that the availability of zinc decreased as lime content increased but this did not hold good for all.

Seatz et al (1960) revealed that the severity of zinc deficiency due to rise in pH by liming was reduced by using liming material containing some $MgCO_3$.

Increased application of lime i.e. 2500 to 7500 lb/ac induced zinc deficiency (Hutton and Fiskell, 1963).

Stewart and Leonard (1963) reported that though $CaCl_2$ increased the availability of zinc still it had very little effect in releasing zinc from the soil. They suggested that high concentration of zinc were necessary to allow movement into the root zone and that the $CaCl_2$ influenced the uptake of zinc at the root surfaces. They also reported the reduced retention of zinc in the presence of excess of calcium.

A green house study conducted by Brown and Jurinak (1964) revealed that availability of Zn and Cu was almost unaffected by liming on a sandy soil but decreased by increasing rates of $CaCO_3$ on a clay soil of pH 6.9 .

Tiwari and Misra (1964) studied the effect of $CaCO_3$ on retention of added zinc in 3 soils i.e. black, red and alkali soils of U.P. and observed that with higher dose of $CaCO_3$, the retention of applied zinc increased gradually in all the soils due to adsorption of ions at the colloidal surfaces and formation of some basic zinc carbonates. Maximum retention was recorded at 2.5 % level of $CaCO_3$ in black soil and 1.5 % level in red soil.

A sand culture undertaken by Pauli et al (1968) with P^{32} and Zn^{65} revealed that addition of calcium carbonate decreased dry weight, top and root ratio, and zinc concentration in all parts of Navy bean (*Phaseolus vulgaris*) plant. $CaCO_3$ decreased zinc translocation from roots to leaves.

Exchangeable zinc and copper tend to accumulate in subsurface and then decrease with depth (Bansal et al , 1969).

Mauer et al (1971) reported that liming had a much greater effect on zinc uptake . But liming the soil to a pH 5.5 only did not decrease soil zinc availability .

Phosphorus

In many cases zinc deficiency have been observed being associated with the use of heavy dose of phosphate due to negative phosphate zinc interaction.

Rogers and Wu (1948) observed the uptake of zinc by oat was decreased by the application of phosphate.

From a green house study using sweet corn as test crop, Brown et al (1970) reported that application of P accentuated zinc deficiency symptoms on O-Zn treated plants. But the deficiency was corrected by the application of zinc.

Warnock (1970) observed zinc deficiency in corn plants at high P and low zinc content of soil. Applied P reduced zinc concentration in tissue but not uptake/plant. He also reported the accumulation of Fe in zinc deficient plants.

Melton et al (1970) reported that a heavy P application (500 ppm) generally induced a greater zinc deficiency on soils testing above pH 7.0 .

Stanton et al (1971) showed that $Ca(H_2PO_4)_2$ reduced the availability of zinc . This effect increased progressively between soil pH values of 4.7 and 6.5 but diminished as the pH rose above 6.5.

Organic Matter

The presence of organic matter may promote the availability of zinc probably by complexing the substance which fix zinc. At the same time, the soils containing greatest amount of organic matter are deficient in zinc.

Tucker et al (1953) reported that organic matter content of soils did not play an important role in predicting the availability of zinc by *Aspergillus niger* .

Pratt et al (1959), Bandyopadhya and Adhikari (1968) obtained significant positive correlation between organic matter and extractable zinc. The increased availability of zinc with higher organic matter content was due to zinc content of organic matter and also due to change of soil pH.

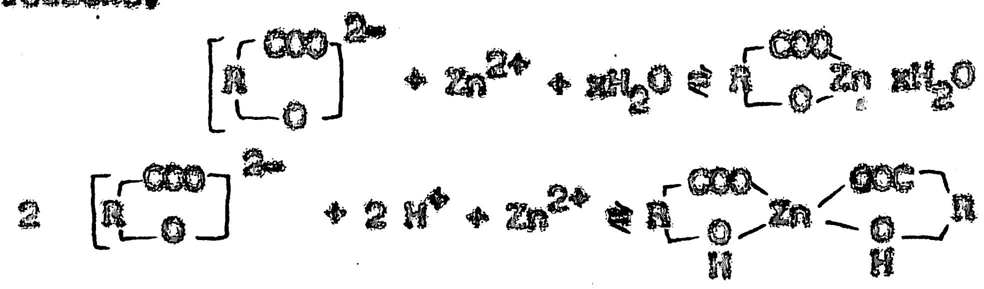
Nair and Mehta (1959 a) reported a positive relationship (r = + 0.358) between organic matter and aic soluble zinc which might be due to formation of pockets of acid material in alkaline soils thereby maintained the availability of zinc.

Randhawa and Broadbent (1965 a) reported that pH governed the adsorption of zinc in exchange sites. They (1965 b) also found out that monovalent form of zinc was retained by very acidic exchange sites on humic acid. Weakly acidic sites retained zinc in the divalent form. They also observed 30 to 73 % increase in effective sites retaining monovalent form of zinc when pH was reduced from 7.0 to 3.6 .

Brown et al (1971) reported a significant positive correlation between extractable zinc and organic carbon for EDTA and 0.1 N HCl.

Tan et al (1971) studied the complex reaction of organic matter with zinc. They reported that number of moles of fulvic compounds complexed by 1 mole of zinc at pH 5.5 was low in the case of high molecular weight fractions, but the low molecular weight fraction was complexed in amounts twice that stated for the high molecular weight compounds. By increasing the pH to 7.0 a tenfold increase in amounts of low molecular weight fractions complexed by zinc was obtained. They also revealed that Zn form coordinate covalent bond with OH group and electrovalent linkage with carboxyl group (COOH).

The complex reaction as given by them is as follows.



<u>Clay</u>

Nair and Mehta (1959) could not get any significant correlation between finer fractions of soils and acid soluble zinc.

Randhawa and Kanwar (1964) found a positive correlation between finer fractions and extractable zinc in Punjab soils.

Chatterjee and Dass (1964) reported the illite rich clay mineral possessed much higher extractable zinc than montmorillonite type of clay.

Martens et al (1966) reported that the interaction between clay and organic carbon content in relation to amount of zinc extracted by 0.1 N HCl could be explained on the basis of organo clay complex formation. An increase in organic matter content at constant levels of clay increased the amount of zinc bound by the organo-clay complex thereby resulting in increased extractability of soil zinc by 0.1 N HCl.

Bandyopadhya and Adhikari (1967) could not get any significant correlation between finer fractions of soils and acid soluble zinc.

Navrot and Ravikovitch (1970) reported that total zinc content of 21 calcareous soils increased with the clay content of soil and they got a significant correlation co-efficient between total zinc and percentage of clay (r = 0.60).

Kalyanasundaram and Mehta (1970) reported that availability of zinc depended on the rate of application and inherent soil properties. He also reported a decreased of % availability zinc with increased content of clay .

Other Factors

Krantz et al (1968) reported that zinc uptake and translocation by rice were greatly decreased by low temperature.

Brown et al (1962) also reported that soil application of zinc increased consistently the extractable zinc content in all soils studied.

Wallace et al (1969) reported the relation of temperature with plant uptake of zinc. Plants which showed moderate to severe zinc deficiency in their early growth have out grown the visual symptoms by early or mid July. Zinc deficiency symption was not visualised when planting date was shifted to July

Mokrievich and Yorovoi (1970) reported that nitrogen fertilization increased the availability of zinc in soil and combination of N and Zn fertilization almost doubled the readily soluble zinc content. $(NH_4)_2SO_4$ had a greater effect on the available zinc than NH_4NO_3. Also reported that symptoms of zinc starvation were pronounced on dry and sunny days.

Bolar and Keeney (1971) reported that the interation between Cu, Zn and Mn affected their individual uptake.

Uptake of Zinc by Plant

Plant takes zinc by its root in form of ion Zn^{2+} or molecular complex of chelating agents as EDTA may be absorbed by its root . Zinc also enters the plant body through leaves.

Govindan (1952 b) reported that activity of RNA in leaves increased by zinc deficiency. Also observed the decrease of carbohydrate fraction with increased concentration of zinc in tomatoes.

According to Lal and Subba Rao (1959) the efficiency of different plants to utilize zinc in the yield and dry matter were in order of rice > maize > barley > sugar cane.

As revealed by Nelson (1956) addition of zinc did not increase zinc content of soyabean tops but total zinc uptake from the soil was increased. Zinc content of soyabean plants was 15 ppm when it was grown in deficient soil but 30 ppm was recorded in normal soil.

An experiment conducted at I.A.R.I., New Delhi on soil and foliar application of zinc by Sadaphal and Dass (1956, 1961 a,b) revealed that application of zinc sulphate increased the protein content of wheat.

A significant negative correlation between uptake of zinc by corn with soil pH (r = -0.486) and a positive correlation between uptake of zinc and Dithizone extractable soil zinc was observed by Massey (1957).

Dikshit (1958) recovered the chlorosis of citrus of zinc sprays.

By the use of radio active zinc Riceman and Jones (1959) studied the distribution of zinc in different parts of subterranean clover proved that for growth and development of young buds zinc was essential.

Experiments conducted by Kanwar et al (158-62) and Dhumbla et al (1963-65) in calcareous soil revealed that by spraying zinc sulphate the grain and drymatter yield of rice was increased.

According to Naik and Asana (1961), reduced rate of protein synthesis and increased accumulation of non-protein intermediates in cotton resulted in zinc deficiency.

Ahuja and Gautam (1961) recorded a good response of hybrid maize to zinc application in soils containing 20 ppm of zinc with NPK. Seed soaking treatment proved more effective in increasing drymatter yield than soil treatment or spray application. They observed a 20 % increase in drymatter yield as compared to NPK alone.

A field experiment conducted by Kanwar (1962 b) at Palampur revealed an increase of 12.32 quintals/acre of potato tuber over NPK alone by soil application of $ZnSO_4$ at 33.7 kg / ha.

A green house experiment undertaken by Brown et al (1962) using sustarn as test crop revealed an excellent response of soil applied $ZnSO_4$ in soils containing 0.55 ppm or less dithizone extractable zinc. He also reported that increased rates of zinc application could increase the total uptake and zinc concentration in plants.

Rao (1962) observed major portion of zinc uptake of rice was at milk stage. Crops grown on soils containing less than 0.55 ppm of dithizone extractable zinc responded to zinc (Brown et al , 1962).

Ellis et al (1964) recorded an increase in maize yield from 7504 to 8690 kg/ha by applying 4 kg/ha zinc to a calcareous soil.

Koraddi (1964) recorded 90 % increase in drymatter yield of wheat by the application of zinc during sowing time.

Singh and Jain (1964) reported that application of 2.33 kg/ha of zinc in the soil increased the production of dry weight and tillering but when applied as spray at higher levels an appreciably increased paddy yield was obtained.

Gauton et al (1964) reported that soil application of 12 to 17 kg $ZnSO_4$/ha along with NPK increased the yield of hybrid maize, ganga 101 and texas 26' by 18 to 32 % over NPK alone.

A field trial undertaken by Govinda and Gopal Rao (1964) on the red loamy soils of Bangalore revealed the responce of zinc on yield of ragi (Eleusine coracana)

According to Koraddi and Seth (1964), protein content of wheat was not affected by application of zinc

A decrease in grain yield and increase in drymatter yield of maize was recorded by Fuehring and Soofi (1964). Grain yield was high at 20 ppm Zn in the 6th leaf at tasselling but clover yield was highest at 148 ppm zinc content.

Govindrajan and Gopal Rao (1964) observed a considerable increase of nitrogen content in pods of horse gram by the application of zinc sulphate.

7 experiments conducted on calcareous soils of Punjab by Govindrajan and Gopal Rao (1964) recorded significant increase in rice yield by spraying $ZnSO_4$.

Kanwar and Joshi (1964) observed in the acidic soils of Palampur that $ZnSO_4$ over NPK gave significant higher yields than NPK alone.

As reported by Pillai (1967) application of zinc @ 2.53 kg/ha resulted an increase in drymatter yield and tillering. But an appreciable increase in paddy yield was recorded by spraying zinc at higher doses. He also suggested the application of $ZnSO_4$ @ 11.2 kg/ha to get higher yield.

He also observed that top dressing with $ZnSO_4$ after 45 to 90 days of germination of wheat, which showed severe zinc deficiency symptoms at 7 locations in Punjab, increased the yield of wheat from 2 to 13 quintal / ha.

A field trial conducted by Gupta and Ram (1967) taking hybrid maize as test crop in Rural area of Uttar Pradesh recorded an increased grain yield by 3.5 quintal/ha by the soil application of zinc sulphate @ 21.5 kg/ha to Ganga 101 maize along with NPK over NPK fertilized plots.

According to Navrot and Ravikovitch (1968) zinc content of test crops varied with plants and nature of soils. They also indicated a decrease in zinc content of plant with increase in $CaCO_3$ in soils. A significant correlation was obtained between zinc uptake by plants and amount of soil zinc extracted.

Mukherjee (1969) reported highest concentration of zinc in mature leaves of sugar cane.

Yoshida and Tanaka (1969) observed the Khaira disease in India and Hadda in West Pakistan were both due to zinc deficiency. The plant zinc content was not related to total zinc but related to pH. Addition of cellulose to the soil aggravated zinc deficiency suggesting that soil reduction is one of the factors responsible for decreased availability of zinc in submerged soil.

According to Grewal et al (1969) the yield of paddy and maize was increased by spraying $ZnSO_4$.

Yoshida et al (1970) reported that the disorder of rice plant known as Hadda could be corrected by zinc application. Top dressing of $ZnSO_4$ after observation of deficiency symptoms was as effective as a basal dressing. Dipping seedlings in ZnO was the most practical way of correcting zinc deficiency.

Hipp and Cowley (1971) reported that the application of either zinc and phosphorous alone brought slight increase in yield but the combination of P and zinc resulted in the highest yield. Yields of Okra were reduced where P and zinc concentration in 10 to 15 days old plants were ∠ 0.3 % and ∠ 40 ppm respectively.

As indicated by Rajagopal and Mehta (1971), the increase in drymatter yield of hybrid maize was not due to zinc application but due to application of phosphate. But in combination of 5 ppm zinc with 100 kg P_2O_5 gave higher yield of drymatter than applied singly. Application of zinc increased the concentration and uptake of zinc significantly, but application of phosphate reduced the concentration of zinc by 34.3 %. It had no effect on total uptake of zinc by plant. The higher level of zinc i.e. 20 ppm depressed the P level.

A sand culture undertaken by Mohapatra and Kibe (1971) revealed a higher uptake of mineral nutrients by the plants treated with zinc. He also reported a critical level of 11 ppm zinc in drymatter for tomato.

Romano (1971) showed that an increase in the Kaolinite and SiO_2 contents in the soil decreased the uptake of zinc, Co, Cu, Mn and P to a high degree by buck wheat and lupine.

Ghanbari and Mesuchi (1971) reported that zinc content of semidwarf wheat varieties were negatively correlated with the yield and positively correlated with the protein content. Also they suggested that late planting and irrigation increased zinc contents.

Nollendorfs (1971) observed that excess of calcium in nutritional substrate decreased zinc contents in both the leaves and roots of lettuce to a high degree. A simultaneous zinc deficiency and excess of calcium in the substrate decreased zinc content in the roots to (25 mg / kg as compared with control (31 mg Zn / kg)

Rai and Chimonia (1971) reported significant effect of application of zinc on drymatter yield. A plication of zinc at 5 ppm did not increase the concentration of zinc in wheat plant, however, zinc applied @ 10 ppm resulted significant increase in zinc content of plants . They also reported that application of Zn @ 5 ppm from zinc sulphate and foliar application of zinc increased the yield significantly however soil application of zinc @ 10 ppm did not affect the yield. The soil application of Zn @ 5 ppm increased concentration of zinc in maize plants significantly. Effect of zinc on dry matter yield of maize was found significant.

Westfall et al (1971) obtained a maximum grain yield of 4670 kg / ha of rice with an application of 112 kg / ha of Fe plus 12.1 kg / ha of zinc. He also reported that zinc alone did not give maximum yield.

CHAPTER III

MATERIALS AND METHODS

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Soils used in the Investigation

A field experiment was conducted in Block G of Agricultural Experiment Station, Bhubaneswar. The soil is lateritic sandy loam.

The pot experiment was conducted with alluvial soil collected from Dandamukundpur under Pipli block, in the district of Puri.

For laboratory study different soils representing 4 groups were collected from different parts of Orissa. The list of the soils and places of their collection is given below:

Type of soil	Place of collection
(i) Alluvial soil	Pipli
(ii) Alluvial soil	Dandamukundpur
(iii) Alluvial soil	Mathasahi
(iv) Alluvial soil	Patha farm, Cuttack
(v) Alluvial soil	Bharatipur
(vi) Black soil	Chuda
(vii) Black soil	Bhawanipatna
(viii) Black soil	Loisingha
(ix) Lateritic soil	Bhubaneswar farm
(x) Lateritic soil	Koraput
(xi) Lateritic soil	Bolgarh
(xii) Lateritic soil	Janla

Type of soil	Place of collection
(xiii) Lateritic soil	Khurda
(xiv) Red soil	Koraput
(xv) Red soil	Chandragiri

Processing of the soil

The soils were air dried under shade, powdered by means of hammering to break the clods and sieved through a 2 mm sieve. The sieved soils were mixed thoroughly and from each soil about 1 kg sample was preserved for chemical and mechanical analysis.

Results of the Mechanical and Chemical analysis of soils are given in Table IV and V respectively.

Zinc sulphate was used as Zn carrier.

Lime was applied in the form of calcium oxide.

Experimental Procedures

(A) Details of pot culture experiment

A randomised pot experiment was designed to study the response of paddy to different levels of zinc at different pH and to determine the uptake of zinc by plants from different treatments.

Five kg of soil was taken in each of 45 porcelain pots arranged in 3 replications. Calculated amounts of lime in the form of calcium oxide, as per the lime requirement was applied in different pots. Thorough mixing of the soils with CaO was done after adding CaO to pots. Then the pots were watered by deionised water prepared by passing tap water through ion-exchange permutitt chamber. Alternate wetting and drying was continued to hasten the reaction of added CaO in the soil. After 8 days of application of lime calculated amount of Zn in the form of laboratory reagent Zinc sulphate ($ZnSO_4.7H_2O$) and other general fertilizers to supply nitrogen, phosphorus and potash added in the pots.

Treatments

The experiment was designed with 5 levels of zinc (0, 5 ppm, 10 ppm, 15 ppm and 20 ppm) and 3 levels of lime (0, full and half of the lime requirements). There were 15 treatments, distributed randomly in 3 replications of 15 pots each.

The details of the treatments are given in Table I.

The schedule of different fertilizers applied to the pots are given in Table II.

Four seedlings of a high yielding variety paddy (Padma) were transplanted in each pot. After 10 days keeping 2 plants / pot the extra plants were uprooted and incorporated in situ.

Throughout the period of crop growth watering of the pots were done as and when required by deionised water free from heavy metallic ions especially zinc.

The plants were harvested above the soil surface at the stage of flower initiation.

TABLE I

DETAILS OF TREATMENTS OF POT AND FIELD EXPERIMENTS

Zinc levels	Lime levels		
	L_0	$L_{1/2}$	L_1
Z_0	L_0Z_0	$L_{1/2}Z_0$	L_1Z_0
Z_1	L_0Z_1	$L_{1/2}Z_1$	L_1Z_1
Z_2	L_0Z_2	$L_{1/2}Z_2$	L_1Z_2
Z_3	L_0Z_3	$L_{1/2}Z_3$	L_1Z_3
Z_4	L_0Z_4	$L_{1/2}Z_4$	L_1Z_4

Abbreviations :-

Z_0 - No zinc
Z_1 - 5 ppm zinc
Z_2 - 10 ppm zinc
Z_3 - 15 ppm zinc
Z_4 - 20 ppm zinc
L_0 - No lime
$L_{1/2}$ - Half of the lime requirement
L_1 - Full of the lime requirement

TABLE II

FERTILIZER SCHEDULE FOR POT EXPERIMENT (Alluvial soil).

Sl. No.	Types of fertilizer	Dose	Form	Quantity / pot	Time of application	Method of application
1.	Nitrogen	120 kg 'N' / ha	Ammonium sulphate	1.4157 gm	i) ½ Basal dose ii) ½ 30 days after trans-planting	Applied in solution to the soil
2.	Phosphorus	80 kg / ha 'P_2O_5'	Potassium hydrogen phosphate	0.3833 gm	Basal dose	-do-
3.	Potash	80 kg / ha 'K_2O'	Potassium chloride	0.1072 gm	Basal dose	-do-
4.	Lime	i) No lime ii) Half of total lime requirement ($L_{½}$) i.e half ton $CaCO_3$ /acre iii) Full lime requirement (L_1) i.e. one ton $CaCO_3$ / acre	Calcium oxide	- 1.4 gm 2.8 gm	Applied 8 days before trans-planting	Boradcasting
5.	Zinc	i) 0 ppm (Z_0) ii) 5 ppm (Z_1) iii) 10 ppm (Z_2) iv) 15 ppm (Z_3) v) 20 ppm (Z_4)	Zinc sul-phate (chemical grade)	- 110 mg 220 mg 330 mg 440 mg	Basal dose	Applied in solution to the soil

Soil samples were also collected from each pot after thorough mixing for determination of pH, available zinc and total zinc.

(D) <u>Field Experiment</u>

<u>Experimental site</u>

The experiment was conducted in Block C. of central farm, Orissa University of Agriculture and Technology, Bhubaneswar during summer, 1971-72.

<u>Soil</u>

The physical and chemical composition of soil as determined from the composite samples collected from a depth of 15 cm before sowing has been presented in Table IV and V respectively.

<u>Weather condition</u>

The research station, Bhubaneswar is situated at 20°15' latitude and 85°52' longitude and the altitude being 25.5 meters above the mean sea level. The distance of the place is about 64 km west of Bay of Bengal.

<u>Experimental Details</u>

<u>Design & Layout</u>

The experiment was laid out in R. B. D. with 3 replications each having 15 plots. On the whole there were 45 plots.

<u>Treatments</u>

The treatments were comprised of 3 levels of lime and 5 levels of zinc the details of which was described in pot culture treatment.

Sources of nutrients

Zinc was supplied in the form of zinc sulphate available in commercial grade and lime in form of CaO as given in pots.

Particulars of field layout

i) Design - R. B. D.

ii) Number of treatments - 15

iii) Number of replication - 3

iv) Plot size - 6.3 X 5 sq m

v) Crop - Rice (Padma)

The schedule of different fertilizers applied to the crop has been presented in Table III.

Prophylatic measure

Diazinon was applied twice once after 15 days of transplanting and after 30 days other application was done.

Harvesting of crop

The crop was harvested from the surface of the soil after ripening of grains. It was threshed and the weight of the drymatter and grain was recorded. Also from each plot plant samples were kept for chemical analysis.

Soil samples were also collected from each plot for chemical analysis after harvest of crop.

(C) Details of Laboratory Studies

15 different surface soils were collected from some parts of Orissa, as listed previously for measurement of total and available zinc, pH, organic carbon, cation

TABLE III

FERTILIZER SCHEDULE FOR FIELD EXPERIMENT (Lateritic soil)

Sl. No.	Types of fertilizer	Dose	Form	Quantity / plot	Time of application	Method of application
1.	Nitrogen	120 kg 'N' / ha	Urea	820 gm	i) ½ Basal dose ii) ½ 30 days after trans-planting (top dressing)	Broadcasting
2.	Phosphorus	80 kg 'P_2O_5'/ha	Super - phosphate	1575 gm	Basal dose	-do-
3.	Potash	80 kg 'K_2O'/ha	Muriate of potash	420 gm	Basal dose	-do-
4.	Lime	i) No lime (L_0)	-	-		
		ii) Half of total lime required ($L_{1/2}$) i.e. ½ ton $CaCO_3$/acre	Calcium oxide	2.255 kg	8 days before transplanting	-do-
		iii) Full lime requirement (L_1) i.e. 1 ton $CaCO_3$ per acre	Calcium oxide	4.510 kg	8 days before transplanting	-do-
5.	Zinc	i) 0 ppm(Z_0)	-	-		
		ii) 5 ppm(Z_1)	Zinc sulphate (commercial grade)	143 gm	Basal dose	-do-
		iii) 10 ppm(Z_2)	Zinc sulphate (commercial grade)	286 gm	Basal dose	-do-
		iv) 15 ppm(Z_3)	Zinc sulphate (commercial grade)	429 gm	Basal dose	-do-
		v) 20 ppm(Z_4)	Zinc sulphate (commercial grade)	572 gm	Basal dose	-do-

exchange capacity, individual cations, mechanical analysis, and N.P.K., the results of which have been given in the Table IV, V and VI.

Correlation of total and available zinc with pH, organic carbon, C.E.C. and % clay was worked out.

Analytical Procedure

(1) Analysis of Soil

Mechanical analysis

The fractionation of sand, silt and clay separates was made by the standard Hydrometer method as described by Piper (1949). The results are tabulated in Table IV.

Chemical Analysis

Organic carbon

Organic carbon % was determined by Walkley and Black's rapid titration method described by C.S. Piper (1949) . The results have been tabulated in Table V.

Total C. E. C.

This was determined by leaching 10 gm of soil with 300 ml of normal neutral ammonium acetate buffer solution, washing the leached soil with 60% alcohol and distilling the adsorbed ammonium using mild alkali MgO.

Soil reaction

pH measurements were made by using Elico pH meter both in 1: 2 soil : water and soil : $CaCl_2$ 0.01 M suspension. The results have been tabulated in Table V.

Total nitrogen

Kjeldahl's digestion method was followed for estimation of total nitrogen as described by Jackson (1962). The results have been tabulated in Table V.

Available phosphorus

Bray's I extraction method was followed for determination of available phosphorus. Phosphorus was determined colorimetrically after developing the chloro-stanous reduced molybdophosphoric blue colour in Klett-Summer-Son colorimeter as described by Jackson(1962).

Exchangeable cations

Lime requirement of soil was determined by taking 5 gm of soil, 5 ml of distilled water and 10 ml of Woodruff's (1948) buffer solution and equilibrated with stirring and the reading was taken in Elico pH meter after allowing to stand for 30 minutes.

Available zinc

NH_4- Dithizone extraction method

Available zinc was extracted by shaking 2.5 gm of soil, sieved through 18 mesh sieve, in 25 ml of 1 N NH_4OAc. (pH 7.0) and 25 ml of 0.01 % dithizone reagent for 1 hour. Then it was centrifuged until a continuous carbon tetrachloride phase was obtained. Water and soil particles remaining on the top of the organic phase was siphoned off and 10 ml of the aliquot of Dithizone- CCl_4 solution was transferred to 125 ml separatory funnel. After this the analysis of zinc was done according to procedure of Shaw and Dean(1952) The results have been tabulated in Table 6.

<u>0.1 N HCl extraction method</u>

2 gm of soil in 20 ml of 0.1 N HCl was shaken for 5 minutes and then it was centrifuged until a clear supernatant liquid was obtained which was decanted into a 100 ml pyrex volumetric flask. This process was repeated two more times. The combined extracts were made to volume and a suitable aliquot was taken for estimation of zinc according to Nelson et al (1959) procedure.

The results have been tabulated in Table 6.

<u>Total zinc</u>

Total zinc was determined by digesting 1 gm of processed soil with a mixture of 10 ml of HNO_3, 5 ml of 60 % $HClO_3$, 3 drops of H_2SO_4 and 10 ml of HF in a 500 ml conical flask. The digestion was carried out till moist dryness. After cooling 10 ml of distilled 1 : 1 HCl was added and kept for 1 hour to dissolve the salt. The sample was transferred to a 100 ml pyrex volumetric flask and diluted to volume with double distilled water. Then from this 5 ml of aliquot was taken and zinc was determined as per method suggested by Shaw and Dean (1952).

(2) Analysis of Plant

The harvested plants were dried at 80°C in an oven for 24 hours and the dry weights were recorded.

For further chemical analysis the plants were chopped and ground to pass through 40 mesh sieve.

Digestion

Before digestion the plant samples were dried at 105°C and cooled in desiccator and 1 gm of oven dry sample was taken in a conical digestion flask for digestion.

Digestion was carried out in ternary acid mixture ($HNO_3 : H_2SO_4 : HClO_4 = 10 : 1 : 4$) as suggested by Jackson (1962) and 10 ml of the aliquotes of solution was taken and zinc was determined by the procedure suggested by Shaw and Dean (1952)

(3) Statistical Analysis

The data obtained from pot experiment, field experiment and laboratory studies were analysed statistically for correlation coefficient (r) and analysis of variance.

CHAPTER IV

EXPERIMENTAL RESULTS

CHAPTER IV

RESULTS OF THE INVESTIGATION

The results of the investigation of the laboratory study, pot culture and field experiment are presented in this chapter on the availability of zinc, its relationship with soil properties and the response to high yielding paddy variety in alluvial and lateritic soils of Orissa.

Laboratory Studies Involving soil Analysis

The predominant soil types i.e. alluvial and lateritic soils are found in the thickly populated and intensively cultivated areas of Orissa coasts and the principal crop grown is rice. Surface soil samples from 15 different locations of Orissa were collected and analysed in the laboratory to determine the physical and chemical properties. Fifteen soil samples representative of 4 groups of soils viz red lateritic, alluvial and black. Out of 4 soil groups, the alluvial soil was selected for pot culture and the lateritic soil was selected for field experiment. For pot culture study, the alluvial soils of Dandamukundpur and for field trial the lateritic soils of Bhubaneswar were selected.

The results of the mechanical analysis of soils are presented in the Table IV. The results of the chemical analysis of soils are presented in the Table V. The total and available zinc content of different soils are given in

TABLE IV

MECHANICAL ANALYSIS OF SOILS

Sl. No.	Soil type	Place of Collection	% Sand	% Silt	% Clay	Textural class
1.	Alluvial	Dandamukund-pur	52.14	28.30	19.56	Sandy loam
2.	-do-	Pipli	58.14	16.30	25.56	Sandy clay loam
3.	-do-	Mathasahi	64.44	18.00	17.56	Sandy loam
4.	-do-	Patha farm	90.44	4.00	5.56	Sand
5.	-do-	Bharatipur	74.44	16.00	9.56	Sandy loam
6.	Lateritic	Bhubaneswar Farm	81.84	12.60	5.56	Loamy sand
7.	-do-	Koraput	56.14	22.30	21.56	Sandy clay loam
8.	-do-	Belgarh	52.74	22.00	25.26	-do-
9.	-do-	Janla	58.44	22.00	19.56	Sandy loam
10.	-do-	Khurda	48.44	22.00	29.56	Sandy clay loam
11.	Red	Koraput	48.14	10.30	41.56	Clay
12.	-do-	Chandragiri	60.44	16.00	23.56	Sandy clay loam
13.	Black	Chuda	49.82	18.62	31.56	Sandy clay loam
14.	-do-	Bhawanipatna	67.84	16.00	16.16	Sandy loam
15.	-do-	Laisingha	53.84	14.00	32.16	Sandy loam

the Table VI. Available zinc was determined by two different methods (1) 0.1 N HCl extraction method and (2) NH_4-Dithizone extraction method.

Mechanical analysis of soils

Mechanical analysis indicates that the alluvial soils collected from different places are coarse textured and classified as sandy loam except the soils of Patha - farm which is completely a sandy soil with less content of silt and clay. In case of alluvial soils the % of sand varies from 52.14 to 90.44 %, the silt varies from 4.00 to 28.30 % and the % of clay varies from 5.56 to 25.56 % . But the lateritic soils contain some amounts of clay more in few places in comparison to other places, and classed as sandy clay loam in texture except the soils of Bhubaneswar and Khurda which are loamy sand and sandy loam in texture respectively. In case of lateritic soils, the % sand, % silt and % clay ranges from 48.44 to 81.84, 12.60 to 22.30 and 5.56 to 29.56 % respectively. In case of red soils, the samples from Koraput contain a high amount of clay, being clayey in texture but the samples of red soil from Chandragiri is sandy clay loam in texture. Red soils varies from 40.14 to 60.44 % in sand content; 16.00 to 18.30 % in silt content and 23.56 to 41.56 % in clay content with regard to black soils, it is indicated that the soils of Bhawanipatna and Loisingha are sandy loam in texture and the black soil of Chuda is classified as sandy clay loam in texture . Black soil ranges from

48.82 to 67.84 %; 14.00 to 18.62 % and 16.16 to 32.16 % in sand, silt and clay content respectively. From the above representation it is observed that the soil texture differed from place to place although the soil type remains same.

Chemical properties of soils

The soils were analysed for pH, % organic carbon and C.E.C. The pH of the soils were determined by two different methods (1) soil and water 1 : 2 ratio. The results of the chemical properties are presented in Table V. Chemical analysis of the soils reveal that all the soils except the black soil are acidic in nature. Black soils collected from Bolangir district are neutral in reaction. In case of alluvial soil the highest pH recorded was 7.20 by soil : water (1 : 2) method. Patha farm soil is neutral in reaction. Except the soils of Patha farm, the other alluvial soils collected from different places are ranging in pH values from 5.95 to 6.65 which indicates that the soils are mildly acidic. The pH values in case of lateritic soils ranged from 5.05 to 6.75 which indicates that these soils are also moderately acidic. The % of total nitrogen was determined by Macrokjeldahls method, the results of which are recorded in the Table V. The % total nitrogen varies from 0.019 to 0.078 % in case of alluvial soils with an average value of 0.046 % , 0.020 to 0.079 % in case of lateritic soils with an average value of 0.046 %

TABLE V

CHEMICAL PROPERTIES OF DIFFERENT SOILS OF ORISSA

Sl. No.	Soil type	Place of collection	pH 1:2 Soil: water	pH 1:2 Soil: 0.01M $CaCl_2$	C.E.C in meq/100 gm	% Organic carbon	% Total Nitrogen	Available P_2O_5 kg / ha	Exchangeable 'K' in meq/100 gm	Exchangeable 'Ca' in meq/100 gm
1.	Alluvial	Dandamukundpur	5.95	5.20	9.4935	0.331	0.050	34.6	0.0370	3.45
2.	-do-	Pipli	6.65	5.70	12.0000	0.375	0.038	1.2	0.1411	5.90
3.	-do-	Nothasahi	6.15	6.05	12.0213	0.732	0.078	84.0	0.2030	4.80
4.	-do-	Potha farm	7.20	6.80	4.3230	0.201	0.019	8.0	0.1590	1.95
5.	-do-	Bharatipur	6.05	5.55	5.3571	0.404	0.045	18.4	0.0560	2.10
6.	Lateritic	Bhubaneswar Farm	6.55	5.90	3.0988	0.275	0.025	6.8	0.0358	1.65
7.	-do-	Koraput	5.05	4.20	5.6266	0.457	0.040	11.2	0.0820	1.40
8.	-do-	Dolgarh	5.65	4.80	7.9980	0.801	0.075	3.6	0.4350	3.15
9.	-do-	Janla	6.75	6.60	7.5402	0.201	0.020	6.8	0.2010	3.70
10.	-do-	Khurda	5.20	4.85	10.6822	0.737	0.072	Trace	0.3040	4.25
11.	Red	Koraput	5.50	5.45	11.0269	0.513	0.054	4.0	0.3330	4.55
12.	-do-	Chandragiri	6.56	5.90	7.4650	0.467	0.049	7.6	0.4250	2.90
13.	Black	Chuda	7.25	7.00	23.7808	0.687	0.069	32.4	0.8460	10.20
14.	-do-	Bhawanipatna	7.40	7.10	17.6911	0.660	0.059	76.0	0.2350	13.00
15.	-do-	Loisingha	6.75	5.90	22.8616	0.450	0.048	70.0	0.3710	7.00

and 0.048 to 0.054 % in case of red soil with an average value of 0.051 % and 0.048 to 0.069 % in black soils having an average value of 0.058 % . In case of alluvial soils highest percentage of total nitrogen was found in Bharatipur and lowest in Patha farm.

From the above representations, it is obvious that in respect of nitrogen content black soils are superior over all the soils studied. In general nitrogen status of the soils were low to medium.

Available P_2O_5 of different soils was recorded in Table V. It may be seen from the table that among the alluvial soils Mathasahi ranks first in available P_2O_5 content and lowest content was found in Pipli soil. However, the average P_2O_5 content was found to be 29.44 kg / ha .

In respect of available P_2O_5 , red soil was considered as the poorest having an average value of 5.8 kg / ha which is near about similar to lateritic soil and which has an average value of 6.08 kg / ha. Among the 4 groups of soil black soil was the richest in available P_2O_5 content which has an average value of 59.46 kg / ha . It is obvious from the results that red and lateritic soils are present in available P_2O_5 content.

Exchangeable calcium of 15 different soils are recorded in Table V. It is found that in case of alluvial

alluvial soil it varies from 1.95 to 5.90 meq / 100 gm with an average value of 3.64 meq / 100 gm and highest exchangeable calcium was found in Pipli soil. Patha farm soil was poor in exchangeable calcium. None of them are said to be properly balanced soil in respect to calcium as none of them contain calcium saturated with 75 % of their cation exchange capacity. The exchangeable calcium varies from 1.40 to 4.25 in lateritic soils with an average value of 2.83 meq / 100 gm. This is also considered as poorly balanced soil in respect to calcium content. Exchangeable calcium varies from 2.90 to 4.55 in case of red soil having an average value of 3.72 meq / 100 gm of soil. Exchangeable calcium of black soils varies from 7.0 to 13.00 meq / 100 gm with an average value of 10.1 meq / 100 gm. Among the black soils, Bhawanipatna soils can be taken as a properly balanced soil having saturated with more than 75 % of its C.E.C. by exchangeable Ca. Except the

Exchangeable potassium values of 15 different soils are listed in Table V. The data reveals that exchangeable potassium of alluvial, lateritic, red and black soils varies from 0.056 to 0.205 meq / 100 gm, 0.035 to 0.438 meq / 100 gm, 0.338 to 0.425 meq / 100 gm and 0.235 to 0.846 meq / 100 gm respectively. The highest amount of potassium was found in black soil collected from Chuda. The sequence of potassium status between different groups of soils is of the following order -

Black soil $>$ red soil $>$ lateritic soil $>$ alluvial soil

(0.484 meq / 100 gm) (0.379 meq / 100 gm) (0.232 meq / 100 gm) (0.129 meq / 100 gm)

With a close observation of the values for potassium the soils from Patha farm, Bolgarh, Dhurda, Koraput (red soil), Chandragiri and Chuda can be grouped as properly balanced soil with respect to potassium status as their 2.3 % of C.E.C. is saturated with exchangeable potassium. So they are called as good soil with respect to potassium status.

The soils taken for pot and field experiment studies are poor in potassium status.

The % of organic carbon ranged from 0.201 to 0.732 in case of alluvial soils, 0.201 to 0.737 in lateritic soils, 0.467 to 0.913 in red soils and 0.45 to 0.687 in case of black soils. It indicates that the soils contain neither low nor high organic matters but medium in organic matter content. In comparison to alluvial and lateritic soils the red and black soils contain more organic matter. The lateritic soils of Bhubaneswar, Janla, the alluvial soils of Patha farm and Pipli have low organic matter content.

The C. E. C. varies from 4.3230 meq / 100 gm to 12.0213 meq / 100 gm in case of alluvial soils, 3.0988 to 10.6822 meq / 100 gm in case of lateritic soils, 7.4650 to 11.0269 meq / 100 gm in case of red soils and 17.6911 to 23.7808 meq / 100 gm in case of black soils. It indicates that the cation exchange capacity of black soils are more than the C. E. C. of alluvial, red and lateritic soils. The high C. E. C. in case of black soils may be due to the presence of the predominant clay minerals montmorillonite and illite and the kaolinite being the predominant clay minerals in case of red, lateritic and alluvial soils, the C.E.C. is low in these soils. These soils are also highly leached of bases due to heavy precipitation and light and sandy loam in texture.

Zinc Status of Soils

Available zinc contents of soil

As the main aspect of the present study is to evaluate the response of zinc for the high yielding paddy total zinc and available zinc were determined from all the soils. Available zinc was extracted by 2 methods (1) 0.1 N HCl extraction method and (2) NH_4-Dithizone extraction method. Total Zn was determined as per the method suggested by Shaw and Dean (1952). The values of various zinc fractions (available and total zinc) are present in different soils are presented in Table VI. These data are graphically illustrated in Fig. 1 and 2.

Data in Table VI and Fig. 1 and 2 indicates that the available zinc in case of alluvial soils was lowest in the soils of Patha farm in both the methods

TABLE VI

ZINC STATUS OF SOILS OF ORISSA

Sl. No.	Soil type	Place of collection	Available Zinc in ppm		Total Zn in ppm
			NH_4-Dithizone Extractable Zn	0.1 N HCl Extractable Zn	
1.	Alluvial	Dandamukund-pur	1.875	2.000	58.75
2.	-do-	Pipli	1.125	1.100	42.75
3.	-do-	Mathasahi	2.750	2.250	68.00
4.	-do-	Patha farm	0.250	0.375	38.25
5.	-do-	Bharatipur	1.000	0.800	53.75
6.	Lateritic	Bhubaneswar Farm	0.875	1.250	52.00
7.	-do-	Koraput	2.250	1.250	43.00
8.	-do-	Dalgarh	1.900	1.400	50.00
9.	-do-	Jonla	0.875	0.900	49.75
10.	-do-	Khurda	2.250	2.200	60.00
11.	Red	Koraput	1.125	1.750	49.00
12.	-do-	Chandragiri	0.750	0.400	50.00
13.	Black	Chuda	2.000	4.400	48.00
14.	-do-	Bhawanipatna	1.750	3.000	42.00
15.	-do-	Loisingha	1.200	1.125	48.75

i.e. 0.250 ppm and 0.375 ppm in case of NH_4-Dithizone and 0.1 N HCl extraction respectively and highest in the soils of Mathasahi in both methods i.e. 2.75 ppm and 2.250 ppm in case of NH_4-Dithizone and 0.1 N HCl extraction methods respectively. The values of available zinc in case of alluvial soils varies from 0.250 ppm to 2.750 ppm in NH_4-Dithizone extraction method, and 0.375 to 2.250 ppm in case of 0.1N HCl extraction method and is of the following ascending order.

Patha farm $\angle$ Bharatipur $\angle$ Pipli $\angle$ Dandamukundpur
$\left(\frac{0.250\ ppm}{0.375\ ppm}\right)$ $\left(\frac{1.000\ ppm}{0.500\ ppm}\right)$ $\left(\frac{1.125\ ppm}{1.100\ ppm}\right)$ $\left(\frac{1.875\ ppm}{2.000\ ppm}\right)$

$\angle$ Mathasahi
$\left(\frac{2.750\ ppm}{2.250\ ppm}\right)$

In both the methods the order remains equal. The numerator gives the value of available zinc by NH_4-Dithizone extractable zinc and the denomination gives the value of available zinc by 0.1 N HCl extraction method.

In case of lateritic soils, it indicates that the available zinc was lowest in the soils of Janla and Bhubaneswar in both the methods and highest in the soils of Khurda in both the methods. A slight difference remains in the lateritic soils of Koraput which gave also highest available zinc in case of NH_4-Dithizone extraction but resulted a lower value in case of 0.1 N HCl extraction. The lowest extractions of available zinc recorded by both the methods are 0.875 ppm (Janla and Bhubaneswar) and 0.500 ppm (Janla)in NH_4- Dithizone method and

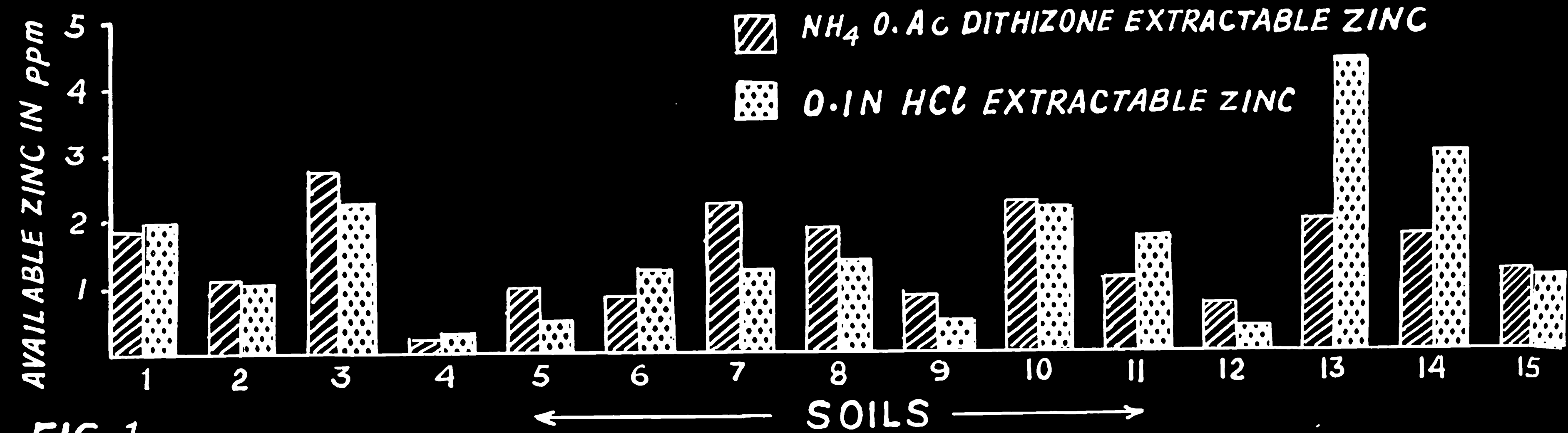


FIG.1

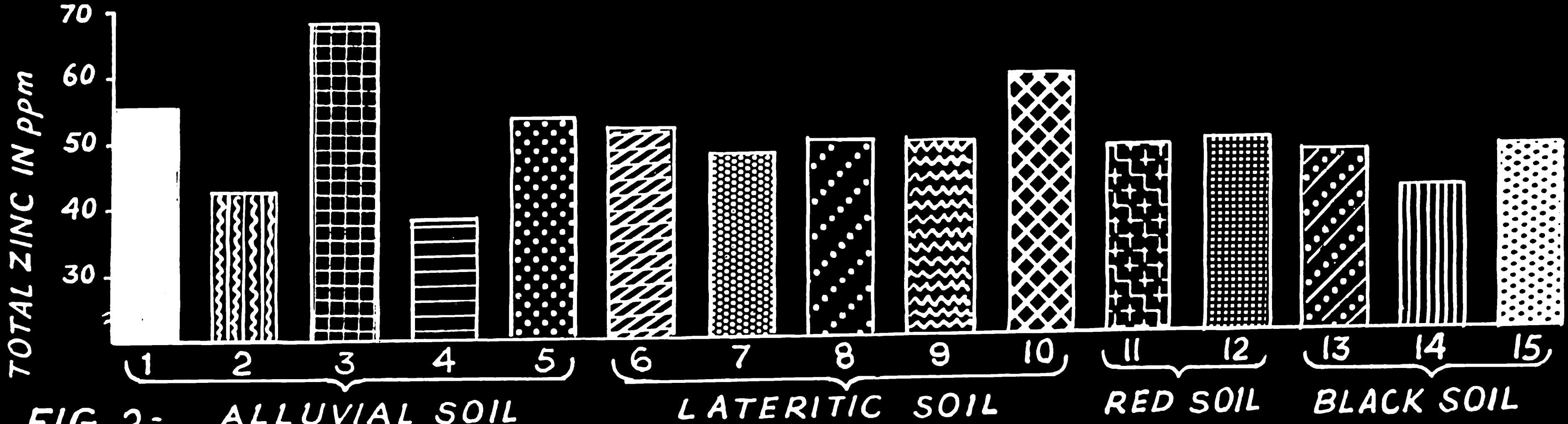


FIG.2-

1. DANDAMUKUNDA PUR
2. PIPLI
3. MATHASAHI
4. PATHA FARM
5. BHARATIPUR
6. BHUBANESWAR FARM
7. KORAPUT
8. BOLGARH
9 JANLA
10. KHURDA
11. KORAPUT
12. CHANDRAGIRI
13. CHUDA
14. BHAWANIPATNA
15. LOICINGHA

0.1 N HCl extraction methods respectively. The available zinc varies from 0.875 ppm to 2.250 ppm in case of NH_4-Dithizone extraction method and 0.500 ppm to 2.200 ppm in case of 0.1 N HCl extraction method and for both the methods the following ascending order remains for available zinc.

$$\underset{\left(\frac{0.875\text{ ppm}}{0.500\text{ ppm}}\right)}{\text{Janla}} = \underset{\left(\frac{0.875\text{ ppm}}{1.250\text{ ppm}}\right)}{\text{Bhubaneswar}} < \underset{\left(\frac{1.900\text{ ppm}}{1.400\text{ ppm}}\right)}{\text{Bolgarh}} < \underset{\left(\frac{2.250\text{ ppm}}{1.250\text{ ppm}}\right)}{\text{Koraput}} < \underset{\left(\frac{2.250\text{ ppm}}{1.250\text{ ppm}}\right)}{\text{Khurda}}$$

$$\left(\frac{\text{Numerator}}{\text{Denominator}} = \frac{NH_4\text{-Dithizone extractable zinc}}{0.1\text{ N HCl extractable zinc}}\right)$$

Red soils collected from two different places i.e. Koraput and Chandragiri indicate that the available zinc was lowest in Chandragiri and highest in Koraput in both the methods. The value of available zinc in these places is of the following ascending order.

$$\underset{\left(\frac{0.750\text{ ppm}}{0.400\text{ ppm}}\right)}{\text{Chandragiri}} < \underset{\left(\frac{1.125\text{ ppm}}{1.750\text{ ppm}}\right)}{\text{Koraput}}$$

In case of black soils, the results indicate that the lowest available zinc present in the soils of Loisingha and the highest in Chuda. The available zinc in these soils is of the following ascending order.

$$\underset{\left(\frac{1.200\text{ ppm}}{1.125\text{ ppm}}\right)}{\text{Loisingha}} < \underset{\left(\frac{1.750\text{ ppm}}{3.000\text{ ppm}}\right)}{\text{Bhawanipatna}} < \underset{\left(\frac{2.000\text{ ppm}}{4.400\text{ ppm}}\right)}{\text{Chuda}}$$

Further, it can be high lighted that the availability of zinc with regard to different soil groups can be arranged from the average values in the following descending order.

(1) NH_4- Dithizone extractable available zinc

Black soil > Lateritic soil > Alluvial soil > Red soil
(1.650 ppm) (1.630 ppm) (1.400 00m) (0.930 ppm)

2) 0.1 N HCl extractable available zinc

Black soil > Lateritic soil > Alluvial soil > Red soil
(2.841 ppm) (1.320 ppm) (1.245 ppm) (1.075 ppm)

From the above representation, it is obvious that the available zinc content in different soil groups follow an equal descending order in both the methods i.e. Black soil > Lateritic soil > Alluvial soil > Red soil Alluvial soil no doubt contains more amount of available zinc than red soil, but seems to be less in available zinc content in comparison to black and lateritic soil. Lateritic soilsare superior to alluvial and red soils but inferior in available Zn content to black soil . Among all black soil is superior in available Zn content to all of others.

<u>Comparison Between the Methods of Extraction of Available Zinc</u>

The alluvial soils show an appreciable decrease in the amount of extraction of available zinc in case of 0.1 N HCl extraction method in comparison to the NH_4 - Dithizone extraction within a range of 0.025 to 0.500 ppm except two places of the samples collected from Dandamukundpur and Patha farm where an increase in extraction amounts was obtained within a range of

0.025 to 0.0125 ppm by 0.1 N HCl extraction method in comparison to NH_4 - Dithizone extraction. This indicates that the picture of variation remains very negligible either by or slight increase or decrease without any wide difference, it can be justified that the values for NH_4 - Dithizone extraction Zn were more or less similar in magnitude to the 0.1 N HCl extractable values.

Similar case is not recognised with lateritic soils where the difference ranges from 0.05 ppm to 1.00 ppm Hence, in the lateritic soil, the values for NH_4-Dithizone extractable zinc remains usually slightly higher than those obtained for 0.1 N HCl extraction method.

In case of red soils it can be well understood from the data that it is similar to alluvial soils for this comparison. Out of the two samples of red soils collected from Koraput and Chandragiri, it seems that an increase by 0.375 ppm was obtained in 0.1 N HCl extraction method.

In case of red soils it can be well understood from the data that it is similar to alluvial soils for this comparison. Out of the two samples of red soils collected from Koraput and Chandragiri, it seems that an increase by 0.375 ppm was obtained in 0.1 N HCl extractable zinc in comparison to NH_4-Dithizone extractable value in case of Koraput samples and at the same time a decrease by 0.350 ppm was obtained in 0.1 N HCl extractable zinc than the value obtained for NH_4 -Dithizone in case of Chandragiri. So it gives the idea that the increase or decrease is quite less and it can be recognised that the magnitude of the values obtained by both the methods remains more or less equal.

For black soils, the two samples from Chuda and Bhawanipatna exhibited an increase value by 0.1 N HCl extraction method i.e. 2.2 ppm and 1.25 ppm more values than those obtained for NH_4- Dithizone. The samples of of black soils from Loisingha resulted a decrease value of 0.075 ppm by 0.1 N HCl extraction in comparison to NH_4-Dithizone extractable value. But undoubtedly majority of the samples exhibited higher extraction values in case of 0.1 N HCl method than NH_4- Dithizone extraction method.

Out of all the soils analysed, comparing the methods of extraction on the average values of different oil broad groups, it can be observed that there is always an increasing trend by a range of 0.135 ppm for alluvial soil, 0.138 ppm for red soils and 0.310 ppm for lateritic soils in case ofthe values obtained for NH_4 - Dithizone extractable zinc than the values of 0.1 N HCl extractable zinc except the case with black soils. The black soils not only exhibited a higher trend in the majority of the samples analysed but also in average, the value gives a similar increasing trend upto an extent of 1.191 ppm in case of 0.1 N HCl extractable zinc than the value obtained for NH_4-Dithizone zinc.

The relationship between the two methods can be briefly summarised that the values for NH_4 -Dithizone extractable zinc were more or less similar in magnitude to 0.1 N HCl extractable zinc values in case of alluvial soils and red soils with slight increase and for lateritic soils usually higher but on an average the slight increasing gradient exists for all three soils (Alluvial, Lateritic and Red) with the values of NH_4 - Dithizone extractable zinc in contrast to 0.1 N HCl It can be best suggested that there is no distinguished variation between the two methods in all the soils analysed.

Total Zince Contents of the Soils

Total zinc contents of all the soils are represented in the Table VI and the data are graphically illustrated in Fig. 2.

Total zinc in case of alluvial soils was found to be the lowest in case of Patha farm (38.25 ppm) and highest in Mathasahi (68.00 ppm). The range varies from 38.25 ppm to 68.00 ppm in case of alluvial soils. Placewise distribution of total zinc follows the following sequence.

Patha farm (38.25 ppm) ∠ Pipli (42.75 ppm) ∠ Bharatipur (53.75 ppm) ∠ Dandamukundpur (55.75 ppm) ∠ Mathasahi (68.00 ppm)

In case of lateritic soils the range varies from 48.00 ppm to 60.00 ppm. Total zinc was found to be the lowest in case of Koraput (48.00 ppm) slighest in Khurda (60.00 ppm). Placewise distribution of total zinc follows the following ascending order for lateritic soils.

Koraput (48.00 ppm) ∠ Janla (49.75 ppm) ∠ Bolgarh (50.00 ppm) ∠ Bhubaneswar (52.00 ppm) ∠ Khurda (60.00 ppm)

In red soils out of the two samples analysed for total zinc, the lowest was found in case of Koraput (49.00 ppm) and the highest was found in case of Chandragiri (50.00 ppm). The difference in the range of variation is very less i.e. only one ppm between the two soils The following sequence gives the total zinc content of red soils.

Koraput (49.00 ppm) ∠ Chandragiri (50.00 ppm)

Total zinc in case of black soils was found to be lowest in Bhawanipatna (42.00 ppm) and highest in case of Loisingha (48.75 ppm). The range of total zinc for black soil varies from 42.00 ppm to 48.75 ppm and follows the following sequence.

Bhawanipatna (42.00 ppm) ∠ Chuda (48.00 ppm) ∠ Loisingha (48.75 ppm)

On comparison of different soil groups on the total zinc content the following sequence in descending order was obtained.

Lateritic soil > Alluvial soil > Red soil > Black soil
(51.95 ppm) (51.70 ppm) (49.50 ppm) (46.25 ppm)

The lowest total Zn on an average was found in case of black soils (46.25 ppm) and the highest total zinc was obtained in case of lateritic soils (51.95 ppm average value). Alluvial soils contain more total zinc in comparison to red and black soils but lesser than lateritic soils.

The total zinc content in all the soils ranged from 38.25 to 68.00 ppm with an average value of 51.70 ppm in alluvial soils, 51.95 ppm in case of lateritic soils, 49.50 ppm in case of red soils and 46.25 ppm in case of black soil. In general the total zinc content in all soils seems to be similar with a slight variation.

Correlation Studies

The availability of zinc is much affected by the physico-chemical properties of soils like clay content, pH, organic carbon, cation exchange capacity and total zinc. Hence under this investigation conscientious efforts by statistical analysis were made to correlate the total zinc and available zinc extracted by two methods i.e. 0.1 N HCl extracted zinc and NH_4 - Dithizone extracted zinc of all the fifteen different soils with their pH, organic carbon, C. E. C. and clay % . Also the available zinc contents by two methods were correlated with total zinc. The results of the correlation studies showing the correlation. Coefficient are recorded in Appendix Table III The lines of regression of some correlations have been drawn in Fig. 8, 9, 10 and 11. The graphical representation illustrate the 'r' and 'y' values i.e. correlation coefficient values and regression lines respectively by plotting the data of different variables correlated. The following relationships have been obtained.

pH

There is no significant correlation between the NH_4 -Dithizone extracted zinc and pH values (r = -0.3562). The 'r' value indicates that they are negatively correlated but the correlation is not significant. There exist a positive nonsignificant correlation between 0.1 N HCl extractable zinc and pH (r = 0.2564).

Total zinc and pH values are negatively and significantly correlated at 5 % level with r = -0.524. The regression line is drawn in Fig. 11.

Cation Exchange Capacity

The negatively charged clay of the soil constitute a system of anions which is accompanied by the cations that make up the ions of the exchange complex and a interchange of different kinds of cations in a soil depends on the percentage of clay, type of clay and organic matter content. In the present study NH_4 -Dithizone extractable zinc and C. E. C. are positively but not

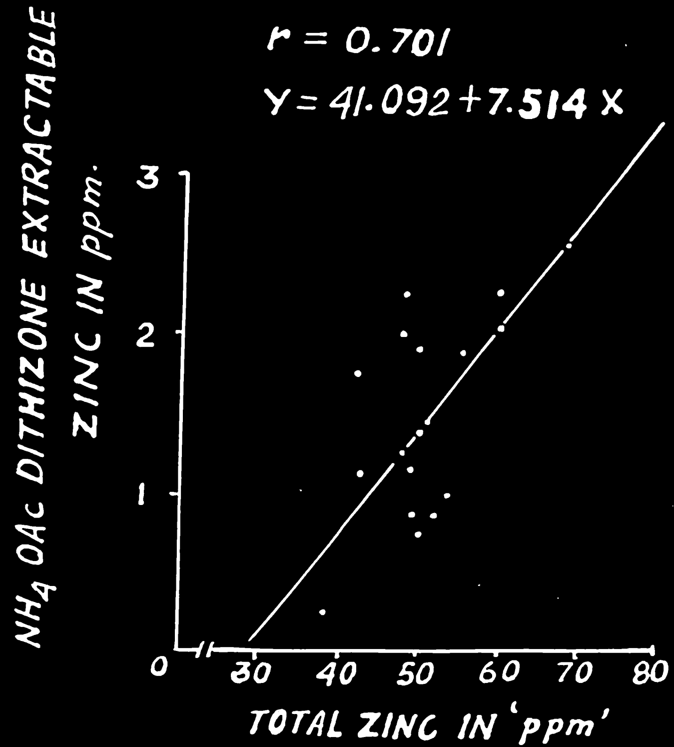


FIG. 8 RELATIONSHIP BETWEEN TOTAL ZINC AND NH_4 O.Ac DITHIZONE EXTRACTABLE ZINC

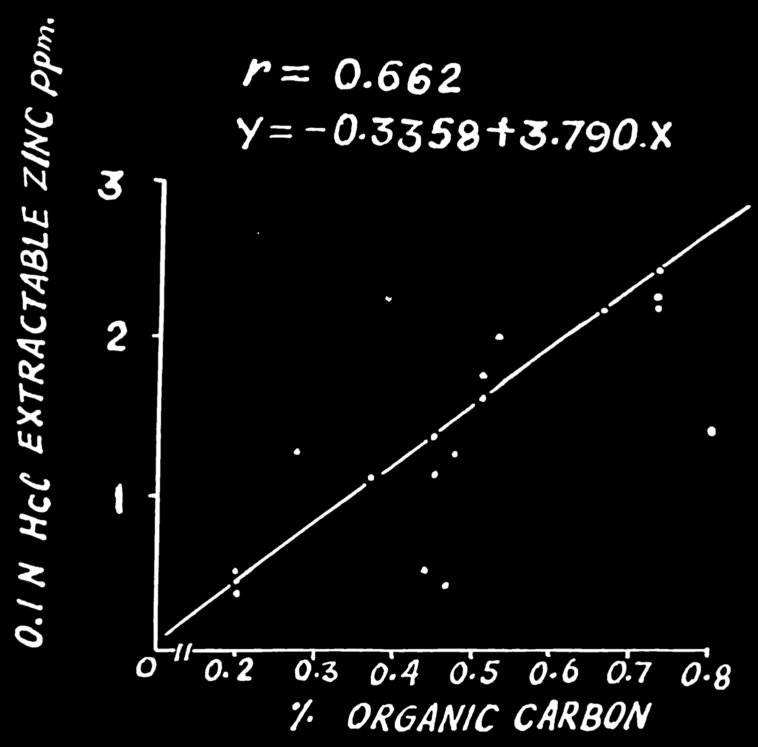


FIG. 9- RELATIONSHIP BETWEEN % ORGANIC CARBON AND 0. IN HCl EXTRACTABLE ZINC

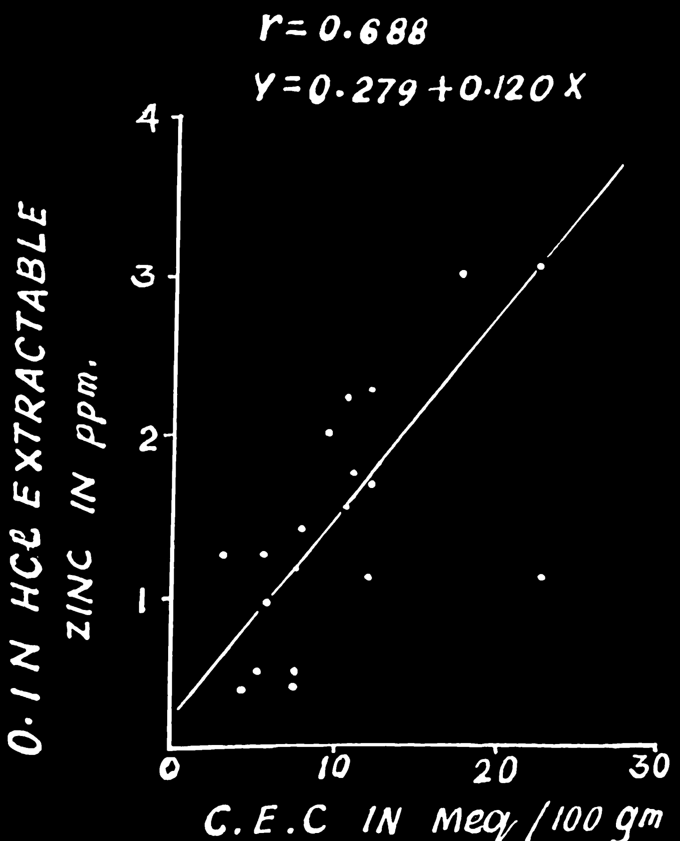


FIG. 10- RELATIONSHIP BETWEEN C.E.C AND 0.1N HCl EXTRACTABLE ZINC.

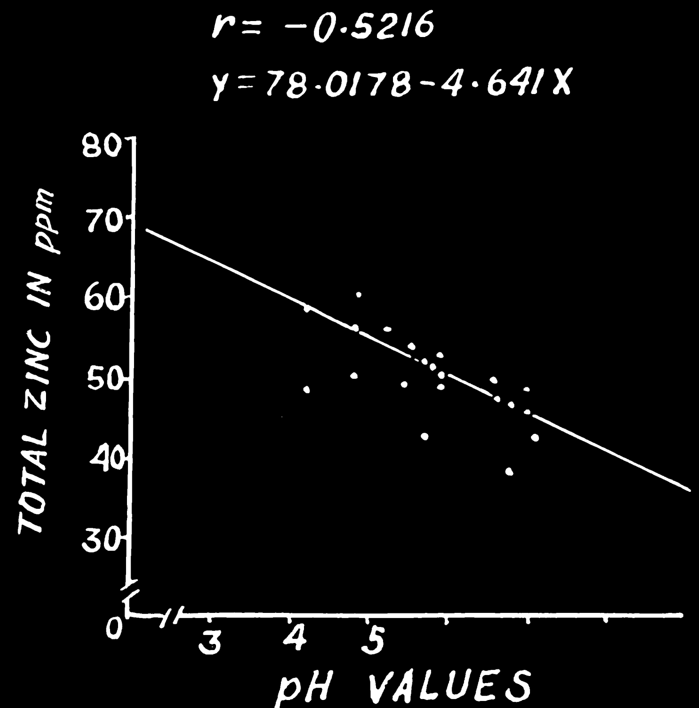


FIG. 11-RELATIONSHIP BETWEEN TOTAL ZINC AND pH.

significantly correlated (r = 0.328). Similarly a negative and non-significant correlation was obtained between total zinc and C. E. C. (r = -0.138). But a positive and significant correlation was obtained between the 0.1 N HCl extractable zinc and C.E.C. at 5 % level of significance with r = 0.688. Fig. 10. The above findings agree that C. E. C. is a good indicator for available zinc content of soil.

<u>Organic Carbon</u>

Correlation studies shows that there is positive correlation between organic carbon and total zinc as well as available zinc extracted by both methods. 0.1N HCl extractable zinc and organic carbon are positively and significantly correlated at 5 % level with r = 0.662. The lime of regression has been drawn in Fig. 9. NH_4- Dithizone extractable zinc and organic carbon are positively but not significantly correlated with correlation coefficient value of r = + 0.269. There is also positive but not significant correlation between total Zn and organic carbon (r = 0.427). From these above results it is evident that organic matter content of a soil is a good indicator of zinc status of soil.

<u>Clay Content</u>

A positive but not significant correlation was obtained between the % of clay and 0.1 N HCl extractable zinc with r = 0.358. Similarly NH_4 -Dithizone extractable zinc and % of clay are not positively correlated but their correlation is not significant (r = 0.2948). Similarly a not significant positive correlation was obtained between the total zinc and percentage of clay. Correlation study show that apparently there is positive correlation between % of clay and total zinc but not significantly (r = 0.0631).

From these results it is evident that apparently there is positive correlation between clay content, available zinc and total zinc.

Total Zinc

A highly significant positive correlation was found between the total zinc and NH_4- Dithizone extracted zinc at 1 % level of significance (r = 0.701). The regression line has been drawn in Fig. 8 . There is positive correlation between total zinc and 0.1 N HCl extractable zinc but not significant (r= 0.135). This relationship magnifies that availability of zinc increases with the increase in total zinc content of the soil.

Pot Experiment

The soil taken under this investigation is alluvial soil of Dandamukundpur village, Pipili block, Puri district of Orissa State. Padma variety of high yielding paddy was selected as a test crop for investigation in Summer season. The high yielding paddy plants were grown for 8 weeks in clay pots containing 5 kg of soil (dry basis).

The lime requirement of the soil as determined was found to be 1 ton /acre. Accordingly 3 levels of lime were taken (1) No lime (L_0) (2) Half of the requirement of lime($L_{½}$) (3) Full lime requirement (L_1) with 5 levels of zinc as Z_0, Z_1, Z_2, Z_3 and Z_4 which stands for no zinc, 5 ppm, 10 ppm, 15 ppm and 20 ppm zinc respectively. Available zinc content of the soils after harvest of crop was determined by the two different methods and total zinc and pH were also measured. The zinc uptake and drymatter yields of the plants are also recorded . The following results are obtained .

Effect of Different Levels of Zinc on the Drymatter Yield of the Rice Crop of Pot Experiment at Different Levels of Liming

The mean drymatter yields of the crop under pot experiment due to different treatments in alluvial soils have been recorded in Table VII and graphically illustrated in Fig. 3. The data obtained were statistically analysed and the report of the analysis has been appended in Appendix Table I.

It is evident from the presentations that the differential effects of various levels of zinc were significantly different in alluvial soils. The different levels of zinc were statistically significant at 1 % level of significance. However, the different levels of lime application and the interaction of levels of

TABLE VII

MEAN DRYMATTER YIELD IN gm / pot

Pot Experiment

Alluvial soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	22.166	21.366	22.400	21.977
2.	Z_1	25.066	19.933	21.133	22.044
3.	Z_2	22.900	23.533	24.200	23.544
4.	Z_3	24.866	25.166	24.266	24.766
5.	Z_4	23.666	23.133	23.500	23.433
Means of levels of lime application		23.733	22.626	23.099	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	Sig. **	N.S.	N.S.
S.E(m)	0.790	0.617	1.380
C.D(0.05)	1.619	1.263	2.826

Sig. ** - Significant at 1 % level

Sig. * - Significant at 5 % level

N.S. - Not significant

zinc and levels of lime application did not appear to have any effect on dry matter yield in this soil as there is no significant differences.

Application of zinc in general enhanced the dry matter yield over control in case of alluvial soil and it is found that zinc application at 15 ppm Zn in general over all the levels of Zn treatments as well as also over the control resulted in high dry matter yield. The application of zinc at the level of 5 ppm zinc yielded lowest drymatter yield in comparison to other levels of application but definitely resulted a slight increase in dry matter yield over the control.

Application of Zn at 10 ppm level was undounbtedly more effective than control and Z_1 level (5 ppm Zn) but inferior to Z_3 level (15 ppm). The Z_4 level (20 ppm) seems to be inferior to Z_3 level application and is some what equal in performance with a negligible increase in dry matter yield to Z_2 level (10 ppm) of application but definitely superior to the Z_1 level. and over the control . From the Table it is also clear than the three levels of Zn i.e. Z_2, Z_3 and Z_4 come under one group having no statistically significant difference in this soil. Also no statistical significant difference was observed between Z_2, Z_1 and Z_4 levels. But a significant difference lies between Z_1 and Z_3 levels of zinc application as the drymatter yield obtained by

Z_3 level being the highest yield i.e. 24.766 gm / pot So it can be undoubtedly told that Z_3 level is superior to Z_2 and Z_4 levels on drymatter yield. Depending on the mean yield of dry matter the different levels of zinc can be arranged in the following sequence of performances in descending order.

$$Z_3 > Z_2 > Z_4 > Z_1 > Z_0$$

(15 ppm) (10 ppm) (20 ppm) (50 ppm) (no zinc)

and statistical analysis indicates the following descending order.

$$Z_3 > (Z_2 = Z_3 = Z_4) = Z_2 = Z_1 = Z_4 > Z_0$$

$$\text{or} \quad Z_3 > (Z_3 = Z_4) > (Z_2 = Z_1) > Z_0$$

No significant difference was found in the different levels of lime application and in general it may be seen that there is not much difference between the L_0 , $L_{1/2}$ and L_1 levels of lime application. However depending on the mean values it seems that no application of lime proves better for drymatter production. Similarly no significant difference was found in the interaction of levels of zinc and levels of lime application in alluvial soils. But by close observation to the mean values of zinc and lime interactions, it may be seen that $L_{1/2}Z_3$ combination proved best among all and ranked the highest in drymatter production (25.166 gm / pot) and $L_{1/2}Z_1$ combination proved to be lowest (19.933 gm / pot) in drymatter yield.

Effects of Different Levels of Zinc on the Total Uptake OfZinc by the Rice Crop of Pot Experiment at Different Levels of Lime Application

The mean uptake of total zinc as affected by different treatments have been recorded in Table VIII. These data are graphically illustrated in Fig. 4 and the results of the 'F' test are given in the Appendix Table I. The data appears to be self explanatory in judging the relative efficiency of the different levels of zinc in alluvial soils. It is evident from the presentation that the differential effect from various levels of zinc were significantly different in total uptake of zinc in alluvial soils, and are statistically significant at 1 % level of significance. However the different levels of lime application and interaction of levels of lime and levels of zinc did not appear to have any effect on the total uptake of zinc in plants as there is no significant difference.

From the close observation of Table VI it may be seen that the drymatter yield and total uptake of zinc due to respective treatments were related to each other . Thus the sequence of performance of different treatments on dry matter yield was also maintained in case of total uptake of zinc in the plant with a little deviation depending on the mean total uptake the following is the

TABLE VIII

MEAN TOTAL UPTAKE OF ZINC IN mgm / pot

Pot Experiment

Alluvial soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	0.998	1.211	1.294	1.168
2.	Z_1	1.655	1.594	1.404	1.551
3.	Z_2	1.077	1.226	1.964	1.422
4.	Z_3	2.213	1.801	2.144	2.053
5.	Z_4	2.075	1.945	1.747	1.922
Means of levels of lime application		23.733	22.626	23.099	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' Test	Sig. **	N. S.	N. S.
S. E(m)	0.183	0.140	0.317
C.D(0.05)	0.375	0.286	0.649

Sig. ** - Significant at 1 % level

Sig. * - Significant at 5 % level

N.S. - Not significant

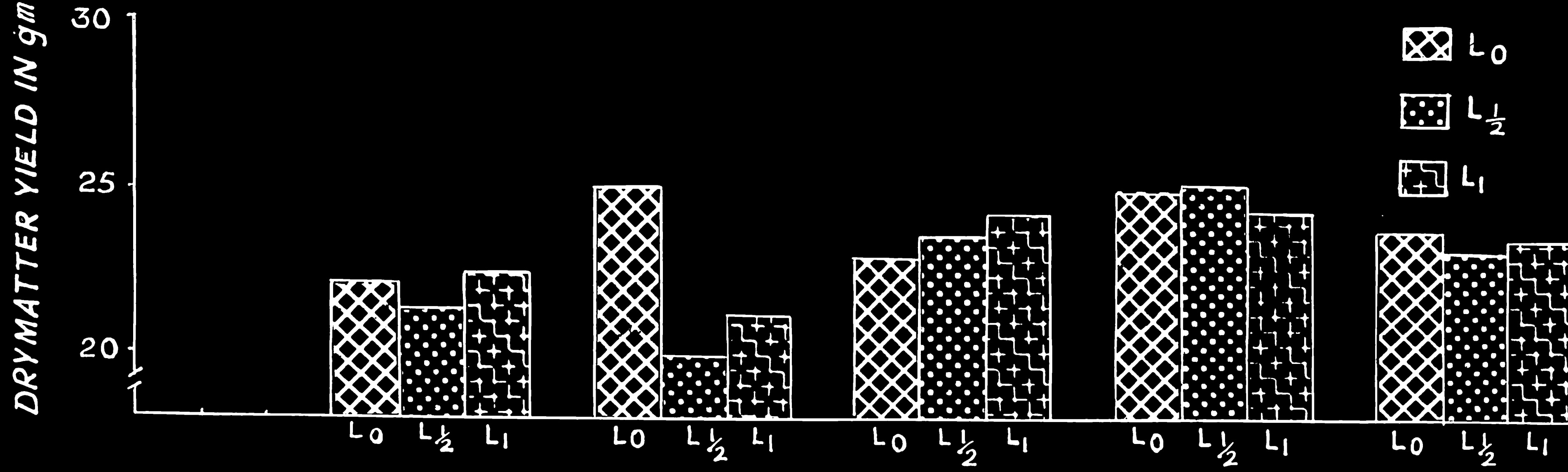


FIG.3 - MEAN DRYMATTER YIELD OF POTTED RICE AS AFFECTED BY DIFFERENT TREATMENTS

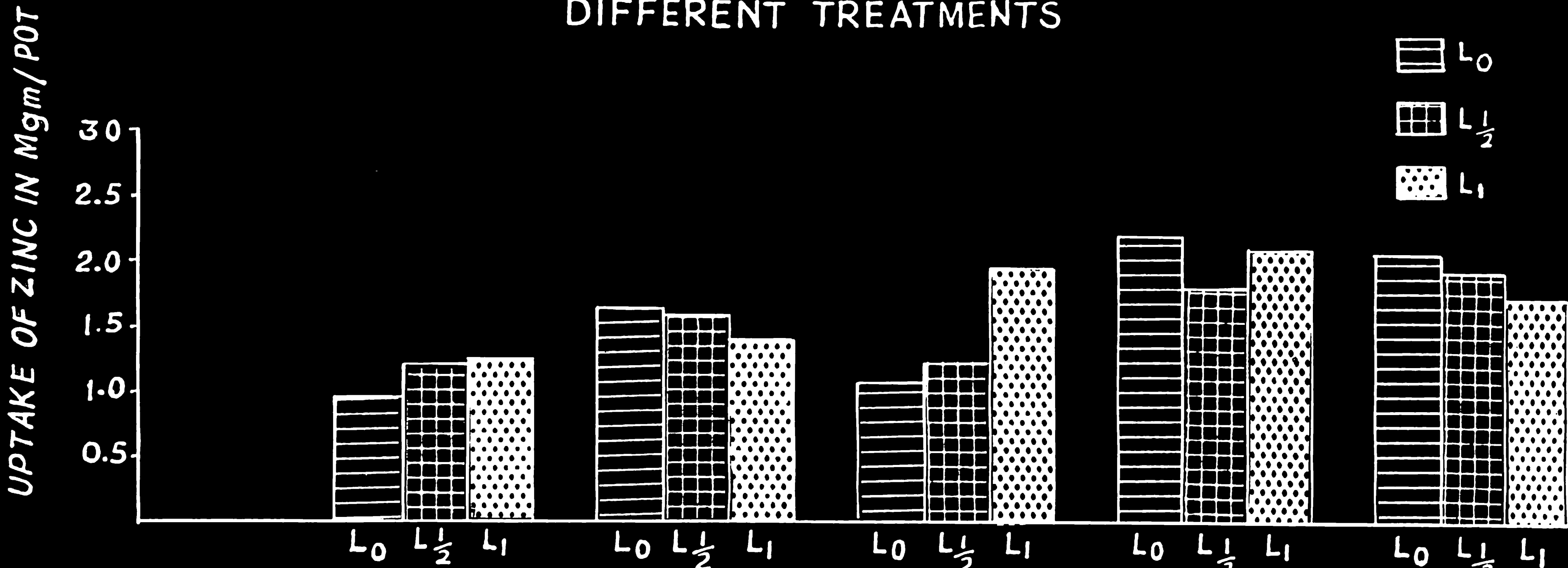


FIG.4- MEAN UPTAKE OF ZINC OF POTTED RICE AS AFFECTED BY DIFFERENT TREATMENTS.

discending order of performance.

$$Z_3 > Z_4 > Z_1 = Z_2 > Z_0$$

Application of zinc in general enhanced the total uptake of zinc over control in case of alluvial soil and it is found that zinc application at 15 ppm in general over all the levels of zinc treatments as well as also over the control resulted in high total uptake of Zn. The application of zinc at the level of 10 ppm zinc yielded lowest total uptake in comparison to all other levels of application but definitely resulted higher uptake of total zinc over the control. The application of Zn at 5 ppm level was undoubtedly more effective in total uptake of zinc over the control and Z_2 level (10 ppm) though it proved to be the lowest in drymatter yield. But it is inferior to Z_3 and Z_4 level in the total uptake of zinc by plant. Z_4 level (20 ppm) application seems to be inferior to the Z_3 level (15 ppm) application in total uptake by plants but definitely superior over the Z_2 and Z_1 level, and also over the control.

No significant difference was found in the different levels of lime application and in general not much difference can be observed between the L_0, $L_{½}$ and L_1 levels of lime application. It seems that both in drymatter yield and total uptake of zinc no significant differences lies in the different levels of lime application.

The total uptake of zinc in pot experiments also indicates that there is no significant differences between the interaction of levels of zinc and levels of lime application in alluvial soils. Similar results have also been obtained in case of drymatter yield. By close observation to the means of interaction treatment it is found that the Z_3 level (15 ppm) application at L_0 (no lime) requirement proved best among all and resulted high total uptake of zinc (2.213 mg / pot) in alluvial soil. The lowest uptake of zinc was found to be 0.998 mg / pot at the Z_0 level of zinc with L_0 level of lime application.

Effect of the Different Levels of Zinc on the Total Zinc Contents of the Soil at Different Levels of Liming after harvest of the Crop of Pot Experiment

The total zinc measured from the soils after harvest of the crop have been presented in Table IX. The data have been analysed statistically the analysis of variance Appendix Table I.

It is clear from the treatments that the differential effect of various levels of zinc on the total zinc content of the soils after harvest of crop were significantly different at 1 % level of significance in alluvial soil. There is also significant difference between the interaction values of zinc and lime levels at 5 % level . But no significant difference was found in the levels of lime application.

Application of zinc increased the total zinc content of alluvial soil and application @ 20 ppm Zn in general resulted in higher increase of total zinc content in the soils. Total zinc content was found to be comparatively very less where no zinc was applied. Application of Zn @ 5 ppm (Z_1 level) resulted lowest total zinc content in comparison to other levels of zinc application but gave a relatively higher value over the control. The application at Z_3 level undoubtedly increased the total zinc content of soils ranking a second position next to Z_4 level which is superior to all other 3 levels. The Z_2 level is definitely superior to Z_0 and Z_1 levels in increasing the total zinc content of the soils but inferior to Z_3 and Z_4 levels in this regard. Hence the following order can be suggested on the effect of different zinc levels on the amount of total zinc present in the soil after harvest of crop.

Z_4	7	Z_3	7	Z_2	7	Z_1	7	Z_0
(20 ppm)		(15 ppm)		(10 ppm)		(5 ppm)		(no zinc)

This indicates that the total zinc in soil increases successively with the increase in the rate of zinc application. Statistically Z_4 level also gave the highest significance difference among all the levels. Z_2 and Z_1 comes under same group having no statistical significant

TABLE IX

MEAN TOTAL ZINC IN SOIL IN ppm

Pot Experiment

Alluvial soil

Sl. No.	Levels of zinc appli-cation	Means of zinc levels and levels of lime application			Means of levels of zinc appli-cation
		L_0	$L_{½}$	L_1	
1.	Z_0	41.833	32.833	45.416	40.027
2.	Z_1	32.916	52.833	49.283	45.010
3.	Z_2	53.166	36.166	51.666	46.999
4.	Z_3	67.500	96.083	51.833	71.805
5.	Z_4	72.750	95.416	85.833	84.666
Means of levels of lime appli-cation		53.633	62.666	56.806	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	Sig. **	N.S.	Sig. *
S. E(m)	3.752	2.906	11.25
C.D (0.05)	7.684	5.951	23 .04

Sig. ** - Significant at 1% level

Sig. * - Significant at 5% level

N.S. — Not significant

difference but Z_2 level is superior to Z_1 level as it is observed from the mean values.

The sequence as revealed by statistical analysis is as follows.

$$Z_4 > Z_3 > Z_2 = Z_1 > Z_0$$

Application @ 20 ppm proved to be best among all other levels of application as far as the increase of total zinc content is concerned.

With regards to the levels of lime application no significant difference was observed for the total zinc content of soils effected by lime application and as such gives the same not significant relationship which were obtained both in case of drymatter yield and total uptake of zinc. However from the mean values it seems that lime applied at $L_{1/2}$ level raises total zinc content of the soils appreciably in comparison to L_0 and L_1 levels. This indicates that application of lime in half of the requirement for alluvial soils seems to be better than no application in increasing the total zinc content of the soil.

Regarding the interaction between the different levels of zinc and levels of lime application a statistical significant difference was obtained. The highest value of (96.083 ppm) total Zn in soil was obtained at Z_3 level (15 ppm) application of $L_{1/2}$ requirement. And the lowest value was obtained (32.833 ppm) in the interaction level of Z_0 and $L_{\frac{1}{2}}$. This represents that the lime requirement i.e. $L_{\frac{1}{2}}$ remaining same in both cases, zinc application at the rate of Z_3 level (15 ppm) definitely increases the total zinc content of soil over no application. Interacted values of zinc and lime gives the following descending order.

$L_{\frac{1}{2}}Z_3 > L_{\frac{1}{2}}Z_4 > L_1Z_4 > L_0Z_4 > L_0Z_3 > L_0\ Z_2 > L_{\frac{1}{2}}Z_1 > L_1Z_3$

$L_1Z_2 > L_1Z_1 > L_1Z_0 > L_0Z_0 > L_{\frac{1}{2}}Z_2 > L_0Z_1 > L_{\frac{1}{2}}Z_0$

This indicates that the Z_3 and Z_4 levels of zinc applications have a definite contribution to increase the total zinc content in soils with the level of lime application at half ($L_{\frac{1}{2}}$) of the total requirement in alluvial soil.

<u>Effect of the Different Levels of Zinc on the Available Zince Content of the Soil at Different Levels of Liming After Harvest of the Paddy crop of Pot Experiment</u>

The available zinc was extracted by two different methods (1) NH_4-Dithizone extractable zinc and (2) 0.1 N HCl extractable zinc from the alluvial soil after harvest of the crop have been in Table X . The data are analysed statistically and the results of the analysis has been appended in Appendix Table I.

It is evident from the data that the differential effect of various levels of zinc were significantly different in alluvial soils with the extractable available

TABLE X

EFFECT OF DIFFERENT LEVELS OF ZINC AND LIME TREATMENTS ON AVAILABLE ZINC CONTENT AFTER HARVEST OF CROP

Pot Experiment
Alluvial soil

Sl. No.	Levels of zinc application	Available zinc in 'ppm'							
		NH_4[illegible] - Dithizone extraction method				0.1 N HCl extraction Method			
		Means of zinc levels and levels of application			Means of levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1		L_0	$L_{1/2}$	L_1	
1.	Z_0	2.083	0.750	1.416	1.416	1.583	1.666	1.825	1.691
2.	Z_1	2.783	2.633	1.433	2.283	3.041	3.291	2.708	3.013
3.	Z_2	5.533	4.530	2.233	4.098	4.258	3.583	4.150	3.997
4.	Z_3	6.466	5.460	3.750	5.225	5.008	5.125	4.600	4.911
5.	Z_4	6.200	6.166	3.860	5.400	4.800	4.625	5.408	4.944
Means of levels of lime application		4.613	3.907	2.538		3.738	3.658	3.738	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime	Levels of zinc application	Levels of lime application	Levels of Zn X Levels of lime
'F' test	Sig. **	Sig.**	**	Sig.**	N.S.	N.S.
S.E(m)	0.527	0.562	0.39	0.251	0.194	0.436
C.D(0.05)	0.468	0.364	0.813	0.514	0.397	0.893

Sig.** -Significant at 1% level; Sig.*-Significant at 5% level; N.S.-Not significant zinc by the two methods at 1 % level of significance. The interaction of levels of zinc and levels of lime application appear to have definite effect on the availa-ble zinc determined by NH_4-Dithizone extractant as there is significant difference but no such significant relationship lies with 0.1 N HCl extractable zinc. The different levels of lime application represent a significant difference at 1 % level of significance in case of the available zinc extracted by NH_4-Dithizone extraction method whereas no such significant differences has been observed with the available zinc extracted by 0.1 N HCl extraction method. The following are the descending orders

(1) NH_4-Dithizone extractable zinc

$Z_4 > Z_3 > Z_2 > Z_1 > Z_0$

(2) 0.1 N HCl extractable zinc

$Z_4 > Z_3 > Z_2 > Z_1 > Z_0$

With regards to the level of lime application there is no significant relationship with the available zinc extracted by 0.1 N HCl method but a significant difference is observed in case of NH_4- Dithizone extractable zinc . The following sequence is observed in case of NH_4- Dithizone extraction of available Zn on the different levels of lime application

$$L_0 > L_{1/2} > L_1$$

This indicates that zinc becomes more available in the soils where no lime is applied.

Regarding the ineractions between the different levels of zinc and levels of lime no statistical difference was obtained in case of 0.1 N HCl extractable Zn but a significant difference was noticed with NH_4-Dithizone extractable Zn. The highest value was obtained at L_0Z_3 level i.e. 6.466 ppm zinc and lowest i.e. 0.750 ppm Zn at $L_{1/2}Z_0$ level in case of NH_4-Dithizone method. Similarly the highest mean value 5.408 ppm Zn in case of 0.1 N HCl extraction method was obtained at L_1Z_4 level of interaction This indicates that Z_3 and Z_4 levels of lime application definitely increases the available zinc in soil over non-application of zinc.

Hence from the above observation it is well understood that availability of zinc increases in the soil with increase in zinc application and 20 ppm zinc proved to be the best in the increased availability of both total zinc and available zinc.

It is found from the data that the Z_3 level also contributes definite increase in available zinc status of the soil without any lime application.

Also by comparing two methods of available zinc determination statistically no significant difference between them was observed . The magnitude of variation is very narrow with a range of 0.835 ppm Zn to 1.341 ppm zinc between their lowest and highest values. It seems to be negligible and as a matter of fact both the methods are equally dependable for extracting available zinc from alluvial soils.

<u>Effect of Different Levels of Zinc on the pH Values of the Soils at Different Liming levels after Harvest of the crop of Pot Experiment</u>

The data obtained on pH values determined by 1:2 soil : 0.01 M $CaCl_2$ suspension are recorded in Table XI.

It may be observed that the soils under this investigation were strongly acidic and its pH did not vary markedly from treatment to treatment. Initially the soil pH was 5.55. The pH values changed with different levels are 5.78, 5.79, 5.68, 5.53, 5.78 by Z_0 , Z_1, Z_2, Z_3 and Z_4 respectively. The pH values increase with a value varying from 0.13 to 0.24 maximum from the initial pH of the alluvial soil taken by this method. This light increase in pH is quite negligible. In case of the levels of lime application such type of negligible increase in pH was observed from the pots where no lime was applied. The pH for L_0 was 5.38 and where L_3 was applied pH increased to 5.74 with a difference of only 0.36 unit.

<u>Availability of Zinc with respect to pH as Influenced by Liming</u>

By close observation of the data represented in

TABLE XI

EFFECT OF DIFFERENT TREATMENTS ON THE 'pH' VALUES OF SOILS AFTER HARVEST OF CROP.

Pot Experiment

Alluvial soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	5.55	5.73	6.08	5.78
2.	Z_1	5.43	5.85	6.11	5.79
3.	Z_2	5.36	5.70	6.00	5.68
4.	Z_3	5.20	5.61	5.80	5.53
5.	Z_4	5.38	5.83	6.13	5.78
Means of levels of lime application		5.38	5.74	6.02	

Table XI for pH and Table IX and X for total and available zinc respectively, it can be opined that at Z_3 level of application, the availability is more in comparison to other levels only because of a decrease obtained in pH level by liming. Hence it can be predicted that availability of zinc increases with the decrease in pH values.

Correlation Studies of Pot Experiment

The available zinc contents of the soils as extracted by different methods (i) NH_4 - Dithizone extraction and (ii) 0.1 N HCl extraction method after harvest of crop of pot experment and total zinc contents of the soils after harvest of the crop were also determined and were correlated separately with drymatter yield, the total zinc uptake in plants and pH values of the soils. Uptake of total zinc were also correlated separately with drymatter yields and pH values of the soils. The lines of regression have been drawn in Figs. 12, 13, 14, 15 and 16 and 25. The results of the correlation studies have been recorded in the Appendix Table IV showing the correlation coefficient (r) values.

Correlation Between the Total and Available Zinc by two Methods with the pH Values of Alluvial Soil.

The following correlation results have been obtained. (i) pH and NH_4 -Dithizone extractable zinc are negatively and significantly correlated with r = -0.3682 which is significant at 5 % level of significance. A regression line has been drawn in Fig. 12 . (ii) 0.1 N HCl extractable zinc and pH are not significantly correlated in alluvial soils with a negative value of r = -0.2553 and the regression line has been drawn in Fig. 12 (iii) Total zinc and pH are also not significantly correlated in alluvial soils with a negative value of r = - 0.131 . This indicates that the total zinc and available zinc extracted by two methods of alluvial soils are not significantly correlated.

Correlation Between the Total and Available Zinc by two Methods with the Drymatter Yield of Crop

The following correlations with the available zinc by two methods and drymatter yield of paddy have been obtained (1) NH_4 -Dithizone extractable zinc and drymatter yield are positively and significantly correlated at 1 % level of significance with (r = 0.373). The regression line is drawn in Fig. 15. (2) 0.1 N HCl extractable zinc and drymatter yield is also positively and significantly correlated at 1 % level of significance with r =0.450** in alluvial soil. The line of regression has been drawn in Fig. 14. (3) Total zinc was correlated positively with drymatter yield but their correlation was not significant (r = 0.2546)

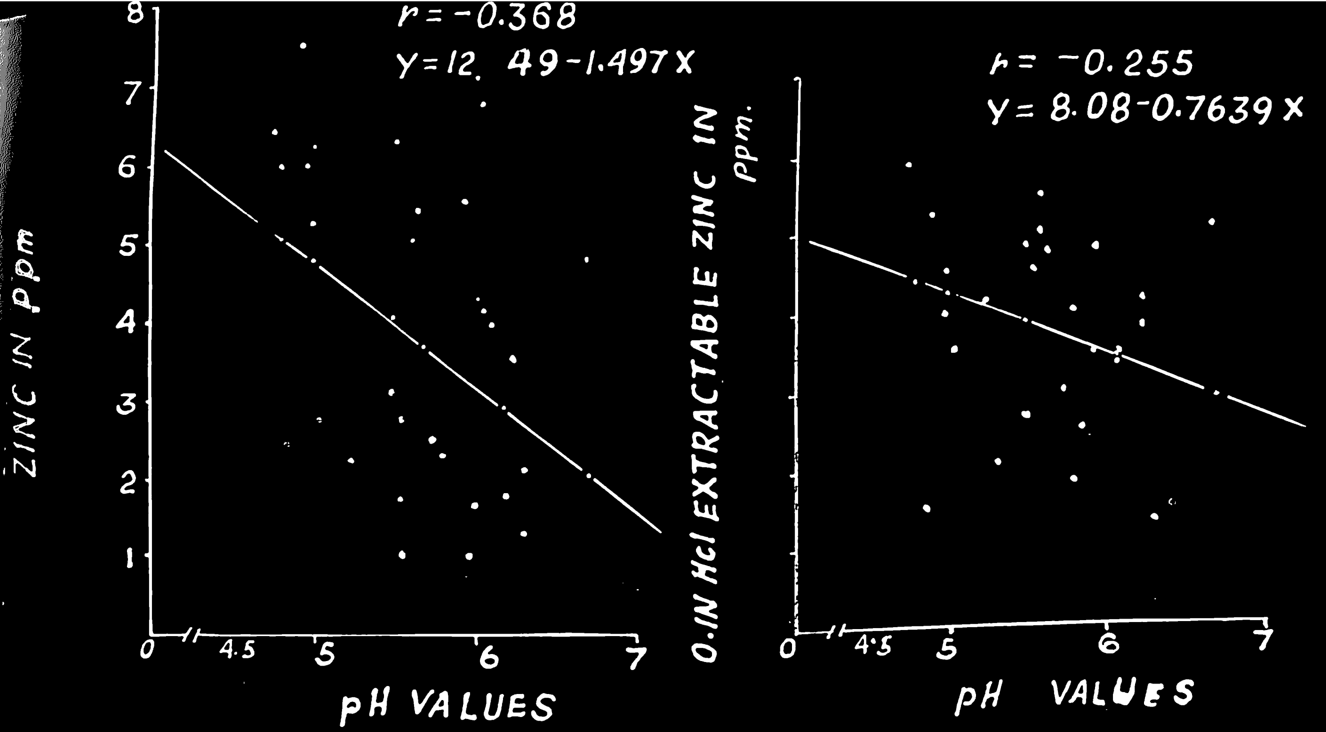


FIG.12- RELATIONSHIP BETWEEN AVAILABLE ZINC AND pH IN ALLUVIAL SOIL.

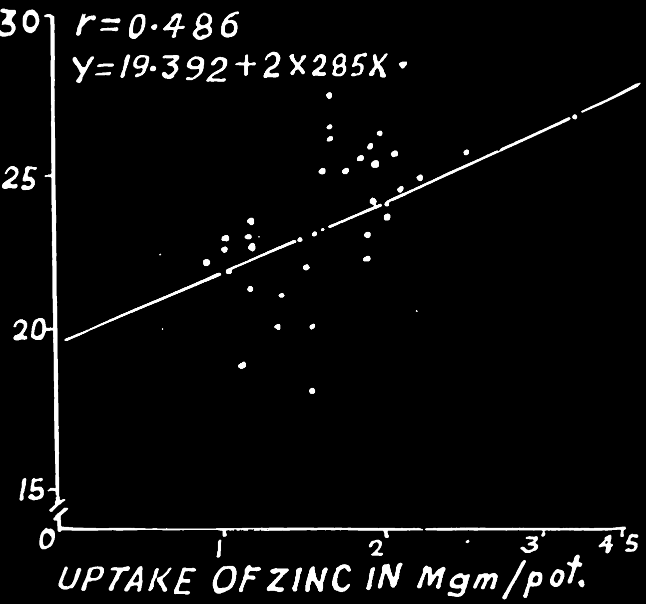


FIG. 13
RELATIONSHIP BETWEEN UPTAKE OF ZINC AND DRYMATTER YIELD IN ALLUVIAL SOIL

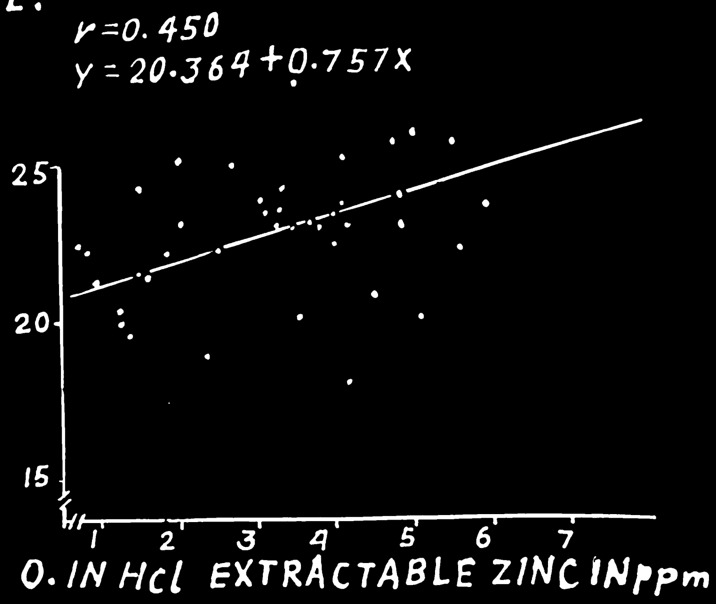
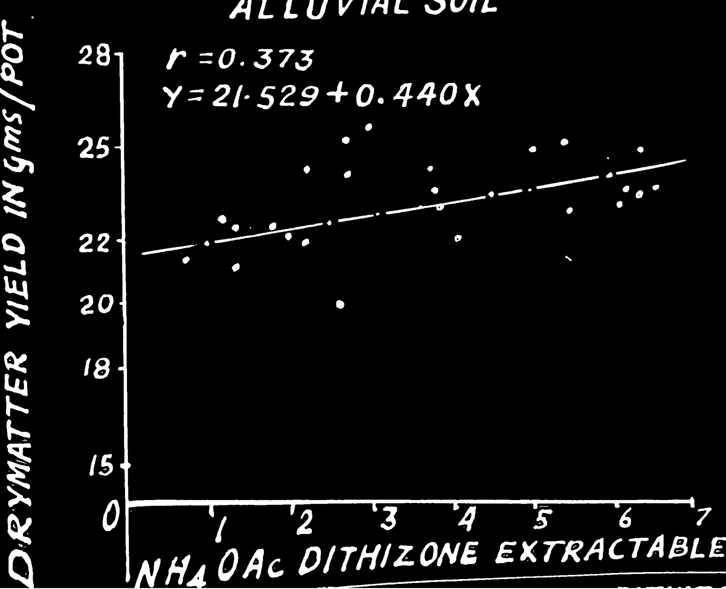


FIG.14
RELATIONSHIP BETWEEN 0.1 N HCl EXTRACTABLE ZINC AND DRYMATTER YIELD IN ALLUVIAL SOIL.



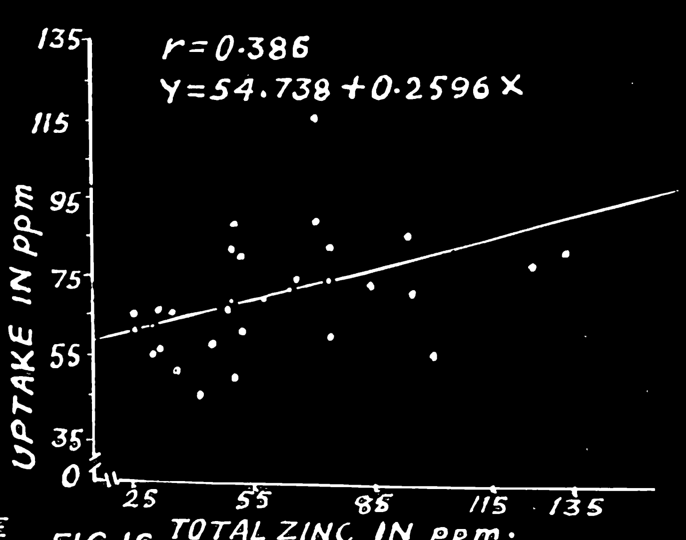


FIG.16

From these relationship it can be indicated that the drymatter yield of rice crop in alluvial soils increase with the available zinc but it is apparently related with total zinc present in soil.

Correlation of Total and Available Zinc with the Uptake of Zinc by Plants

The following correlations between the total and available zinc by two methods and total zinc uptake of paddy have been obtained.

(1) Total uptake of zinc and 0.1 N HCl extractable available Zn are significantly and positively correlated at 1% level of significance with r = 0.589 **. The regression line has been drawn in Fig. 25. (2) Total uptake of zinc and NH_4-Dithizone extractable zinc are also significantly and positively correlated at 1% level of significance with r = 0.3403**. The regression on line has been drawn in Fig.25. (3) There is also positive and significant correlation at 1 % level of significance between total zinc and uptake of zinc in plant (r = 0.386 **). The regression line is drawn in Fig.16.

From the above correlations it is observed that a positive and highly significant correlation at 1% level are resulted between the total uptake of zinc and both the available zinc and total zinc present in the soil. This indicates that the increase in available or total zinc status of the soils increases the total uptake of zinc in plants. So response to zinc application in alluvial soils is highly significant in increasing the total zinc content of the rice crop.

<u>Correlation Between Uptake of Zinc and Yield of Drymatter</u>

The uptake of zinc and drymatter yield are positively and significantly correlated at 1% level of significance with $r = 0.486^{**}$. The regression line is drawn in Fig. 13. This indicates that there is a definite relationship between the uptake of zinc and yield of drymatter which shows that with an increase in uptake the drymatter production also increases.

<u>Correlation Between Uptake of Zinc and pH of the Alluvial soil</u>

There is negative and not significant correlation between the uptake of zinc and pH values of the soil with $r = -0.069$.

This indicates that the pH of the soils after harvest of the crop negatively and not significantly correlated with uptake of zinc, which shows that as the pH increases by liming Zn uptake is reduced in otherwords it can be predicted that the increase in pH of the soil decreases the total uptake of zinc. It may be indirectly due to decreased availability of zinc in soil with an increase in pH reflects in reduced total uptake of zinc in plants

Field Experiments

The soil taken under this investigation is lateritic soil of Bhubaneswar of Orissa State. The experiment was conducted in Block-G of the Agricultural Experiment Station, Bhubaneswar. Padma was taken as test crop which was grown in summer season. The results obtained under this investigation are presented hereunder.

Effects of Different Levels of Zinc on the Drymatter yield of rice at Different levels of liming in Lateritic Soils

The drymatter yields of the rice crop after harvest have been recorded in Table III and the data are graphically illustrated in Fig. 5. The data obtained are statistically analysed and the results of the analysis have been appended in the Appendix Table II.

By scrutinizing the statistical analysis, it is observed that the different effects of various levels, of zinc application were statistically significant at 1% level of significance for lateritic soils. However, various levels of lime applications and the interacted values of zinc and lime levels were found to be nonsignificant in this soil.

TABLE XII

MEAN DRYMATTER YIELD IN Q / ha

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{½}$	L_1	
1.	Z_0	41.29	51.95	51.22	48.16
2.	Z_1	56.45	58.54	61.47	58.82
3.	Z_2	58.65	67.22	55.93	60.60
4.	Z_3	64.81	68.06	57.50	63.46
5.	Z_4	74.02	69.57	59.59	67.73
Means of levels of lime application		59.04	63.07	57.14	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	Sig. **	N.S.	N. S.
S.E(m)	1.003	0.778	1.74
C.D(0.05)	6.52	5.05	11.31

Sig. ** Significant at 1 % level

Sig. * Significant at 5 % level

N.S. Not significant

Almost all the levels of zinc with successive increase exhibited a rising trend of superiority over the control. Application of zinc in general increased the drymatter production over the control and it is found that lime application at 20 ppm zinc in general overall the levels of zinc treatments as well as also over the control resulted in high drymatter yield in alluvial soils for rice crop. Among the different levels of zinc, zinc application at the rate of 20 pp, (Z_4) is proved to be highly superior to other levels of application in producing drymatter yield in case of lateritic soils. The application of zinc at the level of 5 ppm yielded lowest drymatter in comparison to other levels but definite increase over the control was observed. Z_2 level (10 ppm) is undoubtedly more effective than control and Z_1 level (5 ppm) but inferior to Z_3 and Z_4 levels. Z_3 levels seems to be superior to Z_0, Z_1 & Z_2 X level but inferior to Z_4 level. So the mean yields of dry-matter production at different levels of zinc can be analysed in the following descending order.

$$Z_4 \; 7 \; Z_3 \; 7 \; Z_2 \; 7 \; Z_1 \; 7 \; Z_0$$

Statistically it can be observed from the Table that Z_4 level also gives the highest significant difference among all the levels except the Z_3 level. It seems that Z_3 and Z_4 levels come under one group having no statistical difference and similarlydifference between Z_1 and Z_2 levels belonging to another group are also statistically not

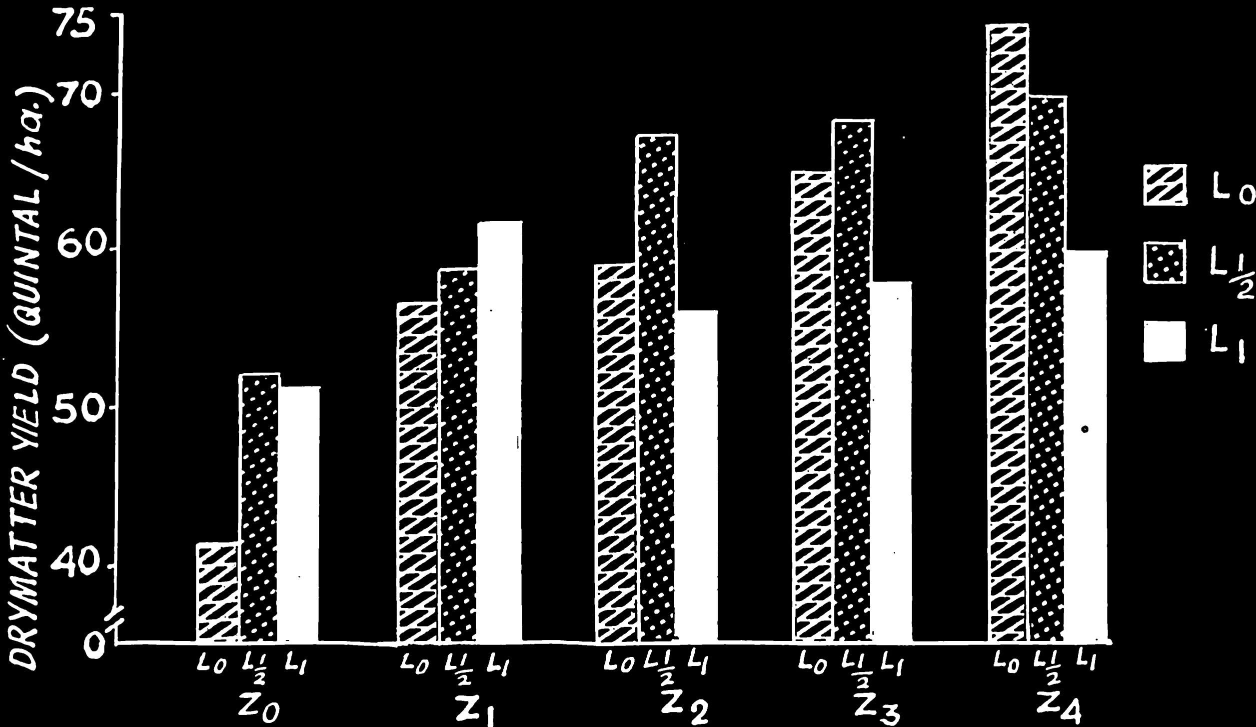


FIG.5 - MEAN DRYMATTER YIELD OF RICE AS AFFECTED BY DIFFERENT TREATMENTS IN FIELD EXPERIMENT.

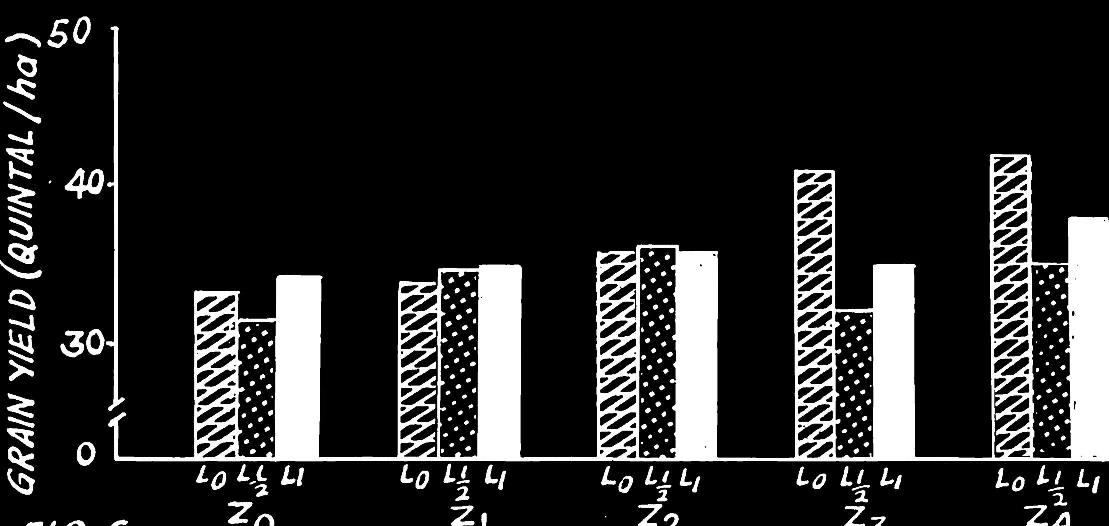


FIG.6 MEAN GRAIN YIELD OF RICE AS AFFECTED BY DIFFERENT TREATMENTS IN FIELD EXPERIMENT.

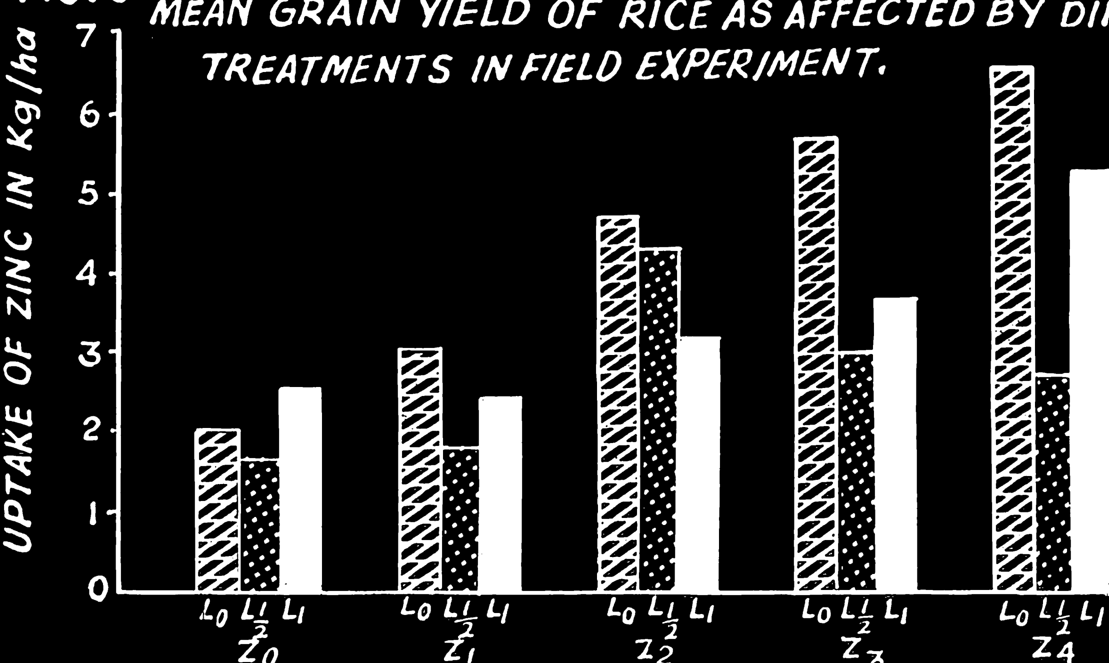


FIG.7 MEAN UPTAKE OF ZINC AS AFFECTED BY DIFFERENT TREATMENTS

significant. But the first group is statistically superior to the second group as there is statistical significant difference between them and vice versa. Z_4 levels seems to be superior over all. So statistically the following is the descending order in performance of zinc levels in lateritic soils.

$$Z_4 > (Z_4 = Z_3) > (Z_2 = Z_1) > Z_0$$

The above results indicated that definitely there is increased drymatter production in high yielding paddy by application of zinc in lateritic soil. The drymatter content increased with increase in zinc application at relatively successive amounts. Application @ 20 ppm zinc consistently proves high among all other levels of application. In comparison to alluvial soil of pot experiment, the field experiment exhibits almost the same valuation except in the level of zinc i.e. 20 ppm zinc application in lateritic soils whereas 15 ppm Zn application in alluvial soils. No significant difference was observed in case of interacted values. Depending on mean values it seems that highest drymatter production obtained in case of L_0Z_4 level and lowest in case of L_0Z_0 level. This indicates that zinc application has a definite contribution for increasing drymatter yield in case of lateritic soils with no lime application.

Between the levels of lime application a non-significant relation was obtained which indicates that there is no statistical significant difference among the levels of lime application. On the basis of mean values, the highest being 63.07Q/ ha at $L_{1/2}$ level and lowest 57.14 Q / ha at L_1 level. The sequence of lime levels agree the following order.

$$L_{1/2} > L_0 > L_1$$

Half lime application ($L_{1/2}$) of total lime requirement seems to be better in drymatter yield in lateritic paddy soil.

Effect of Different Levels of Zinc on the Total Uptake of Zinc by Rice crop at Different Levels of Liming in Lateritic Soils:-

In Table XIII the relative amounts of total uptake by plants in field experiment from different levels of zinc sources in lateritic soils at different liming levels. The crop was harvested and the data of the total Zn uptake / pot are recorded in kg / ha and are graphically presented in Fig. 7. From the statistical analysis of the results it was observed that the difference between the effects of zinc levels and levels of liming were significant at 1 % level of significance in this lateritic soil. But the interaction values between the zinc levels and lime levels were not significant. The 'F' test values have been appended

TABLE XIII

MEAN TOTAL UPTAKE OF ZINC IN kg / ha

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	2.05	1.59	2.56	2.06
2.	Z_1	3.08	1.75	2.44	2.42
3.	Z_2	4.69	4.29	3.12	4.04
4.	Z_3	5.65	2.88	3.59	4.04
5.	Z_4	6.55	2.61	5.29	4.82
Means of levels of lime application		4.40	2.62	3.40	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	Sig. **	Sig. **	N.S.
S.E(m)	1.890	1.410	3.270
C.D(0.05)	1.228	0.905	2.100

Sig. ** Significant at 1 % level

Sig. * Significant at 5 % level

N.S. Not significant

in Appendix Table II for reference which gives a similar trend in significance with the values of those which are obtained in case of the drymatter yield.

The graded values of different zinc levels were almost in similar sequence whether they are measured in terms of drymatter yield (a) uptake of zinc in this soil. However, an equal performance was observed between Z_2 and Z_3 levels. The following will be the descending order, according to their mean values.

$$Z_4 \; 7 \; (Z_3 = Z_2) \; 7 \; Z_1 \; 7 \; Z_0$$

Statistically there exists no significant difference between the Z_2, Z_3 and Z_4 levels, which coming under one group definitely seems highly superior to Z_1 and Z_0 levels.

$Z_4 = Z_3 = Z_2 \; 7 \; Z_1 \; 7 \; Z_0$ is the sequence maintained by them statistically.

The above facts resulted that application of zinc in general enhanced the total uptake of zinc in case of lateritic soils and it is found that zinc application at the level of Z_4 in general is consistently superior over all. The application of zinc at the levels of Z_2, Z_3 and Z_4 i.e. 10, 15 and 20 ppm Zn remains equal in performance, but these levels are superior over the Z_0 and Z_1 levels. In consideration of the statistical values of levels of lime it seems that the highest uptake is with L_0 level (4.4 kg /ha) whereas L_2 is the lowest (2.62 kg / ha). The sequence is as follow.

$$L_0 > L_1 > L_{1/2}$$

So it can be suggested that no lime application has increased the total uptake of zinc in case of lateritic soils. There is no significant difference between the interacted values of zinc and lime levels.

Effect of Different levels of Zinc on the Grain yield of Rice at Different levels of Liming in Lateritic Soils

The mean grain yields in Q / ha of the rice crop in field experiment after threshing have been recorded according to the different treatments in Table XIV and the data are graphically illustrated in Fig. 6. The data obtained are statistically analysed and the results of the analysis are presented in the Appendix Table II.

From the results of analysis and 'F' test, it is observed that there is no significant difference between all the treatments of levels of zinc, levels of lime and interacted values of zinc and lime. However in comparison to the mean values it can be observed that the similar trend was obtained in grain yield in comparison drymatter production and total uptake of zinc.

The following is the sequence of decreasing order in comparing the mean values of the different treatments on grain yield in case of lateritic soil for rice crop.

$$Z_4 > Z_3 > Z_2 > Z_1 > Z_0$$

TABLE XIV

MEAN GRAIN YIELD IN Q / ha

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{½}$	L_1	
1.	Z_0	33.44	31.37	34.17	32.99
2.	Z_1	33.81	34.55	34.70	34.35
3.	Z_2	35.66	36.08	35.71	35.81
4.	Z_3	40.84	31.85	34.81	35.83
5.	Z_4	41.85	34.92	37.72	38.16
Means of levels of lime application		37.12	33.75	35.42	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	N.S.	N.S.	N.S.
S.E(m)	0.596	0.468	1.04
C.D (0.05)	3.87	3.04	6.75

Sig. ** - Significant at 1 % level

Sig. * - Significant at 5 % level

N. S. - Not significant

This indicates that the yield of high yielding rice increases with the increased application of zinc in successive amount and zinc application at the rate of Z_4 level (20 ppm) is definitely suitable for lateritic soils for high grain yield i.e. 38.16 Q / ha and no application of lime seems to be better in increasing grain yield. Hence at L_0Z_4 level the interacted value obtained was the highest (41.85 Q/ha)

According to statistical analysis these can be arranged as follows.

$$Z_4 \; 7 \; Z_4 = Z_3 = Z_2 = Z_1 \; 7 \; Z_0$$

From this above sequence it can be interpreted that undoubtedly Z_4 is superior to all as there is significant difference between Z_4 and control (Z_0) which is not found in case of others.

With regard to performance of lime application it is well understood that no lime is best for lateritic soils for increase of uptake of Zn and grain yield. At the interacted levels of zinc and lime, it is found that Z_4 at L_0 level i.e. 20 ppm zinc with no application of lime seems to give a consistent increase in yield in all cases.

<u>Effect of Different Levels of Zinc on the Total Zinc Content of the lateritic soils at Different levels of Liming after harvest of the paddy crop of field experiment</u>

The total zinc measured from the soils after harvest of crop have been presented in Table XV. The total zinc

TABLE XV

MEAN TOTAL ZINC OF SOIL IN ppm

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	31.666	23.666	22.833	26.055
2.	Z_1	37.833	25.666	17.833	27.111
3.	Z_2	37.000	25.000	41.166	34.388
4.	Z_3	36.666	57.000	41.666	45.111
5.	Z_4	59.833	38.666	32.500	43.666
Means of levels of lime application		42.599	33.999	31.199	

	Levels of zinc application	Levels of lime application	Levels of zinc X Levels of lime
'F' test	Sig. **	Sig. **	Sig. **
S.E(m)	3.281	2.540	5.657
C.D(0.05)	6.719	5.202	11.586

Sig. ** - Significant at 1 % level

Sig. * - Significant at 5 % level

N. S. - Not significant

content obtained are statistically analysed and the results in Appendix Table II. It seems from the presentation that the differential effects of various levels of zinc levels of lime and interaction of levels of zinc and lime, all are significantly different even at 1 % level of significance.

In comparison the following trends in relationship has been pronounced.

(1) Depending on mean value of zinc.

$$Z_3 = Z_4 > Z_2 > Z_1 > Z_0$$

But statistically the sequence is

$$Z_3 = Z_4 > Z_2 = Z_1 > Z_0$$

Hence it indicates that the total zinc content in lateritic soils increases with the successive increase of zinc application and both Z_3 and Z_4 levels (15 ppm and 20 ppm) proves to be the best in increasing total zinc content of soils though a little superiority of Z_3 over Z_4 remains. There is equal performance of the Z_3 and Z_4 remains. There is equal performance of the Z_3 and Z_4 levels with the total zinc content of lateritic soils. Similarly Z_2 and Z_1 levels also are of equal performance. So that they can be grouped into two categories i.e. (1) 5 ppm and 10 ppm, and (2) 15 ppm and 20 ppm, both having almost equal influence to total zinc content of lateritic soils .

In regard to the levels of lime application of no lime proves best in comparison to others and the order according to their mean value is $L_0 > L_{1/2} > L_1$ statistically the order remains $L_0 > (L_{1/2} = L_1)$

There is no significant difference between $L_{1/2}$ and L_1 levels. But L_0 level was definitely superior and statistically significant to both $L_{1/2}$ and L_1 levels. This indicates that application of lime to laterite soils do not influence the total extractable Zn content.

In consideration of interaction values of zinc and lime, statistical significance is also obtained between them. The highest is at L_0Z_4 (59.833 ppm) and the lowest at L_1Z_0 level. The following trend in sequence can be observed.

$L_0Z_4 > L_{1/2}Z_3 > L_1Z_3 > L_1Z_2 > L_{1/2}Z_4 > L_0Z_1 > L_0Z_2 > L_0Z_3 > L_1Z_4 > L_0Z_0 > L_{1/2}Z_1 > L_{1/2}Z_2 > L_{1/2}Z_0 > L_1Z_0 > L_1Z_1$

This indicates that the Z_3 and Z_4 levels of zinc application definitely increased the zinc content of the lateritic soils with no lime application.

<u>Effect of the Different levels of Zinc on the Available Zinc content of the Soil at Different levels of Liming in Lateritic soil of Field Experiment After harvest of the Crop</u>

The Table XVI indicates that the application of zinc at various levels has definitely subscribed to the available zinc reservoir of the soil even after harvest of the crop and was undoubtedly superior over control.

TABLE XVI

EFFECTS OF DIFFERENT LEVELS OF ZINC TREATMENTS ON AVAILABLE ZINC CONTENT AFTER HARVEST OF CROP

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Available zinc in 'ppm'							
		NH_4 - Dithizone extraction method				0.1 N HCl extraction method			
		Means of Zn levels and levels of lime application				Means of Zn levels and levels of lime application			
		L_0	$L_{½}$	L_1	Means of levels of Zn application	L_0	$L_{½}$	L_1	Means of levels of Zn application
1.	Z_0	0.5416	0.2083	0.5083	0.4194	0.8733	0.6250	0.7500	0.7494
2.	Z_1	2.4166	1.3666	0.9583	1.5805	2.0500	1.2166	0.9500	1.4055
3.	Z_2	4.5416	3.8583	3.4583	3.9527	3.2916	3.0833	3.3750	3.2499
4.	Z_3	4.1666	2.5500	3.2000	3.3050	2.7000	4.1666	1.5166	2.7944
5.	Z_4	6.1666	1.8083	3.9833	3.9860	5.9166	2.0580	3.3333	3.7692
Means of levels of lime application		3.5660	1.9580	2.4210		2.9660	2.2290	1.8490	

	Levels of Zn application	Levels of lime application	Levels of Zn X Levels of lime	Levels of Zn application	Levels of lime application	Levels of Zn X Levels of lime application
'F' test	Sig. **	Sig.**	N.S.	Sig.**	N.S.	N.S.
S.E(m)	0.513	0.397	0.889	0.591	0.453	1.010
C.D(0.05)	1.050	0.813	1.820	1.210	0.927	2.068

Sig.** -Significant at 1 % level; Sig.*-Significant at 5% level
N.S.- Not significant

The available Zn extracted by two methods (1) NH_4-Dithizone extraction (2) 0.1 N HCl extraction method, from the laterite soils after harvest of the crop have been presented in Table zinc is expressed in 'ppm' Zn. The data obtained are statistically analysed and the report of the analysis are appended in the Appendix Table II. It is evident from the data that the differential effects of various levels of zinc were significantly different at 1 % level of significance by two methods. However, interacted values of zinc and lime levels are not significant in case of NH_4-Dithizone extractable zinc and also 0.1 N HCl extractable zinc.

In looking to the values of different lime levels and its 'F' test value, it shows that it is signific-ant at 1 % level of significance in case of NH_4-Dithizone extractable Zn and not significant in case of 0.1 N HCl extractable zinc.

Since there is close association between the available zinc content and total uptake the order of effectiveness or response of different treatments remains almost same in each of the aspects of study. By pulling the values in the definite sequence it is easy to compare the different treatments. In case of both (1) NH_4-Dithizone extractable zinc and (2) 0.1 N HCl extractable zinc.

(1) Depending on the mean values of available zinc the the sequence is $Z_4 > Z_2 > Z_3 > Z_1 > Z_0$

The slight deviation remains with the shift of Z_2 level to second position. But statistically the sequence remains equal.

$$Z_4 = Z_3 = Z_2 > Z_1 > Z_0$$

This shows that in both the methods Z_4, Z_3 and Z_2 levels have no statistical significant difference. These findings represent that increased application of zinc definitely increased the available zinc content of lateritic soils and application of 20 ppm Zn proved to be the best in the icreased availability of zinc. But an equal performance has been obtained in all the levels of zinc i.e. Z_2, Z_3 and Z_4 except Z_1 level towards the contribution of increasing available zinc status of alluvial soils.

NH_4- Dithizone extractable zinc and levels of lime are ineracted and the values show that they did not possess an significant difference by statistical analysis. The highest available zinc extracted is (6.1666 ppm) at Z_4L_0 level. Hence it seems that the Z_4 level of application of zinc with no application of lime raised the available zinc status of the soil. The lowest was $L_{\frac{1}{2}}Z_0$ level i.e. 0.2083 ppm zinc.

In case of O. 1 N HCl extractable method the interaction of zinc with lime was found to be non-significant. But depending on the mean values. The highest result (3.9166 ppm Zn) was found in case of L_0Z_4 level and lowest result was at $L_{\frac{1}{2}}Z_0$ level. i.e. 0.625 ppm. In both the methods the highest value was obtained at L_0Z_4 level and lowest at $L_{\frac{1}{2}}Z_0$ level. This indicates that Z_4 level of application of zinc with no lime increased the availability of zinc in soil solution of lateritic soil.

Considering the liming levels significant difference was obtained in case of NH_4- Dithizone extractable zinc whereas significant difference was observed with 0.1 N HCl extractable zinc. In comparison, it seems that in both the methods the values obtained follow the following descending order,

$$L_0 > L_{\frac{1}{2}} = L_1$$

This indicates that statistically there is no significant relationship between $L_{\frac{1}{2}}$ and L_1 levels. So it can be easily predicted that liming of lateritic soils did not help in increasing the availability of zinc in the soil.

While considering the amounts of extraction between the two methods on the measurement of available zinc in the lateritic soils, in general it may be marked that there is not much difference between the two methods in the magnitude of the values obtained which only varies within a range of 0.25 ppm Zn to 0.41 ppm Zn at their highest and lowest values respectively. So it seems that variation in the amount of extraction is quite negligible and both the methods are equally dependable for determining the available zinc in case of lateritic soils.

Similar results were obtained in case of the alluvial soils of pot experiment. So this proves that both the methods (1) NH_4- Dithizone and (2) 0.1 N HCl extraction methods are equally dependable for assessing the available zinc in both alluvial and lateritic soils of Orissa.

<u>Effects of Different levels of Zinc on the pH Values of the Soils at Different Liming Levels in Lateritic Soils after harvest of the Crop of Field Experiment</u>

The pH values are recorded in Table XVII. Soil pH values measured under this investigation (by 1 : 2 Soil : 0.01M $CaCl_2$) were strongly acidic with a pH value of 5.78 and the pH values did not vary markedly from treatment to treatment. The pH values at different levels are 6.20, 6.34, 6.22, 6.01 and 6.23 at Z_0, Z_1, Z_2 , Z_3 and Z_4 levels respectively. This indicates that the pH values vary within a range of 0.03 to 0.66 at different

TABLE XVII

EFFECT OF DIFFERENT TREATMENTS ON THE 'pH' VALUES OF SOILS AFTER HARVEST OF CROP

Field Experiment

Lateritic soil

Sl. No.	Levels of zinc application	Means of zinc levels and levels of lime application			Means of levels of zinc application
		L_0	$L_{1/2}$	L_1	
1.	Z_0	5.78	6.25	6.58	6.2
2.	Z_1	6.30	6.15	6.58	6.3
3.	Z_2	5.90	6.20	6.58	6.2
4.	Z_3	5.35	6.20	6.50	6.0
5.	Z_4	5.70	6.26	6.73	6.2
Means of levels of lime application		5.80	6.21	6.59	

levels of zinc application. This gives the relationship that the variation is quite negligible and zinc application has no direct effect in increasing soil pH and the slight increase in pH may be due to subergence of the soil which creates a favourable atmosphere for reduction of the different components of soil. With regard to levels of lime application it also seems that the variation range is from 0.02 to 0.79 maximum. This establishes the fact that lime application to lateritic soils has not influenced the pH markedly.

<u>Availability of Zinc with particular reference to pH as influenced by Liming</u>

By close observation of the data presented in the Table XVII for pH as influenced by liming and the total zinc and available zinc contents of soil presented in Table XXVI and XVI respectively, it can be found that the total zinc content were found to be highest at Z_3 level where the pH has an decreased value of 6.01. Similarly at L_0Z_4 level of interaction as the soil pH has been decreased to 5.70, the resulted available zinc in both the methods was found to be highest among all the values. These results indicate that the availability of zinc increases with a decrease in pH value or vice - versa in case of the lateritic soils which was distinctly noticed.

Correlation Studies of Field Experiment

The available zinc contents of lateritic soil determined by two methods, and total zinc contents of the soil after harvest were correlated separately with drymatter yield, total uptake of zinc in plants and pH values of the soil. Also the uptake of zinc by plants are correlated separately with the drymatter yield and pH values of the soil. The grain yields in case of lateritic soils are correlated separately with drymatter yield and uptake of zinc. The lines of regression has been drawn in Figs. 17, 18, 19, 20, 21, 22, 23 and 24 and the results of the correlation studies have been presented in the Appendix Table IV showing the different correlation coefficient (r) values.

Correlation Between Total and Available Zinc by Two Methods with the pH values of Lateritic Soils

The following correlation results have been obtained: (1) pH and Dithizone extractable zinc are negatively and not significantly correlated with r =-0.139. The regression line has been drawn in Fig. 17 which shows no significant relationship with dithizone extractable zinc and pH (2) 0.1 N HCl extracted zinc and pH have also shown a negative and not significant correlation with r = -0.2644. Regression line has been drawn in Fig. 17. (3) Total zinc and pH have a negative and not significant

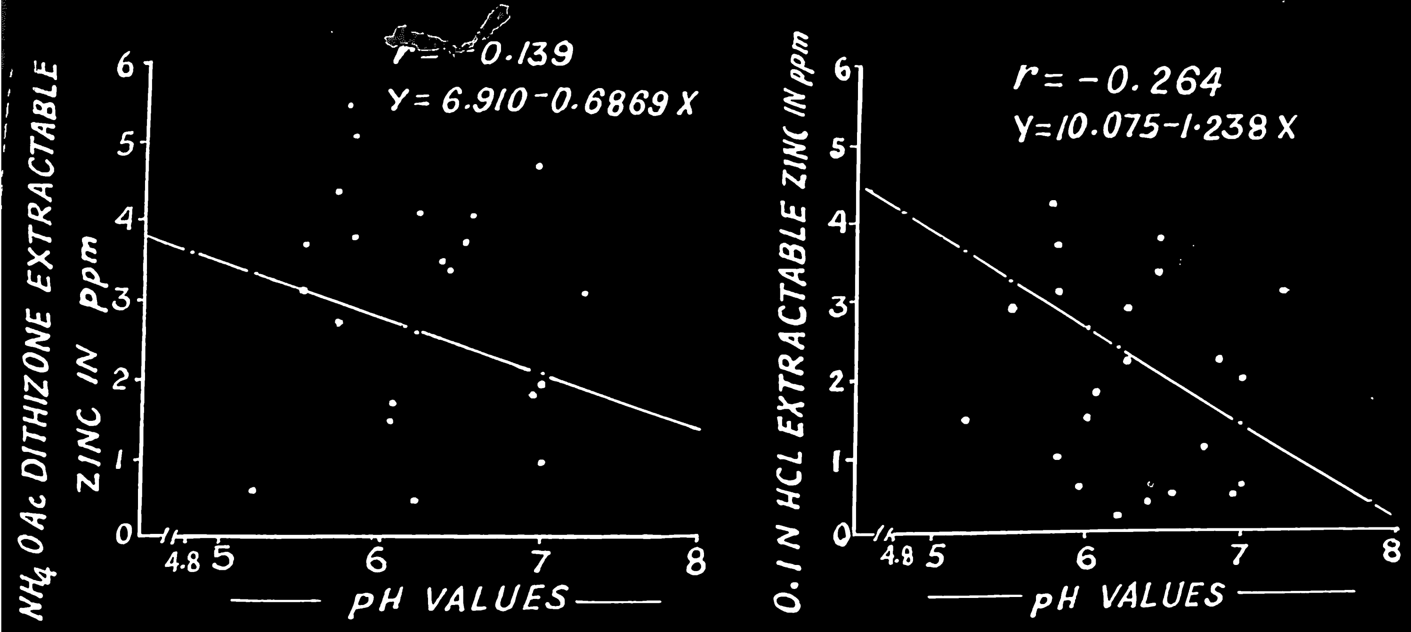


FIG. 17- RELATIONSHIP BETWEEN AVAILABLE ZINC IN TWO METHODS AND pH IN LATERITIC SOIL.

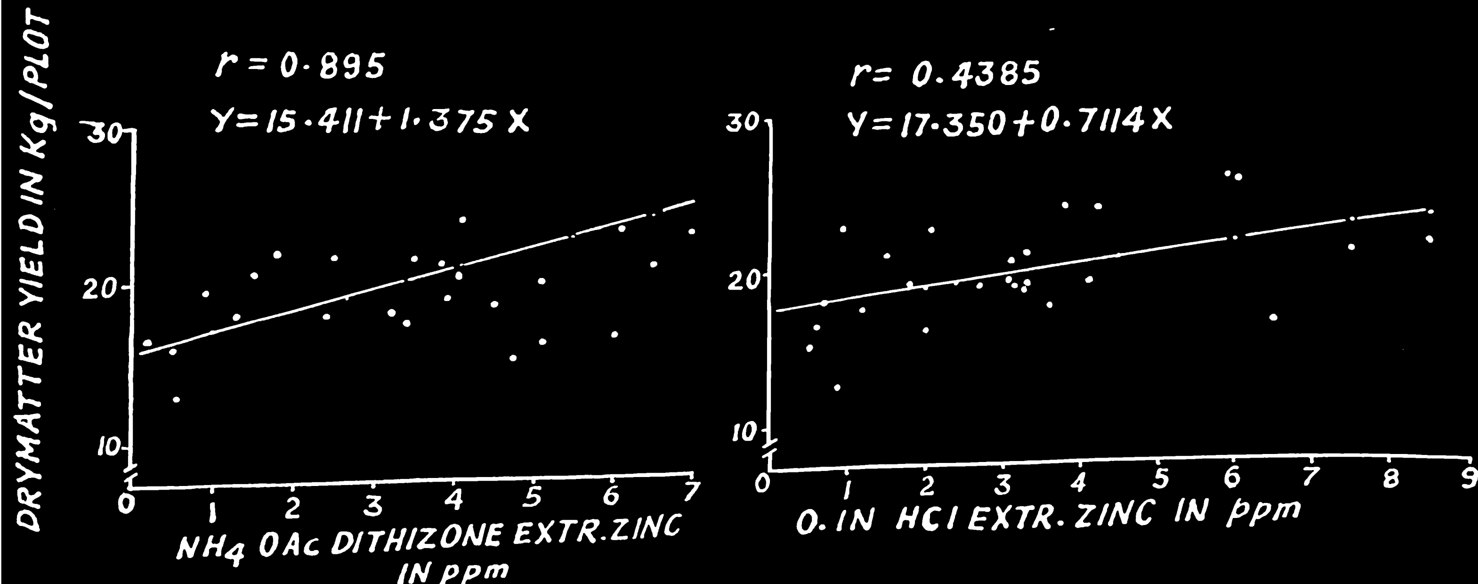


FIG. 18- RELATIONSHIP BETWEEN AVAILABLE ZINC IN TWO METHODS & DRYMATTER YIELD OF RICE IN LATERITIC SOIL.

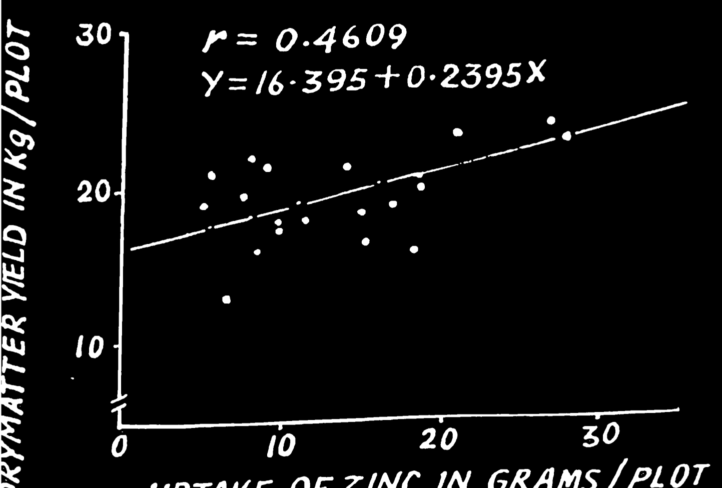


FIG. 19- RELATIONSHIP BETWEEN UPTAKE OF ZINC AND DRYMATTER YIELD OF RICE IN LATERITIC SOIL

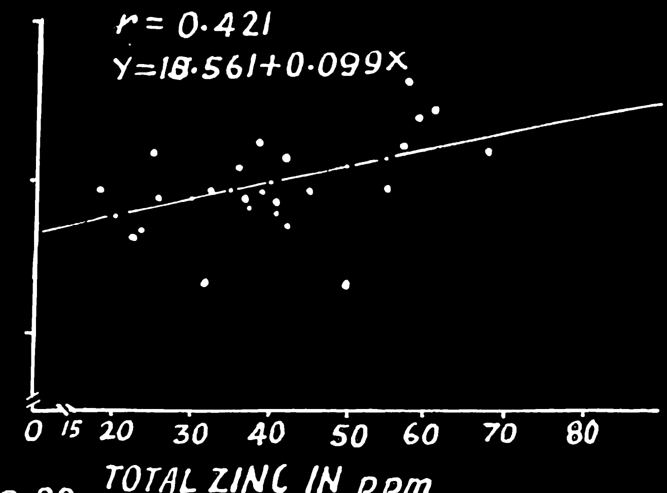


FIG. 20 RELATIONSHIP BETWEEN TOTAL ZINC AND DRYMATTER YIELD OF RICE IN LATERITIC SOIL

correlation with r = -0.149.

The above results indicate that both the total and available zinc present in soil, though possess a negative relationship with pH, still their relationship is not significant. From the negative values and regression lines, it can be seen that the availability of zinc decreases with an increase in the pH value.

<u>Correlation Between the Total Zinc and Available Zinc by two Methods with the Drymatter yield of the Crop in Lateritic Soils</u>

The following correlations with different variables correlated as stated above have been obtained. (1) Total zinc and drymatter yield are positively and significantly correlated at 1 % level of significance with r = 0.421 ** . The regression line has been drawn in Fig. 20. (2) NH_4- Dithizone extractable zinc and drymatter yield are also positively and significantly correlated even at 1 % level of significance with r = 0.895 **. The regression line has been drawn in Fig.18. (3) 0.1 N HCl extractable zinc and drymatter yield are also positively and significantly correlated at 1 % level of significance with r = 0.4385. The regression line has been drawn in Fig. 18.

These correlations indicate the clearcut fact that the drymatter yield of rice crop is highly responsible to zinc application and increases with the increase in the total zinc and available zinc content present in the soil. Similar results were also been obtained in alluvial soils. This gives the idea that the application of zinc in lateritic and alluvial soils of Orissa has a definite relationship to correct the zinc hunger in case of the high yielding rice crops.

Correlation Between the Total and Available Zinc with the Total Uptake of Zinc by Plants in case of Lateritic Soils

The following results have been obtained.

(1) Total zinc in soil and uptake of zinc by plants are positively and significantly correlated at 5 % level of significance with r = 0.300. Regression line has been represented in Fig. 24. (2) High correlation coefficient between uptake of zinc in plants and available zinc in soil have also been obtained (3) 0.1 N HCl extractable zinc and uptake of Zn are positively and significantly correlated at the level of 1 % . Significance with r = 0.549**. The regression line has been drawn in Fig.23. (3) NH_4 - Dithizone extractable zinc and uptake of zinc are also positively and significantly correlated at the level of 1 % significance with r = 0.78. The regression line has been drawn in Fig. 22.

From the above results of correlation studies, it seems that there is also definite relationship of the

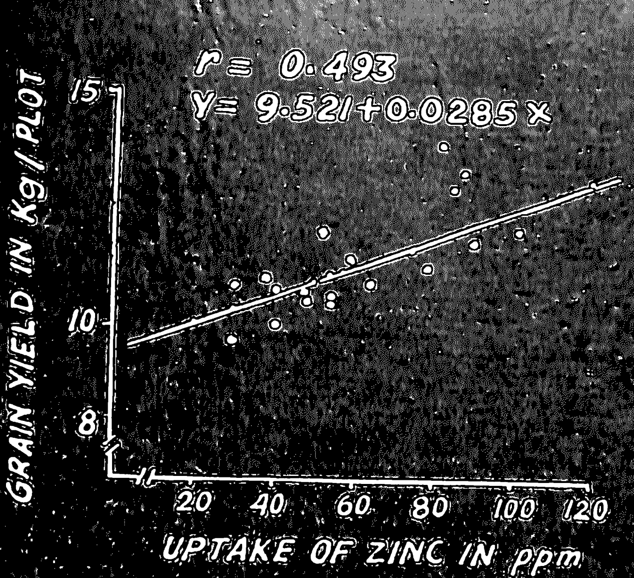


FIG. 21 - RELATIONSHIP BETWEEN GRAIN YIELD OF RICE AND UPTAKE OF ZINC IN LATERITIC SOIL.

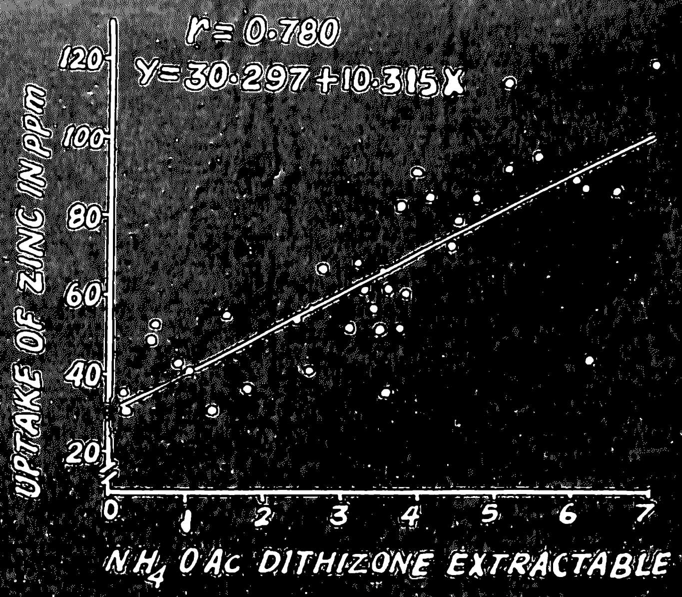


FIG. 22 - RELATIONSHIP BETWEEN NH_4 OAc DITHIZONE EXTRACTCTABLE ZINC AND UPTAKE OF ZINC IN LATERITIC SOIL.

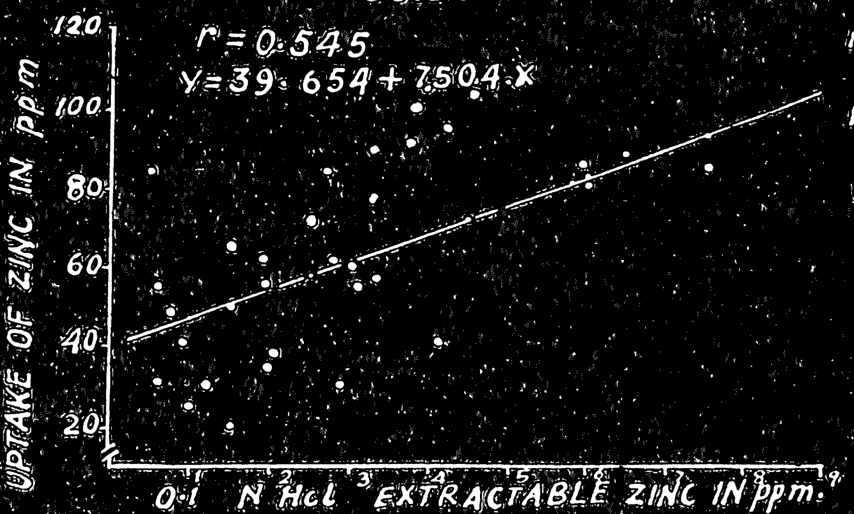


FIG-23 RELATIONSHIP BETWEEN 0.1N HCl EXTRACTABLE ZINC AND UPTAKE OF ZINC IN LATERITIC SOIL.

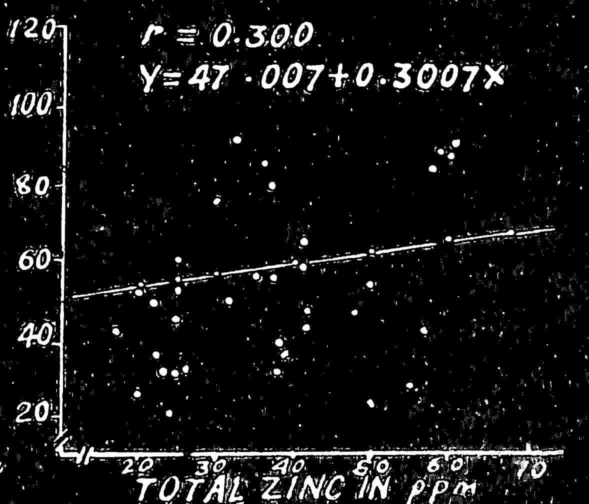


FIG. 24 RELATIONSHIP BETWEEN TOTAL ZINC AND UPTAKE OF ZINC IN LATERITIC SOIL.

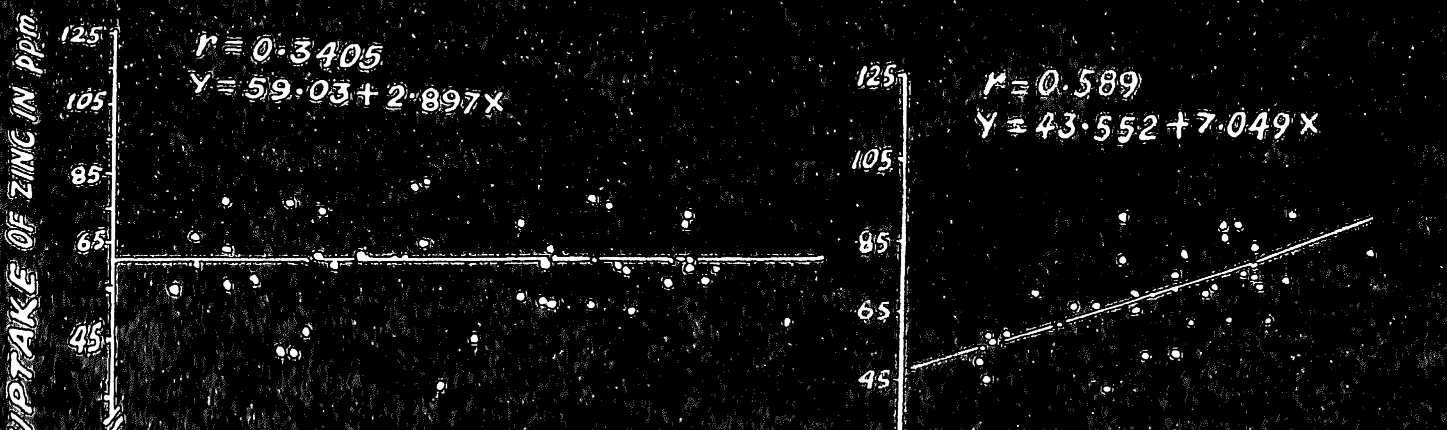


FIG. 25 RELATIONSHIP BETWEEN AVAILABLE ZINC AND UPTAKE OF ZINC IN ALLUVIAL SOIL

(PLOT SIZE 31.5 Sq m)

uptake of zinc in plants with the total and available zinc present in soil. These relationship indicate that increase in the level of available zinc or total zinc status of the soils increased the uptake of zinc. The same results are also found in the alluvial soils of pot experiment.

Correlation Between the Zinc Uptake and Drymatter yield in Lateritic Soil of Field Experiment

No significant correlation was obtained between uptake of Zn and drymatter yield in lateritic soils of field experiment. The positive correlation indicates that the dry matter yield increased with increase in uptake of zinc in plant. The line of regression has been drawn in Fig.19.

Correlation Between the Uptake of Zinc and pH of the Soils taken under Field Experiment

The pH and total uptake of zinc are non-significantly and negatively correlated with $r = -0.208$. This negative relationship indicates that uptake of zinc in rice crop increases with an decrease in soil pH. This relationship reflects indirectly also the availability of zinc. If pH will be decreased, then there will be increased availability of zinc by which uptake of Zn in plant will also be increased.

Correlation of the Grain Yield with the Drymatter yield and Uptake of Zinc in Field Experiment

(1) The correlation of grain yield and drymatter yield are not significant with r = 0.2466.

(2) Grain yield and uptake of zinc are significantly and positively correlated at 1 % level of significance with r = 0.493. Regression line is presented in Fig. 21.

From these relationship it can be opined that the increase in uptake of zinc by the plants increases not only dry matter yield but also the grain yield of rice crop. Hence uptake of zinc is clearly correlated with drymatter and grain yield production in case of both alluvial and lateritic soils.

Comparison Between the Correlation Coefficient values obtained by the two Different Methods

(1) NH_4 -Dithizone extraction and (2) 0.1 N HCl extraction method.

Both the methods resulted high correlation coefficient values in case of drymatter yield and uptake of zinc which are positively and significantly correlated at 1 % level of significance in both the soils i.e. alluvial and lateritic soils in pot culture and field experiment respectively. This shows the clear evidence that both the methods are quite dependable for extraction of available zinc from alluvial and lateritic soils of Orissa. However by close observation of the values, it can be noted that 0.1 N HCl extraction method has given highest correlation coefficient value in alluvial soils of pot experiment in both the cases of uptake of zinc and drymatter yield. Similarly in case of lateritic soils of field experiment the NH_4-Dithizone extraction method exhibited highest 'r' value in both the uptake of zinc and drymatter yield. So it seems that the NH_4 -Dithizone method is a good method for available zinc assessment in case of lateritic soil with r = 0.895 and r = 0.78 with respect to drymatter yield and zinc uptake respectively. In case of alluvial soils, it seems that the 0.1 N HCl extraction method is good for extracting the available zinc from soil having correlation coefficients of r = 0.589 and r = 0.450 with respect to uptake of zinc and drymatter yield respectively.

CHAPTER V
DISCUSSION

CHAPTER V

DISCUSSION

The results obtained from the investigations are discussed briefly in this chapter. The results of the physical and chemical analysis of the soils under investigation have been presented in Table IV and V respectively. The mechanical analysis of the soils shows that the alluvial soil used is coarse textured sandy loam. The lateritic soils of different places can be classed as sandy clay loam in texture. The red soils of Koraput district is loamy and is of coarse textured sandy loam. The alluvial soil of Dandamukundpur village is completely a coarse textured sandy loam soil which was taken for pot culture study. The lateritic soil of Bhubaneswar used for field experiment is of loamy sand texture.

Chemical analysis of the soils revealed that all the soils except black soil are moderately acidic in nature. The black soils are neutral in reaction, the pH being 6.75 to 7.40. The alluvial soil used for pot experiment is acidic with a pH of 5.95 whereas lateritic soil, where field experiment was taken is mildly acidic (pH 6.55).

All the soils used have medium amount of organic carbon. However, red and black soils are richer in organic carbon as compared to alluvial and lateritic soils.

The cation exchange capacity of black soil is more than the alluvial, red and lateritic soils. The black soils have a mixture of illite and montmorillonite clay minerals.

The slight difference in the C.E.C. of all the soils may be due to their variable amounts of clay and organic matter content. The C.E.C. of alluvial, lateritic and red soils reveals the idea that the soils are obviously under saturated with the bases due to high precipitation and leaching.

The % of total nitrogen content of all the soils are low which may be attributed to their low organic matter content.

The available phosphorous of black soil was higher than the rest three groups. Also it is observed that red and lateritic soils are poorest in available P_2O_5 content owing to its fixation in acid soils to a large extent.

The exchangeable calcium of black soils were found to be higher than others and lowest amount was found in lateritic and red soils. Also the highest amount of exchangeable potassium was found in black soil and lowest in alluvial soil.

Zinc Status of the Soils under Laboratory Evaluation Studies

Since the present study was designed to investigate the response of zinc application for higher yielding paddy, it was thought that the evaluation of both total and available zinc of the soils of vital importance.

Total Zinc Content of the Soils of Orissa under Laboratory Evaluation

From the investigation it was found that the lateritic soils of Orissa contain 48 to 60 ppm total zinc with an average 51.98 ppm . Similar results have also been reported by Eswarappa et al (1969) that the total zinc content of lateritic soils varied from 40 to 114 ppm.

The alluvial soils of Orissa contain 30.25 ppm to 68 ppm total zinc with an average of 51.70 ppm. Studying zinc status of upland alluvial soils of U.P., Agarwalla (1963,1964) reported that the zinc content varied from 31.4 to 109.20 ppm. Lal et al (1960) also reported that alluvial soils of Orissa contain 60 ppm total zinc.

In case of red soil the total zinc content is around 50 ppm. Lal et al (1960) reported that the total zinc content of virgin red soils ranged from 34 to 68 ppm.

Black soils examined under the study contain 42 ppm to 48.75 ppm total zinc with an average of 46.25 ppm. Lal et al (1960) reported that the total zinc content of Orissa is 69 to 74 ppm in case of black soils. Eswarappa et al (1969) reported that total zinc content of black soils varied from 30 to 106 ppm which corresponds to the results obtained under this investigation. Satyanarayan (1958 a) reported that zinc content of black cotton soils varied from 14.3 to 61.7 ppm. Ranadive et al (1964) also got the similar results in black soils of Maharastra.

The total zinc content ranged from 38.25 ppm to 68.00 ppm. with an average of 51.70 ppm in case of alluvial soils, 51.95 ppm in case of lateritic soils, 49.50 ppm in case of red soils, and 46.25 ppm in black soils. Randhawa and Kanwar (1964) found out by analysing 41 soils representing 7 profiles from different agro-climatic zone of Punjab that total zinc content varied from 18 to 97.50 ppm with an average value of 54.50 ppm. Routray (1971) reported the total zinc content of red and lateritic soils of Orissa to be 38 to 88 ppm. Swaine (1955) reported that on an average, soils contained 10 to 300 ppm total zinc. Hibbard (1940) observed that surface soils contain more total zinc and extractable zinc than sub-soils.

The total zinc content of different groups of soils may be rated as under:

Lateritic soil $>$ Alluvial soil $>$ Red soil $>$ Black soil
(51.95 ppm) (51.70 ppm) (49.50 ppm) (46.25 ppm)

It is seen that total zinc content was low in case of red and black soils and high in case of lateritic and alluvial soils. Similar results have also been obtained by Kanchiro (1964) that very highly weathered and leached ferruginous oxisols and ultisols (red, ferruginous red soil) showed relatively low total zinc content. Eswarappa et al (1969) reported that the lateritic soils were richer in total zinc as compared with the red and black soils. Lyman and Dean (1942) have also reported that the lateritic soils contain more total zinc as compared with red soils.

Available Zinc Content of the Soils of Orissa under Laboratory Evaluation

The available zinc contents extracted by two different methods are presented in Table VI. Depending upon the type of extractant used the available zinc in Indian soils varied from $<$ 1 ppm to a few parts per million. Soil being a multiphase system consisting of a solution phase in equilibrium with a solid phase, the potentiality of zinc of the solid phase can easily be measured by extracting into solution.

NH_4- Dithizone Extracted Zinc

The available zinc as extracted by NH_4-Dithizone method varied from 1 ppm to 2.75 ppm in case of alluvial soils with an average of 1.400 ppm, 0.875 to 2.25 ppm with an average of 1.63 ppm for lateritic soils, 0.75 to 1.125 ppm with an average of 0.937 ppm in case of red soils and 1.2 to 2.0 ppm with an average of 1.65 ppm for black soils.

In different soils of Orissa it was observed that the NH_4-Dithizone extractable zinc varied from 0.250 to 2.700 ppm . Grewal et al (1968) reported that the Gujrat soils have been reported to contain 1.00 to 3.00 ppm dithizone extractable zinc. The above relation-ship indicates that the NH_4- Dithizone extractable zinc is quite dependable for extracting available zinc.

0.1 N HCl Extractable Available Zinc

In case of alluvial soils 0.1 N HCl extractable zinc varied from 0.375 ppm to 2.250 ppm with an average value of 1.24 ppm. Similar results have been also obtained by Agarwala (1963, 1964)who reported that the 0.1 N HCl extractable zinc of alluvial soil of U.P. falls within a range of 0.1 to 7.00 ppm .

In case of lateritic soils 0.1 N HCl extractable available zinc varied from 0.5 ppm to 2.2 ppm with an average value of 1.32 ppm. 0.1 N HCl extractable zinc of red soils ranged from 0.400 ppm to 1.750 ppm with the mean value of 1.07 ppm. Black soils contained available zinc extracted by above method ranged from 1.125 ppm to 4.400 ppm with an average value of 2.841 ppm. Rai et al measured the available zinc in the range of 0.14 ppm to 5.36 ppm in deep black soils of M.P.

In different soils of Orissa, 0.1 N HCl extracted zinc varied from 0.375 ppm to 4.400 ppm. Lal et al (1960) ported that 0.1 N HCl extractable zinc of Orissa soils ried from 1.2 ppm to 7.0 ppm. Nair and Mehta (1959) so obtained the similar results that the 0.1 N HCl tractable zinc of different soils of Gujrat varied from 0.5 to 6.1 ppm. Chatterjee and Dass (1969) reported similar results that some Indian soil contained 2.2 ppm to 9.2 ppm 0.1 N HCl extractable zinc. Similar results have also been obtained by Ranadive et al (1964), Crewal et al (1968), Wear and Sommer (1947)

The available zinc determined by two methods in different soils of Orissa varies from 0.250 ppm to 4.400 ppm. Routray (1971) reported the available zinc of red and lateritic soils of Orissa varied from 2 to 6 ppm. Gupta and Singh (1972) reported the available zinc of some soils of Indore district varied from 0.90 ppm to 3.25 ppm. Similar results as obtained in this investigation have also been repoted by Holtz et al (1953)

Lyman and Dean (1942), Hibbard ((1940), Prasad and Pagel (1971).

It is seen that black soils contain highest amount of available zinc which show superiority over all revealing the idea that zinc deficiency may not be suspected in this soil, whereas lateritic, alluvial and red soils containing less amount of available zinc may exhibit zinc deficiency in crop plants of Orissa. Sharma and Motiramani (1969) reported that available zinc content was higher in black soils and lowest in alluvial soils. In comparison to the different soils it is observed that the available zinc contents fall less than 3 ppm in all soils except with a little deviation in case of black soil. Tucker and Kurtz (1955) reported that soils containing less than 3 ppm available zinc are deficient while those containing 3 to 6 ppm are moderately deficient. As per their findings it is clear that the soils taken for investigation are deficient in available zinc.

Comparison Between the Methods of Extraction of Available Zinc

An over all examination reveals that the values for NH_4- Dithizone extractable zinc were more or less similar in magnitude to the 0.1 N HCl extractable zinc and there were no variations between the two methods. From this it may be inferred that both the methods are equally dependable for assessment of available zinc of soils of Orissa. However there always lies very slight increasing trend with NH_4- Dithizone extraction method over 0.1 N HCl extraction method in case of all the soils studied except black soil. In case of black soils lower values of dithizone extractable zinc were obtained than 0.1 N HCl extractable zinc which corresponds to the results reported by Prasad and Sinha (1969).

Correlation Studies

The results showing the correlation co-efficient have been appended in Table XXI. From the correlation studies the following relationships of total and available zinc with pH, % of organic carbon , C.E.C., and % clay have been obtained. The correlation between total and available zinc are also recorded.

pH

A negative significant relationship (r = -0.521) was found out between total zinc and pH . But no significant correlation between pH and available zinc determined by two methods was obtained. Similar results have been obtained by Sharman and Kanehiro (1967) Chatterjee and Dass (1964) for available zinc. This negative not-significant relationship indicates that availability of zinc decreases with increase in pH values.

<u>Cation Exchange Capacity</u>

A positive correlation has been obtained between C.E.C. and the available zinc. Relationship is significant with 0.1 N HCl extractable zinc (r = 0.688) but not significant with NH_4- Dithizone extractable zinc . These findings agree that C.E.C. seems to be a good indicator for available zinc content of soil. Similar results have been obtained by Routray (1971).

<u>Organic Carbon</u>

Statistical analysis shows that there is also consistent positive relationship between available zinc, total zinc and organic matter content.

A positive significant correlation (r = 0.688*) was found between organic carbon and 0.1 N HCl extractable zinc . A positive but not significant correlation (r=0.323) was observed between organic carbon and NH_4- Dithizone extractable zinc. Similar results were found out by Brown et al (1971), Nair and Mehta (1959), Gupta and Singh (1972), Camp (1945).

This reveals the idea that availability of zinc increases with increase in organic matter content in the soil due to the following reasons.

(i) Zinc content of organic matter itself might be aiding a higher content of zinc not only in soil but also in soil solution for ready availability of zinc to the plant roots.

(ii) CO_2 evolved by organic matter decomposition combines with water and produces carbonic acid (H_2CO_3) which is responsible for decrease in soil pH. (iii) Some organic acids such as tartaric, citric, malonic and malic etc. are also released due to decomposition of organic matter to decrease soil pH resulting an increase availability of zinc.

Pratt et al (1958) Bandyopadhya and Adhikari (1968) are of same opinion.

Clay

Correlation studies indicate that there is no significant correlation between the clay content and both total and available zinc. Similar opinion have also been expressed by Bandyopadhya and Adhikari (1968), Nair and Mehta (1959) and Randhawa and Kanwar (1964). This indicates to believe that clay minerals also contribute towards the availability of zinc in soil and also the predominant clay minerals present in the soil have an apparent relationship in the availability of zinc. Prasad and Pagel (1971) studying the important tropical and sub-tropical soils reported that the availability of zinc was directly proportional to the amount of silt, clay and humus. It indicates that clay fraction also plays an important role in the availability of soil zinc. Zinc is not adsorbed equally well and by the same mechanism on all clay minerals . Zinc may be adsorbed as a monovalent ion thereby increasing the anion exchange capacity. It may occupy exposed holes in the octahedral layer. Zinc also may replace magnesium ions which occupy positions in the octahedra of the crystal lattice and in turn, be partially replaced by added magnesium.

Total Zinc

There is positive and significant correlation between total and available zinc extracted by NH_4-Dithizone extractant but a positive not significant correlation was observed with 0.1 N HCl extractable zinc. Woltz et al (1953) obtained a positive significant correlation between total zinc and extractable zinc (r = 0.874) Also similar results have been reported by Brown et al (1962) Gupta and Singh (1971). However the positive relationship magnifies that availability of zinc increases with increase in total zinc content of soil.

Crop Response as Affected by Different Levels of Zinc in Pot Experiment for Alluvial Soil and Field Experiment for Lateritic Soil

Yield and uptake of zinc by high yielding paddy (Padma) shows that such factors as soil, crop and addition of lime effect the availability of various levels of zinc. The response of rice crop to application of zinc is attributed to the lower content of total and available zinc in case of both the soils i.e. alluvial and lateritic and also due to the acidic condition of the soils.

Brown et al (1962) also found out that crop responded to zinc application when the soil contained less available zinc. Similar results have also been reported by Pillai (1967), Govind and Gopal Rao (1964). The effectiveness of different levels of zinc application in case of alluvial soil for both the drymatter production and total uptake of zinc is of the following descending order.

$$Z_3 \; 7 \; (Z_3 = Z_4) \; 7 \; (Z_2 = Z_1) \; 7 \; Z_0$$

This shows that Z_3 level is superior over all but the application of zinc (a) 5 ppm (Z_1) and 10 ppm (Z_2) as well as 15 ppm and 20 ppm (Z_4) belonging to two different groups exhibit equal performance both in total uptake of zinc and dry matter yield. Undoubtedly in comparison between thse two, the latter group Z_3 and Z_4 comes to be superior over the former group i.e. Z_1 and Z_2.

In case of lateritic soil the efficiency of different levels of zinc is of the following sequence in all cases of dry matter production, total uptake and grain yield : $Z_4 \; 7 \; (Z_3 = Z_4) \; 7 \; (Z_2 = Z_1) \; 7 \; Z_0$

It indicates that Z_4 (20 ppm) proves superior over all the levels of zinc. Z_3 and Z_4 (15 ppm and 20 ppm) levels of zinc belonging to one group show almost the equal effect and similarly Z_1 and Z_2 (5 ppm and 10 ppm) levels belong to another group having equal effect. Above all the first group is superior to second group.

In comparison between the two soils i.e. lateritic and alluvial it is clearly indicated that zinc application definitely increase the dry matter yield, total uptake of zinc and grain yield in rice crop in both the soils. Grewal et al (1969) obtained increased yield of paddy by application of zinc. Pillai (1967) reported similar results that production of dry matter and tillering was increased when zinc was applied @ . 2.83 kg / ha in the soil. Kanwar et al (1958, 1962) and Dhumbla et al (1963, 1965) reported by conducting several experiments on calcareous soil that yield of grain and dry matter of rice was increased by zinc application. Similar results have also been presented by Govindrajan and Gopal Rao (1964), Hipp and Cowley (1971), Pillai (1967), and Koraddi et al (1964).

The increase in yields of dry matter and grain and also the uptake of zinc by the test plants indicatesthat there might have been better utilization of N by application of zinc. Hence sometimes the nutritional disorders like yellowing of the leaves may be due to zinc deficiency which can be corrected by application of zinc. Govindrajan and Gopal Rao (1964), Sadaphal and Das (1956, 1961), . Joshi and Johri (1949)

Yoshida et al (1970), Yoshida and Tanaka (1969), Dikshit (1958), and Naik and Asana (1961).

On the above points it is clearly indicative that application of zinc sulphate with N.P.K fertilisers is of much importance for getting higher yields. Kumar and Joshi (1964), Goutam et al (1964) are of same view.

In general it is found out that application of zinc @ 15 ppm proved to be the best among all levels of application both in influencing dry matter yield and total uptake of zinc with special reference to alluvial soil. But in case of lateritic soil application of 20 ppm may be better among the other levels for dry matter production, grain yield and total uptake of zinc.

Ahuja and Gautam (1961) reported that application of 20 ppm zinc gave good response to hybrid maize for increasing the dry matter yield . Fuehring and Soofi (1964) reported also similar results that grain yield of maize was relatively high with application of 20 ppm of zinc. Such types of results have also been obtained by Gautam et al (1964), Pillai (1967), and Rajgopal and Mehta (1971).

Analysing the above results one could be inclined to think that zinc is one of the most essential nutrients responsible for plant growth, development and yield and there is high response of high yielding varieties of rice to application of zinc for correcting zinc deficiency in alluvial and lateritic soils of Orissa.

<u>Effect of Liming on the Availability of Zinc and Response of Rice</u>

Considering the different levels of lime application it was found that there was no significant difference both in uptake of zinc and drymatter yield in case of alluvial soil. No lime application seems to be necessary in case of alluvial soil to influence the uptake of zinc and drymatter production as a whole. Similar results are also evident in case of lateritic soils. The interacted levels of zinc and lime as found out indicates that Z_4 (20 ppm) at L_0 level (no lime application) gave increase in yield in all cases i.e. drymatter production, uptake of zinc and grain yield. So no lime is probably necessary for lateritic soil to raise the zinc availability . Similar results have been found out by Navrot and Ravikovitch (1968) that zinc contents of test crops decreased with increase in $CaCO_3$ in soil. Similar observation was noticed in case of lettuce by Nollendorfs (1971). The low response of zinc with the presence of excess lime may be attributed to the fact that (i) $CaCO_3$ may act as a strong absorbant for heavy metals; (ii) Due to increase in pH, the availability of zinc is decreased; (iii) The transloca-tion of zinc in plant may be decreased with less availability in soil·Leeper (1952) and Pauli et al (1968) are of same opinion. Several authors also reported that zinc concentration in plants decreases with the increased rates of lime application. The authors Rogers and Wu(1958) Epstein and Stout (1951), Nair and Mehta (1959), Stewart and Leonard (1963) Seatz et al (1960) reported that soil zinc unavailability was enhanced by raising pH by liming. Winter and Park (1955) observed that increased deficiency was due to liming. These results lead us to believe that good response can be obtained from application of zinc to alluvial and lateritic soils without liming.

<u>Effect of Different Levels of Zinc on Total and Available Zinc content of Soils at Different Levels of Liming in Alluvial and Lateritic Soils of Orissa</u>

Addition of zinc undoubtedly increased the level of total and available zinc status of the soil . The order of effectiveness of different levels of zinc in increasing the total zinc and in releasing the available zinc in both the soils is of the following order.

$$Z_4 > Z_3 > Z_2 > Z_1 > Z_0$$

With regard to different levels of liming it is observed that L_0 level increases the total and available zinc in case of lateritic soils and alluvial soils with little variation. The interaction values due to zinc and lime gives the relationship that Z_3 level in case of alluvial soils and Z_4 level in case of lateritic soils with no lime application (L_0) proved to increase the amounts of total zinc and available zinc contents of the soils. Similar results were also obtained for the drymatter yield and uptake of zinc in both the soils. Brown, Krantz and Martin (1961) also reported similar results that application of zinc increased consistently the extractable zinc in all soils studied. Stanton and Burger (1971) reported that zinc sulphate application increased available zinc in soil taking separate millet seedlings as test crop and application of $CaCO_3$ and $MgCO_3$ reduced zinc availability owing to pH changes. Similar conclusions have been drawn by Meuer et al (1971) and Harold et al (1960).

The results obtained in this case support the fact that the 15 ppm zinc (30 kg / ha) of zinc application in case of alluvial soil and 20 ppm (40 kg / ha) zinc application in case of lateritic soils is normally sufficient to correct the inadequate zinc supply of both the soils studied. This attributed to the fact that the soils to which zinc has been applied contained sufficient residual zinc to affect subsequent crops as the results were taken after harvest of crop.

Comparison Between the Two Methods of Extraction

(i) O. 1 N HCl extraction method

(ii) NH_4 -Dithizone extraction method

While comparing the amount of zinc extracted by two different methods in both the soils it was observed that there is not much difference between the two methods in the magnitude of the values obtained which only varied within a narrow range. So both the methods are equally dependable for assessment of available zinc. The dithizone extraction method has been shown to be a useful method for diagnosing zinc deficient soils. Brown and Krantz (1961); and Brown et al (1962); James et al (1971)

In selecting a procedure for diagnosing zinc deficiency, it is important to consider not only the relationship with plant growth but the laboratory facilities available and the simplicity for routine analysis. Each method involves a shaking period, decantation, and final zinc determination with normal care to prevent contamination. From the above discussion it is evident that both the methods are not equally rapid or equally adaptable to routine analysis. Again the use of 0.1 N HCl extraction method for high lime soils offers some problems, but the method can be used with success after determination of titrable alkalinity of the soils.

<u>Effect of Different Levels of Zinc on the pH Values of Lateritic and Alluvial Soils</u>

No remarkable difference in pH was observed when zinc at different concentration were added to the soil. The different concentration of zinc added might be too small to effect the soil reaction. However, the initial pH of the soil was lower than that recorded after harvest of crop. This increase of pH may be due to the submergence condition of the soil creating a reduced condition. It is thegeneral agreement among workers that submergence brings down the redox potential and raises the pH values.

Availability of Zinc with particular Reference to pH as Influenced by Liming

Liming, no doubt, increases the initial soil pH to a little extent but as such it may be observed that lime application to the soils under investigation has not influenced much the pH values. However, availability of zinc with relation to pH increased with the decrease in pH values or vice versa in both the soils as it was distinctly marked. Lime additions to soils no doubt, drastically modify the solubilities of a number of trace elements leading to the alleviation of toxicities in some instances but in otherhand liming leads to the production of deficiencies of certain trace elements like zinc where their availability becomes less due to increase in pH. So the effect of liming, pH and availability of zinc are interrelated to each other. Abichandani and Patnaik (1961) also noted that under field conditions 2000 lbs lime / acre increases initial soil reaction only by one to two pH units but raises ammonium nitrogen content nearly twofold which results in higher drymatter yield and grain yield. Similarly Moschla et al (1962) observed that soil receiving ground lime stone @ 8 tons / acre increased soil pH to slightly below 7.0 in silt loam and to slightly above 7.0 in sandy loam. So it would appear that liming the acid soils both alluvial and lateritic increases the initial soil reaction within a very narrow range. But the remarkable difference in the availability of zinc can be best found out by cursory examination to the data obtained on available zinc and pH as influenced by liming. It would appear from the results that where there is an decrease in pH the availability of zinc is more and where pH increases slowly the availability is also relatively low. So liming does not prove beneficial in the availability of zinc. Brown and Jurinack (1964) observed in a green house study that the availability of zinc was almost unaffected by liming on a sandy soil but decreased by increasing rates of $CaCO_3$ on a clay soil of pH 6.9. Hutton et al (1963) reported that zinc deficiency was induced by increasing application of 2500 to 7500 lbs / acre lime. But treatment with 10 lbs / acre ZnO was sufficient to maintain crop yields at any level of liming likely to be used. These results indicate that deficiency, sufficiency or toxicity of microelements like zinc is governed by soil pH. At lower pH values availability of zinc is maximum and there is optimum availability at pH values nearing neutralization. Though liming does not prove better for acid soils with respect to the availability of zinc, still liming to a certain critical level is to be adopted.

The solubility of zinc is generally believed to decrease when soils are limed (Brown and Holmes, 1956). Similarly results have also been reported by Peech (1941) Epstein and Stout (1951).

Numerous investigators have noted that zinc deficiencies usually occur on soils of pH 6.0 or higher. Deficient soils between pH 7.4 and 8.5 contained adequate total zinc but its availability was low. Camp (1945) gave the critical pH as 5.5 to 6.5 for greater availability of zinc. Wear (1956) found that addition of 1 ton / acre of $CaCO_3$ in Norfolk sandy loam decreased the zinc content of Sorghum and the pH increased from 5.7 to 6.6 . These findings clearly coincides with the results and views obtained from the present study.

<u>Correlation Studies of Pot and Field Experiment</u>

The results obtained in case of correlation studies of both the pot and field experiments are discussed hereunder.

<u>Correlation between the total and available zinc by two methods with the pH values of Alluvial and lateritic soils</u>

In both cases of alluvial and lateritic soils of pot and field experiments respectively the correlation studies revealed that definitely there is negative correlation between pH and available zinc and total zinc in soil i.e. increased pH has effect on decreasing availability of zinc in soil. Prasad and Pagel (1971) reported that zinc content decreased with increasing soil pH. Negative correlations between pH and extractable zinc was reported by Bandyopadhya and Adhikari. The lack of correlation was also obtained by Sherman and Kanehiro (1967). Chatterjee and Dass (1964), Bohn and Aba Husayn are of same opinion.

This inverse relationship of available zinc with pH has been attributed to both direct adsorption of zinc on calcite crystals and to a true pH effect. It is also postulated that Zn^{++} is the principal ionic form, assimi - lated by plant roots and doubted whether the roots can utilize the ZnO_2^{-2} ions which occur under alkaline conditions.

<u>Correlation Between Total and Available Zinc by Two Methods with Drymatter yield of Crops</u>

It may be seen from the 'r' value presented in Appendix Table IV that there exists a strong positive correlation between drymatter yield and available zinc determined by both the methods in both the soils "Alluvial and lateritic. Also a positive relationship was obtained between drymatter yield with total zinc which was found significant in case of lateritic soil. From this it can be concluded that the uptake of zinc is influenced by its availability in soil which ultimately increases the dry-matter yield of crop. Agarwala (1963, 1964) observed significant relationship between 0.1 N HCl extractable zinc and yield of maize and cauliflower grown on Bundelkhand soils of Uttar Pradesh.

Correlation of Total and Available Zinc with the Total Uptake of Zinc in Plants

It is well marked from the correlation studies in both the soils that there exists significant positive relationship between total and available zinc with uptake of zinc by plants. The uptake of zinc by plant was favoured by the existence of zinc in soil in available form. Massey (1957) reported that Dithizone extractable zinc is positively correlated with the uptake of zinc by the plants. Navrot and Ravikovitch (1968) reported also significant correlation between zinc uptake by plants and amount of soil zinc extracted. Similar results have also been obtained by Martens et al (1966), Grewal et al (1968), and Meelu and Randhawa (1970).

Correlation Between Uptake of Zinc and Yield of Drymatter

Correlation studies revealed that there is a positive significant relationship between uptake of zinc with drymatter yield in case of alluvial soil but in lateritic soil the positve relationship obtained was not significant. However, the positive relationship signifies that drymatter yield could be increased with increased uptake of zinc in plant. According to the report of Singh and Dartigues (1970), zinc concentration showed a significant positive correlation with dry weight and application of zinc increased the drymatter production and concentration of zinc considerably.

Correlation Between Uptake of Zinc and pH of the Alluvial and Lateritic Soils of Orissa

A not significant negative correlation was indicated by correlation study between uptake of zinc and pH in case of both the soils . This shows that as the pH decreases the total uptake of zinc increases or vice versa. This may be attributed to the fact that uptake of zinc increased with increasing proportions of hydrogen ions and decreasing Ca-ion. Epstein and Stout (1951) Massey (1957) also opined similarly.

Correlation of the Grains yield with the Drymatter yield and Uptake of Zinc in Alluvial and Lateritic soils of Orissa

It was revealed from the correlation studies that a positive correlation existed between grain yield and drymatter yield but it was found not significant. But a positive significant (at 1 % level) ($r = 0.493$) relationship was observed with the grain yield and uptake of zinc. As there was also a positive correlation between drymatter and grain yield, it revealed that the uptake, drymatter production and grain yield are correlated to each other. This relationship indicates that increased uptake of zinc not only increase the drymatter yield but also the grain yield. Pillai (1967) reported the response of paddy yield to application of zinc sulphate at the level of 11.2 kg / ha . Application @ 56 kg / ha have not recorded any reduction in yield. Similar results of increased grain yield were also reported by Gupta and Ram (1967), Singh and Jain and Pumphrey et al (1963). This indicates that application of zinc definitely influences its uptake by plants and thereby drymatter and grain yield productions are also increased.

Comparison between the Two Analytical Methods for Available Zinc

(i) NH_4 -Dithizone extraction method and
(ii) 0.1 N HCl extraction method according to the correlation studies in both the alluvial and lateritic soils of Orissa

Both the methods resulted significant positive correlation coefficient with uptake of zinc and drymatter production. This indicates that the two methods are not only equally dependable but also equally adaptable for routine analysis for both the soils of Orissa. However, the correlation studies indicated that 0.1N HCl extraction is better for alluvial soils and NH_4-Dithizone extraction is better for lateritic soils.

Rai and Chimania (1971) studying the suitability of 5 chemical extractants reported that among allthe methods NH_4- Dithizone and 0.1N HCl extraction methodsoccupied the top positions. Shaw and Dean (1964) obtained correlation between zinc deficiency and amount of zinc extracted by NH_4- Dithizone solution. Barrows and Tucker and Kurtz observed that 0.1 N HCl is a good extractant in acid soils. Dolar et al (1971) placed these two methods in equal position. The NH_4 -Dithizone extraction method has been shown to be useful method for diagnosing zinc deficiency of soils (Brown and Krantz, 1961; and Brown, Krantz and Martin, 1962) . Brown, James quick and Eddings (1971) have also reported that the four methods (1) Dithizone (2) DTPA (3) 0.1N HCl and (4) Na_2EDTA may be useful for diagnosing zinc deficiency in soils. They also state that for some soils more than one methods may be required to characterize the zinc status and all the four methods exhibited a high degree of correlation with each other for plant response in relation to zinc application.

From the above discussion it is obvious that the two methods showed the best relationship with growth response to applied zinc, and both can be utilized for diagnosing zinc deficiency in both the soils but undoubtedly 0.1N HCl extraction method commands superiority over NH_4-Dithizone extraction method in case of alluvial soils and NH_4-Dithizone extraction method manifests superiority over 0.1N HCl extraction method in case of lateritic soils. In general these two methods can be used satisfactorily in acid soils of Orissa for evaluation of available zinc.

CHAPTER VI

SUMMARY AND CONCLUSION

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In the recent years, we have obtained sufficient information about the wide spread deficiency of zinc and the rate at which this deviciency is accentuating. In India exploitive agriculture leads to serious depletion of micronutrients like zinc with the use of high yielding varieties of crops. Now-a-days the wide spread zinc deficiency has been marked in different areas like Punjab, Haryana, Bihar, A.P. and Terai area of U.P. In Orissa, the soils being acidic and principal crop being rice no systematic work has been done to delineate the areas of zinc deficiency. Hence the present study was undertaken to investigate the response of rice crop to zinc application.

The purpose of this investigation was to measure the total and available zinc status of alluvial and lateritic soils of Orissa and to find out the relationship of availability of zinc as reflected by the physical and chemical properties of soil by laboratory evaluation and correlation study. It was also aimed to investigate the response of rice crop to application of zinc in alluvial and lateritic soils of Orissa by pot culture and field experiment respectively. The third aim was to assess the availability of zinc with particular reference to pH as influenced by liming. Lastly it was also thought worthwhile to test and compare the applicability of determination of available zinc as extracted by 0.1 N HCl and NH_4- Dithizone .

The main purpose of taking 3 levels of lime (L_0, $L_{\frac{1}{2}}$ and L_1) with the 5 different zinc levels (Z_0, Z_1, Z_2, Z_3 and Z_4) was to compare the availability of zinc at different pH values.

Keeping the above objects in view a laboratory study, a pot culture study and a field experiment were conducted.

The laboratory evaluation studies were undertaken with 19 different soils of Orissa representing alluvial, lateritic , red and black soil groups. The physical properties of the soils such as % sand,%silt, and % clay were determined to find out the textural class. The chemical properties such as pH, % organic carbon, cation exchange capacity, N, P, K and Ca were also determined. The pH of the soils determined was measured by two different methods.

1). 1 : 2 soil : water

2). 1 : 2 soil : 0.01M $CaCl_2$ solution.

The total zinc and available zinc by two methods were also determined. Soil analysis revealed that alluvial soil was coarse textured sandy loam with 19.56 % clay on an average. The lateritic soils were sandy clay loam in texture with 20.30 % clay. The red soils of

Koraput district were loamy in texture with 32.86 % clay. The black soils were coarse textured sandy loam with 26.62 % clay. Chemical analyses of all the soils presented that the soils were moderately acidic in nature except the black soils. The black soils were neutral in reaction. The C.E.C. of all the soils were low but comparatively the black soils possessed a high C.E.C. in comparison to alluvial, lateritic and red soils. The % organic carbon in all the soils was medium but comparatively red and black soils contained little more organic matter in comparison to alluvial and lateritic soils. Nitrogen content in all the soils was low. Available phosphorus in case of alluvial and black soils were high in comparison to lateritic and red. Exchangeable calcium was higher in case of black soils than the others.

The total zinc present in all the soils of Orissa varied from 36.25 to 68.00 ppm with an average of 51.70 ppm, 51.95 ppm, 49.50 ppm and 46.25 ppm in case of alluvial, lateritic, red and black soils respectively. But in comparison to different broad soil groups the total zinc content is of the following descending order:

Lateritic $>$ Alluvial $>$ Red $>$ Black

The available zinc extracted by NH_4- Dithizone extraction method varied from 0.250 ppm to 2.750 ppm with an average of 1.400 ppm, 1.630 ppm, 0.937 ppm and 1.650 ppm in case of alluvial, lateritic, red and black soils respectively. 0.1 N HCl extraction zinc varies from 0.375 ppm to 4.400 ppm with an average of 1.245 ppm, 1.320 ppm, 1.075 ppm and 2.041 ppm in case of alluvial, lateritic, red and black soils respectively. In comparison to different soil groups the available zinc content extracted by both the methods is of the following descending order :

Black soil > Lateritic soil > Alluvial soil > Red soil

There was no significant correlation between pH and available zinc but it has significant relationship with total zinc. However the negative correlation indicates that availability of zinc decreases with increasing pH . The consistent positive correlation obtained between C.E.C. and available zinc indicates that C.E.C. seems to be a good indicator of available zinc. Similarly the positive correlation between available zinc, total zinc and % organic carbon reveals that availability of zinc increases with increase in organic matter content in soil. There is consistent positive relationship between the clay content and both available zinc and total zinc but not significant. This relationship indicates that clay fraction also play an important role in the availability of soil zinc.

The positive relationship between total zinc and available zinc shows that the availability of zinc increases with increase in total zinc contents of soil.

For pot experiment, 5 kg of alluvial soils of Dandamukundpur village was taken in each porcelain pot using paddy (Padma) as the test crop. The alluvial soil of Dandmakundpur is a coarse textured sandy loam soil, being medium in organic matter content, low in C.E.C. acidic in reaction, low in nitrogen content, high in available phosphorus and low in exchangeable potassium and calcium.

The soils in the pots were limed @ L_0 (no lime), $L_{\frac{1}{2}}$ (half of total lime requirement i.e. $\frac{1}{2}$ ton per acre) and L_1 (full lime requirement i.e. 1 ton per acre). 5 levels of zinc were applied @ 0. ppm (Z_0), 5 ppm (Z_1), 10 ppm (Z_2), 15 ppm (Z_3) and 20 ppm (Z_4) . The treatments were replicated thrice. Top portions of the crop were harvested after 60 days of transplanting. Dry weight, uptake of zinc, amount of total zinc, and amounts 0.1 N HCl, NH_4-Dithizone extractable zinc and pH of the soils were measured after harvest of crop. The relationship between the total zinc, available zinc by two methods with the different variables like pH, uptake of zinc and amounts of dry matter were examined by correlation studies. The uptake of zinc after harvest of crop was also correlated with pH and dry matter production.

The field experiment was conducted in Block 'C' of Agril. Expt. Station, Bhubaneswar . The lateritic soil of the experimental station is of loamy sand in texture, low in C.E.C., low in organic matter content, acidic in reaction , low in nitrogen and also low in exchangeable potassium and calcium.

Similar treatments of pot experiments were also taken in field experiment except that the soil was lateritic . The size of each plot for each treatment was 31.5 sq. m. The lime requirement determined was of the order of 1 ton /acre. Accordingly the levels of lime application differed as L_0 (no lime), $L_{\frac{1}{2}}$ (half lime requirement i.e. ½ ton /acre), L_1 (full lime requirement i.e. 1 ton / acre). Plants were harvested after maturity. Dry matter yield, grain yield, uptake of zinc by plants, total zinc , available zinc of soil and pH were determined after harvest of crop. The grain yield was correlated with the uptake of zinc and dry matter yield.

The response of rice crop to zinc application is attributed to the lower content of total and available zinc in both the alluvial and lateritic soils. Application of zinc undoubtedly increased the dry matter yield, uptake of zinc and grain yield of rice crop in both the soils. Application of zinc @ 15 ppm or 30 kg/ha proved to be the best dose of zinc application in case of alluvial soils and 20 ppm or 40 kg / ha proved to be the best dose in case of lateritic soil. The effectiveness of the different levels of zinc application is of the following descending order in case of alluvial soil.

Z_3 7 ($Z_3 = Z_4$) 7 ($Z_2 = Z_1$) 7 Z_0 and in case of lateritic soil Z_4 7 ($Z_3 = Z_4$) 7 ($Z_2 = Z_1$) 7 Z_0 . From the above relationship it can also be well identified that Z_3 (15 ppm) and Z_4 (20 ppm) levels of zinc being similar in case of both the soils, both the rates of application can also be recommended for both the soils in general to obtain higher yields.

It is also found that a high response to zinc can be obtained for rice crop without application of lime in the soils of Orissa and obviously response to zinc application would be low when acid soil is over limed. So no lime application can be advocated for greater availability of zinc.

Addition of zinc definitely increased the total and available zinc of both the soils. The results supported the facts that application of 15 ppm zinc in case of alluvial soil and 20 ppm zinc in case of lateritic soils are usually sufficient for low land rice grown in these soils.

The pH values of the soils as determined after the harvest of the crop did not change markedly due to the effect of different treatments.

However a slight increase in pH of potted soils were observed which may be due to submergence .

As regard to the availability of zinc with particular reference to pH as influenced by liming it was observed that the availability of zinc increases with the decrease in pH. At lower pH values availability of zinc was maximum and there is optimum availability at pH values nearing neutrality. Liming does not prove to be better in acid soils for increasing availability of zinc. The solubility of zinc is generally decreased when soils are limed.

There was no significant relationship between soil pH and level of dithizone and 0.1 N HCl extractable zinc in both the alluvial and lateritic soils of Orissa and in all cases a negative correlation has been obtained. This type of inverse relationship between soil pH and zinc availability may be attributed to the fact that zinc content decreased with increased pH as a result of direct absorption of zinc on calcite crystal which serves as a good adsorbent for zinc.

Correlation between total and available zinc by two methods with the dry matter yield and uptake of zinc seems to be highly significant and positively correlated in alluvial and lateritic soils of Orissa. This indicated that increasing the levels of zinc increase the dry matter and uptake of crops.

Positive correlation of drymatter yield with uptake of zinc reveals the idea that application of zinc increased the dry matter production and concentration of zinc considerably.

A negative carrelation was obtained between pH and uptake of zinc which showed that increasing the pH, total uptake was reduced. Hence the uptake of zinc was thought to be increased with the increasing proportions of hydrogen ion and decreasing calcium ion.

Similarly a positive correlation of grain yield with the dry matter and uptake of zinc reveals the idea that uptake, dry matter production and grain yield are correlated, to each other and increased uptake of zinc not only increases dry matter yield but also increases grain yield in both the lateritic and alluvial soils.

The relationships of extractable zinc by the two methods with dry matter yield and uptake indicated that these methods are quite satisfactory for alluvial and lateritic soils. The 0.1 N HCl extractant proved better in case of alluvial soil and in case of lateritic soil NH_4-Dithizone method proved better. In selecting a procedure for diagonizing zinc deficiency it is important to consider not only the relationship with plant growth but the laboratory facilities available and the simplicity for routine analysis. Undoubtedly, though both the methods are equally dependable for determination of zinc in lateritic and alluvial soils of Orissa, they are not equally rapid or equally adoptable for routine analysis.

Conclusion

1. Surface soil samples from different parts of Orissa State were found to have total zinc content in the order of 38 to 68 ppm with an average of 51.70 ppm, 51.95 ppm, 49.50 ppm and 46.25 ppm in case of alluvial, lateritic, red and black soils respectively. Soil-wise distribution of total zinc is of the following decending order.

Lateritic (51.95 ppm) > Alluvial (51.70 ppm) > Red (49.50 ppm) > Black (46.25 ppm)

Total zinc content of lateritic soil and alluvial soils is more than red and black soils.

2. The available zinc content of soils of Orissa extracted by NH_4-Dithizone method ranged from 0.250 to 2.750 ppm with an average of 1.400 ppm, 1.630 ppm, 0.937 ppm and 1.650 ppm for alluvial, lateritic, red and black soils respectively.

0.1 N HCl extractable zinc varied from 0.375 to 4.400 ppm with an average of 1.245 ppm, 1.320 ppm, 1.075 ppm and 2.001 ppm for alluvial, lateritic, red and black soils respectively.

Available zinc extracted by both the methods may be put in the following sequence :

Black > Lateritic > Alluvial > Red

The availability of zinc is more in case of black and lateritic soils than alluvial and red soils.

3. Soils differ widely in their zinc supplying capacity regardless of the amount of zinc present in non-replaceable form and the availability of zinc is much influenced by the physico-chemical property of the soil like pH, % organic carbon, C.E.C., and % clay.

4. Application of zinc definitely increases the dry matter production, uptake of zinc and grain yield for rice crop in both the alluvial and lateritic soils of Orissa. Both the levels of zinc application (Z_3 and Z_4) can be recomended to both the soils alluvial and lateritic but Z_3 level of application i.e. @ 15 ppm (30 kg /ha) and Z_4 level of application @ 20 ppm (40 kg / ha) proved to be best in alluvial and lateritic soils respectively. The order of effectiveness of different levels of application in case of lateritic soils is $Z_4 > (Z_3 = Z_4) > (Z_2 = Z_1) > Z_0$ and in case of alluvial soils $Z_3 > (Z_3 = Z_4) > (Z_2 = Z_1) > Z_0$.

5. Application of zinc undoubtedly increased the total and available zinc content in both the lateritic and alluvial soils of Orissa. The increasing trend

is of the following order :

$$Z_4 > Z_3 > Z_2 > Z_1 > Z_0$$

This indicates that increased application of zinc increases total and available zinc successively.

6. The availability of zinc decreased by liming the acid lateritic and alluvial soils.

7. At lower pH value availability of zinc is maximum and there is optimum availability at pH values nearing neutrality. So it is well established that the availability of zinc declines as the pH of the soils rise. Addition of lime to such acid soils is not necessary to raise the zinc availability.

8. From the results of investigation, it is clear that 0.1 N HCl extractant and NH_4- Dithizone extractant are better for alluvial and lateritic soils respectively for assessing zinc availability.

The problem of zinc deficiency for varieties of crops and different soils have gained imprtance with the introduction of high yielding varieties . So the conclusions drawn from the short investigation is quite adaptable for low land rice grown in different soils of Orissa . Earlier, it was thought that the lateritic and alluvial soils are rich in available zinc but the results have shown that it may be profitable to apply zinc to such soils for rice. However, wide scale verification trials would be necessary to formulate definite recommendations.

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* Orginal not seen .

APPENDIX

APPENDIX TABLE I

ANALYSIS OF VARIANCE OF DRY MATTER YIELD, 'Zn' UPTAKE TOTAL AND AVAILABLE 'Zn' DATA IN POT EXPERIMENT

(Alluvial soil)

Sl. No.	Aspects of study	Source of varia-ance	Treatment: Repli-cation	Treatment: Levels of zinc application	Treatment: Levels of lime application	Treatment: Levels of zinc X Levels of lime	Error	Total
		D.F	2	4	2	8	28	44
1.	Dry matter yield	M.S	27.344	12.240	4.520	5.010	2.864	
		Cal.F	9.547	4.273**	1.578 N.S.	1.749 N.S.		
2.	Total uptake of 'Zn'	M.S	0.131	1.108	0.097	1.389	0.151	
		Cal.F	0.087	7.338**	0.065 N.S.	0.173 N.S.		
3.	Total 'Zn' in soil	M.S	1180.045	3412.807	313.790	576.892	190.071	
		Cal.F	6.200	17.950**	1.650 N.S.	3.035*		
4.	NH_4-Dithizone extractable 'Zn'	M.S	0.074	28.444	16.675	1.480	0.237	
		Cal.F	0.310	120.010**	70.350**	6.246**		
5.	0.1 N HCl Extractable 'Zn'	M.S	2.119	17.116	0.032	0.349	0.285	
		Cal.F	7.400	60.050**	0.112 N.S.	1.127 N.S.		
	Table 'F' value (0.05)		3.34	2.71	3.34	2.29		
	Table 'F' value (0.01)		5.45	4.07	5.45	3.23		

** Significant at 1 % level * Significant at 5 % level N.S. Not significant

APPENDIX TABLE II

ANALYSIS OF VARIANCE OF DRY MATTER YIELD, GRAIN YIELD, 'Zn' UPTAKE TOTAL AND AVAILABLE 'Zn' DATA IN FIELD EXPERIMENT

(Lateritic soil)

Sl. No.	Aspects of study	Sources of Variance	Replication	Treatment: Levels of zinc application	Treatment: Levels of lime application	Treatment: Levels of zinc X Levels of lime	Error	Total
		D.F	2	4	2	8	28	44
1.	Dry matter yield	M.S	1.717	48.789	13.968	8.739	4.546	
		Cal.F	0.377	10.732**	3.072 N.S.	1.922 N.S		
2.	Grain yield	M.S	10.422	3.319	4.213	1.530	1.654	
		Cal.F	6.301	2.006 N.S.	2.547 N.S.	0.925 N.S.		
3.	Total uptake of 'Zn'	M.S	118.683	126.592	120.996	16.891	16.082	
		Cal.F	7.379	7.871**	7.523**	1.045 N.S.		
4.	Total 'Zn' in soil	M.S	145.416	714.102	349.40	297.844	48.464	
		Cal.F	3.000	14.734**	7.20	6.145**		
5.	NH_4-Dithizone Extractable 'Zn'	M.S	8.970	22.570	10.281	2.162	1.187	
		Cal.F	7.550	19.014**	8.661**	1.821 N.S.		
6.	0.1 N HCl Extractable 'Zn'	M.S	11.814	14.549	3.913	3.517	1.543	
		Cal.F	7.656	9.429**	2.536 N.S.	2.279 N.S.		
	Total 'F' value (0.05)		3.34	2.71	3.34	2.29		
	Total 'F' value (0.01)		5.45	4.07	5.45	3.23		

** Significant at 1% level * Significant at 5% level N.S. Not significant

APPENDIX TABLE III

RESULTS SHOWING THE CORRELATION CO-EFFICIENTS OF LABORATORY STUDY

Sl. No.	Variables correlated	Correlation Co-efficient(r)
1.	pH Vs. NH_4- Dithizone extractable zinc	-0.3562 N.S.
2.	pH Vs. 0.1 N HCl extractable zinc	+0.2564 N.S.
3.	pH Vs. total zinc in soil	-0.5214 *
4.	C.E.C. Vs. NH_4-Dithizone extractable zinc	+0.3280 N.S.
5.	C.E.C. Vs. 0.1 N HCl extractable zinc	+0.6880 *
6.	C.E.C. Vs. total zinc	-0.1380 N.S.
7.	% organic carbon Vs. NH_4-Dithizone extractable zinc	+0.2690 N.S.
8.	% organic carbon Vs. 0.1 N HCl extractable zinc	+0.6620 *
9.	% organic carbon Vs. total zinc in soil	+0.4270 N.S.
10.	% clay Vs. NH_4-Dithizone extractable zinc	+0.2948 N.S.
11.	% clay Vs. 0.1 N HCl extractable zinc	+0.3580 N.S.
12.	% clay Vs. total zinc in soil	+0.0631 N.S.
13.	Total zinc Vs. NH_4-Dithizone extractable zinc	+0.7010 **
14.	Total zinc Vs. 0.1 N HCl extractable zinc	+0.1350 N.S.

** Significant at 1% level

* Significant at 5 % level

N.S. Not significant

APPENDIX TABLE IV

RESULTS SHOWING THE CORRELATION CO-EFFICIENT OF POT AND FIELD EXPERIMENTS

Sl. No.	Variables correlated	Correlation co-efficient (r)	
		Pot experiment (Alluvial soil)	Field experiment (Lateritic soil)
1.	pH Vs. NH_4- Dithizone extractable Zn	- 0.368 *	- 0.139 N.S.
2.	pH Vs. 0.1 N HCl extractable Zn	- 0.255 N.S.	- 0.264 N.S.
3.	pH Vs. total Zn in soil	- 0.131 N.S.	- 0.149 N.S.
4.	Total Zn Vs. drymatter yield	+ 0.254 N.S.	+ 0.421 **
5.	Uptake of Zn Vs. drymatter yield	+ 0.486 **	+ 0.153 N.S.
6.	Dithizone extractable Zn Vs. drymatter yield	+ 0.373 *	+ 0.895 **
7.	0.1 N HCl extractable Zn Vs. drymatter yield	+ 0.450 **	+ 0.438 **
8.	Uptake of Zn Vs. 0.1 N HCl extractable Zn	+ 0.589 **	+ 0.545 **
9.	Uptake of Zn Vs. NH_4- Dithizone extractable Zn	+ 0.340 *	+ 0.780 *
10.	Uptake of Zn Vs. total Zn in soil	+ 0.386 **	+ 0.300 *
11.	Uptake of Zn Vs. pH of soil	- 0.069 N.S.	- 0.208 N.S.
12.	Drymatter yield Vs. grain yield	[illegible]	+ 0.246 N.S.
13.	Uptake of Zn Vs. grain yield		+ 0.493 **

** Significant at 1 % level

* Significant at 5 % level

N.S. Not significant