

APPROVAL OF EXAMINERS FOR THE AWARD OF THE
DEGREE OF MASTER OF SCIENCE (AGRICULTURE)

EFFECT OF ZINC ON RICE CULTIVARS AND ITS RESIDUAL EFFECT ON WHEAT

We, the undersigned, having been satisfied with the performance of Shri Chandan Kumar Pal, in the viva-voce examination held today, the 25/11/2002, recommend that the thesis be accepted for the degree of Master of Science (Agriculture) in Agronomy

**A thesis submitted to the
Uttar Banga Krishi Viswavidyalaya
in partial fulfilment of the requirements for the Degree of
Master of Science (Agriculture)**

in

AGRONOMY

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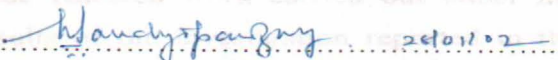
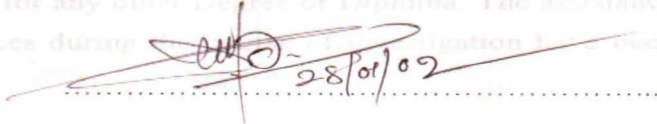

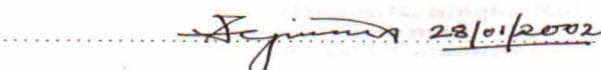
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We, the undersigned, having been satisfied with the performance of Shri Chandan Kumar Pal, in the viva-voce examination, conducted today, the 28th day of January 2002, recommend that the thesis be accepted for the award of the degree of Master of Science (Agriculture) in Agronomy.

CERTIFICATE

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UTTAR BANGA KRISHI VISWAVIDYALAYA
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C E R T I F I C A T E

This is to certify that the work recorded in the thesis entitled **'EFFECT OF ZINC ON RICE CULTIVARS AND ITS RESIDUAL EFFECT ON WHEAT'** submitted by Mr.Chandan Kumar Pal in partial fulfillment of the requirement for the degree of Master of Science (Agriculture) in Agronomy of the Uttar Banga Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received from various sources during the course of investigation have been duly acknowledged.

A.K. Singha Roy
Prof (Dr.) A.K. Singha Roy
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Dated : 11th January
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Chandan K. Pal
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ABSTRACT

A field experiment was conducted to study the effect of zinc (0, 25 & 50 Kg of ZnSO₄/ha), on the yield components and yield of ten rice cultivars viz., IET 4786, IR 68, Lalat, IET 1809, Biplab, MTU 7029, Ajaya, MW10, IR 50 and IET 10384 during wet season (1999) at Pundibari, transplanted on 7th July, 1999 and also to observe the residual effect of zinc on succeeding wheat variety 'Sonalika' in a rice-wheat cropping system.

Different levels of zinc sulphate had no significant influence on growth attributes and yield of wet season rice. However, soil application of zinc as zinc sulphate showed an increasing trend. Application of 25 Kg. ZnSO₄/ha recorded the highest mean grain yield (26.80 q/ha i.e., 1.72 percent increase over control) and the plots fertilised with 50 Kg. ZnSO₄/ha recorded mean grain yield to the tune of 26.73 q/ha. Grain yield was significantly influenced due to the effect of rice cultivars. The highest grain yield (36.13 q/ha) recorded with rice cultivar MTU 7029 was associated with higher number of matured panicles per square metre. The decrease in yield was associated with decrease in the yield components. It was also evident that the different rice cultivars had played a crucial role in the variation of response. These variations of response could be attributed to their genomic difference. The results indicated that IR68 and IET 1809 were susceptible and cultivars Lalat and IR 50 were tolerant cultivars to zinc. So adequate zinc fertilization to the soils is an essential pre-requisite for obtaining higher yields in susceptible cultivars viz., IR68 and IET 1809.

Grain yield of wheat during dry season (1999-2000) as succeeding crop in rice-wheat cropping system significantly increased due to the residual effect of zinc. The results indicated that an increase of 13.82 and 4.6 percent over control was recorded due to soil residual effect application of 50 Kg and 25 Kg ZnSO₄/ha in the preceeding rice crop. However, higher wheat grain yield in rice wheat cropping system was obtained from the soils (plots) where susceptible rice cultivars were transplanted and it might be associated with the less utilisation of applied zinc to the previous wet season rice.

INTRODUCTION

With the increased population growth the demand for food grains is increasing day by day. So, West Bengal in general and the Terai zone of this state in particular needs more and more food grain production, but as the geographical area is confined, so there is limited scope for horizontal expansion. Therefore, the area under cultivation cannot be increased and vertical expansion is the only possibility. In present condition intensified cropping of the existing area is to be geared up to meet the challenge. So our main attempt will be to increase the production per unit area.

The success of food grain production in India over the year is attributed to two crops i.e., Rice and Wheat. The rice - wheat system is covering about 10 m. ha area in India. Rice and Wheat put together contribute about 73% of the national food grain requirement. Rice-wheat is a common cropping sequence of Terai zone of West Bengal. In this zone nearly 45 % and 4 % of gross cropped area are occupied by winter rice and wheat respectively. There is ample scope of increasing the area under rice-wheat cropping system in this zone especially in low land rice eco-system.

The Terai zone of West Bengal is basically and predominantly a rice growing area. In *kharif* season 80 % of land is covered with rice height textured soil with low retention capacity and high rate of leaching appears to be important barrier to increasing the yield of winter rice. Almost uninterrupted rainfall during a part of monsoon months, commonly occurring in the area, causing low rate of photosynthate accumulation would also depress the yield. Uninterrupted rainfall with high humidity causing dis-appropriate disease and pest infestation seems to be another factor that would have been contributed to low productivity. Occasional dry spell at the flowering time would also further add to low productivity. Apart from aforesaid natural constraints, growing of traditional long duration local varieties with relative high proportion and lower level of fertilizer use are to be the important physical constraints in this zone. So attention is needed to introduce high yielding rice varieties in this area and to develop appropriate technology as well as corrective measures to enhance the productivity of rice-wheat system as a whole.

Wheat is the most important winter cereal in Terai zone of West Bengal. There are some natural advantages for higher productivity of wheat like prolonged winter and high residual moisture content in the soil at the initial phase of its growth (that used to save pre-sowing irrigation) in this zone. Despite the prevalence of natural advantages, the low

productivity of wheat in this zone may be due to some constraints. Late sowing due to delayed harvest of winter rice is one of the important constraint wheat sowing under rice-wheat system is delayed due to late release of land causing low productivity of wheat. Before 1975 - 76 wheat was shown in the upland after harvest of Aus paddy or jute, but it is now a common practice that wheat is grown in low and medium land after rice in the rice-wheat system as upland has been occupied by vegetables or potato or mustard.

As pointed earlier, delayed rice harvest is one of the prominent reasons for delayed wheat sowing. The research efforts should, therefore, aim at adjusting time of sowing for both wheat and its preceding crop rice with alternative varieties of varying duration with a view to achieving maximum possible economic returns.

The micronutrient problem in India has recently drawn attention of the agricultural scientists. Micronutrient deficiency, although sporadic, has been observed more in light textured and calcareous soils, soils of Terai zone of West Bengal are light textured and acidic in nature. Such soil with high rainfall has favoured high rate of leaching of plant nutrients and this creates the problem of micronutrient deficiency. Among the micronutrients zinc deficiency appears to be the most important nutritional factor limiting growth and yield of wetland rice next to nitrogen and phosphorous. Then again evidences show that zinc has residual effect on the succeeding crop in the sequence, but in Terai zone of West Bengal information in this aspect is meagre, more particularly in rice-wheat sequence. These factors warranted the need for a careful study on the effect of zinc application on major crops of this zone.

Application of Zinc in every year may create the problem of toxicity of zinc in soil current alternate approach fitting the plants to soil aims at identifying the cultivars having greater tolerance to natural stress. Growing of zinc efficient cultivars on deficient soils can save zinc fertilizers, after additional yield advantage and reduce the land degradation in view of these facts. The present investigation was undertaken to select the rice varieties for soils of low zinc status.

In consideration of the point raised, it was planned to carry out experiments having the undermentioned objectives :

1. To study the performance of rice varieties in zinc deficient soil.
2. To study the compatibilities of rice varieties with wheat to achieve high production in the rice-wheat system.
3. To study the effect of zinc application on the growth attributes and yield of rice.
4. To study the after effect of zinc application to rice on growth attributes and yield of the succeeding wheat crop.

REVIEW OF LITERATURE

Recent advancements in global agricultural productivity have had no historical parallel. We are in the midst of the latest food production revolution the world has known. The growing knowledge of mineral nutrition of plants with special reference to micronutrients has made us realise that great changes are possible through judicious application of certain inorganic substances.

The essentiality of micronutrients was proved long before and their role in crop production was also recognised zinc is one of the micronutrients which even in minute quantities in soil, is indispensable for plant growth. Zinc mainly serves as the metal component of a series of enzymes- the catalyst for growth processes.

Tusi (1948) and Skoog (1940) observed that sub-optimal levels of auxin caused dwarfism and growth reduction. A severe Zn deficiency brought about a complete crop failure.

Zn deficiency in crop plants viz, rice & wheat, in one of the most common features observed in the low land situation of Terai agroclimatic region. Many agricultural soils of Terai agroclimatic conditions are incapable of meeting even a small demand for zinc consequently, the standard fertilizer recommendation of N,P and K is sometimes inadequate in today's quest for higher crop production in rice-wheat cropping system, researchers have established that in many such instances zinc treatment could bring about a striking improvement in the yield.

Possingham (1957) and Tal (1969) reported that zinc is important for protein synthesis. Therefore, Zn-deficient plants happened to be poor in protein. A low supply of zinc to plants restricts optimum production of Auxin-the growth promoting substances.

Safaya *et al.* (1975) found that modern agriculture with the introduction of high yielding varieties had brought about zinc deficiency disorders in soil to a considerable extent.

Yoshida (1981) reported that in view of the physiological significance of zinc and its poor presence in soils all over the world, in general, and submerged soil where zinc concentration decreased due to soil- submergence in particular, it appeared that there was enough scope of improvement of rice crop as well as yield of rice based cropping system due to zinc fertilization in rice and residual effect on the succeeding crops.

2.1 Occurrence of zinc deficiency

Zinc deficiency of low natural to alkaline soils. In their experiments with barley, bean & sunflowers. Sommer and Hipman (1926) reported that zinc was essential for the normal growth of barley, buck wheat, bean and sunflowers.

Zhinevskaga (1958), Chapman et al. (1966), Katalymow (1969) and Mortved *et al.*, (1972) reported the details regarding the occurrence of zinc deficiency and the effects of various fertilizers containing zinc, particularly on carbonate or podzolized soil.

Thomson and Weier (1962) reported that Zn deficiency closely related to the inhibition of RNA synthesis. The deficiency prevents the normal development of chloroplast grana and vacuoles developed in them.

Mikkelsen and Shiou Kuo (1977) denoted zinc deficiency as one of the most important micronutrient problem encountered in rice-growing areas. Since first reported in 1966, it has been recognised as a wide spread disease induced by the increasing use of fertilizers and higher yield in many rice growing countries.

Rahimi and Bussler (1978) reported that the first truly typical symptom of Zn deficiency is the appearance of more or less visible to red pigment in the epidermis cells. Bussler (1981) reported from his different experiments that Zn deficiency symptoms are not always identical in all crop plants.

Yoshida (1981) reported that in severe case of Zn deficiency, transplanted rice seedlings may die or direct sown seeds may fail to emerge. In most cases, however, symptoms become visible about 2-3 weeks after transplanting in low land situation and spontaneous recovery from the deficiency may occur 6-8 weeks after soil submergence.

2.2 Diagnosis of zinc deficiency

The diagnosis of zinc deficiency reported to be difficult because different plants do not always show the same symptom. Plants suffering from Zn deficiency often show chlorosis, pale green, yellow or even white in the interveinal areas of the leaves.

The zinc deficiency symptom in rice and wheat are described in detail as follows.

2.2.1 The deficiency symptom in rice

Karim and Valmis (1962) reported that low land rice was more vulnerable to zinc deficiency there fore, growing rice on permanently wet soils was frequently an early causality

of zinc deficiency. In rice, the middle ribs of young leaves turned yellowish green near the base, but the discolouration decreased towards the tip. The leaves developed characteristic brown rusty spots which coalesced and formed continuous brown areas. Dark brown necrotic lesions appear at the tip of the older leaves. This is most common on the third leaf. The lesions gradually spread to engulf the whole leaf, which twists towards the tip and then fold downwards and stem growth was inhibited.

Tanaka and Yoshida (1970) found that in rice Zn deficiency was often accompanied by visible symptoms of iron toxicities.

Bergmann (1992) observed that leaves that were just unfolding remained very small and displayed the same chlorotic and necrotic lesions as older leaves. There was no tillering. Few or no seed were produced. The whole plant gradually died when the deficiency persisted in the field. The author and uneven stand of rice and stunted plants with brown rusty appearance and delayed maturity were indicative of zinc deficiency. The author reported that zinc deficiency in rice is popularly familiar as 'Khaira' disease in India.

2.2.2 The deficiency symptoms in wheat

Bergmann (1992) found that Zn deficiency appeared as fading of the middle of the lower half of the lamina on the older leaves. The first symptoms of Zn deficiency were, however, seen on the leaf next to the youngest. The chlorotic blotches appearing on the upper side of the older leaves of wheat plants formed an irregular network. They first turned white, then brown, unite and the whole leaf died. The younger leaves appeared to be normal but were small.

Following the commencement of the fading of the lamina, the affected leaves developed minute radish-brown spots which tended to coalesce forming radish brown lesions. These lesions later turned brown and limp. The leaves presented a withered look. In severe Zn deficiency, the whole plant might be affected. Its maturity was delayed. Grain formation and ultimate yield were markedly reduced.

2.3 Zinc status of soil

Schroo (1959); Lucas and Devis (1961); Jackson et al., (1967) reported from their experiments that zinc deficiencies on acid soils are generally associated with low soil zinc content.

Jensen and Lamm (1959) reported that the Zn content of soil was generally in the range of 10-300 ppm. certainly Zn, because of its concentration, could be considered as a trace element in soil.

2.5 Varietal performance on zinc deficient soils

Nena (1966) reported first that Zn had become an important wide spread problem.

Mikkelsen and Kuo (1976) found that deficiencies were correlated not with the total Zn in the soil, but with a complex soil-plant system.

Kanwar and Randhawa (1967) IIRI (1968) reported that the total Zn content in Indian soils varied within very wide limits, 2-1205 ppm.

In West Bengal, Bondopadhy and Adhikari (1968) reported the Zn content to be 31-77 ppm in soils where pH range from 5.0-8.6.

Lucas and Knezek (1972) reviewed the climatic and soil factor that seemed to promote zinc deficiency in crop. Very often, sandy soils are deficient in available zinc. In high rainfall areas where acidic conditions prevailed, weathered minerals released zinc which soon removed by leaching.

De and Chatterjee (1978) reported that the content of zinc estimated to be 11-15 ppm in upland soils of Nadia district as compared to (15 -18 ppm) in the medium land and 18 ppm in low land rice soils.

Blasl and Mayr (1978) reported that availability of iron in acid soils is implicated in the development Zn deficiency. This is because roots and nodes of maize for instance may be "blocked" by excessive iron uptake.

2.4 Zinc in soil solution

Plants absorbed zinc mainly as Zn^{+2} ions. Owing to their poor mobility and the low zinc concentration of the soil solution, uptake is largely by direct contact between root and soil particles. It is not yet known to what degree plants are also able to utilise $ZnCl^+$ and $Zn(OH)^+$ ions sorbed on clay particles, crops vary greatly in their ability to absorb zinc.

Yoshida (1975 c) reported that zinc is only sparingly soluble in soils. The availability soil zinc and applied zinc is much higher in upland soils than in submerged soils. Soil submergence caused a substantial decrease of the zinc concentration in the soil solution. After prolonged submergence, the zinc concentration tended towards an ultimate value between 0.02 & 0.03 ppm.

Halvorson and Lindsay (1977) reported that zinc chelats in soil or nutritive solutions are not taken up as chelats, only the metal ion being absorbed.

2.5 Varietal performance on zinc deficient soils

Some rice varieties differ in their ability to grow on zinc deficient soils. The varieties susceptible to zinc deficiency appear to be less vigorous low tillering.

In marginal zinc deficiency, the varietal difference may be significant on an extremely deficient soil, however, zinc must be applied to the soil to produce profitable yields.

2.6 Effect of zinc on growth & yield of rice and wheat

Attention of scientist has recently been attentively focused on the micronutrient problem in India.

Micronutrient deficiency, although sporadic had generally been observed more in light textured and calcareous soil. Acidic areas with light textured soil and high rainfall accompanied by high rate of leaching for long period might also developed micronutrient deficit tract. Adopting intensive cropping programme with high yielding varieties crops removed more nutrients from soil including micronutrients.

The essentiality of zinc among the other micro nutrients was proved long before to considerable effect on the growth and yield of rice and wheat in low lying situation of acidic soils under rice-wheat cropping system.

2.6.1 Effects of zinc on rice

Sharma *et al.*, (1986) studied the response of rice to zinc and evaluation of some soil tests method for zinc. They reported the effect of zinc application on yield of rice and uptake of zinc by rice and suitability of extractant in some soils in the Bundel Khand region of M.P. The yield of rice significantly increased with the application of zinc to the zinc-deficient soils. Zinc concentration in plant issue and zinc uptake by grain and straw also increased significantly with zinc application.

Sarkar *et al.*, (1988) reported that soil application of 20Kg $ZnSO_4$ / ha., during final land preparation of main field, gave the highest yield of paddy during early wet season (*aus*) and dry season (*boro*).

Paramasivan *et al.*, (1990) studied the response of zinc on low land rice under different seasons with different varieties in zinc deficient soils. The varieties viz., IR 50 during Sornavari, IR 36 during Samba and ADT 36 during Navarai were studied in randomised blocked designed replicated thrice. Four levels of soil application viz., 15,30,45

& 60 Kg ZnSO₄/ha, with control and two levels viz., 0.5 & 1.0 % spray of zinc sulphate on 15th, 25th and 35th day after transplanting were tried the response through soil application was maximum at 60 Kg zinc sulphate per hectare during Sornavri and Samba seasons which was at par with 45Kg znSO₄/ha. and the yield was maximum at 45 Kg ZnSO₄/ha., in Navarai which was at par with 30 Kg ZnSO₄/ha.

2.6.2 Effect of zinc on wheat

Joshi & Joshi (1956), Joshi (1956a) reported that response to application of zinc increased when zinc was added with organic matter.

Kanwar (1964) reported that zinc sulphate application to acid soils increased the wheat yield significantly over NPK where no zinc was applied.

Grewal *et al.*, (1965) reported that application of zinc sulphate increased the yield of wheat by 72 and 146 Kg /ha, at Kulu and Palampur respectively.

Samboornaraman *et al.*, (1968) reported the soil or spray application of zinc was found to be effective in increasing the height of plant, number of tillers and dry wet of wheat plants.

Mehata *et al.*, (1969) reported that soil application of ZnSO₄ increased the wheat yield.

Randhawa *et al.*, (1970); Mozumder (1973); Bhardwaj and Prasad (1979) and chatterjee *et al.*, (1980) reported that the Zn application in soil increased the wheat yield significantly.

Shukla and Raj (1976) conducted field trials with 21 wheat varieties grown on land with a poor zinc status and reported that the yield losses differed by upto 35%.

Rattan *et al.*, (1977) reported that zinc sulphate was the most common source of zinc although other sources such as zinc oxide, zinc EDTA, zinc fruits etc., have been tested.

Katyal and Randhawa (1983) found that in wheat and other field crops soil application as ZnSO₄ was found superior and was generally recommended.

2.6.3 Residual effects of zinc in rice - wheat cropping system

Boawan *et al.*, (1960), Viets, (1961), Brown *et al.*, (1964) reported that the wide spread occurrence of zinc deficiency could make it a serious nutritional problem. Fortunately, zinc deficiencies were relatively easy to correct, either with sprays or with soil application

with zinc fertilizers. Usually soil applications in the range of 5 Kg /ha. of zinc would last 3-8 years.

Most soil tests extractants and plant-uptake trials indicated that zinc fertilizers had a significant residual effect the persisted for several years, depending upon the crop, the soil and the rates at which the fertilizers were applied.

Boawn *et al.*, (1960) reported that approximately 35% of 18 Kg/ha., application of zinc was still extractable with 0.1NHCl after 4 cropping seasons from the upper 20 cm of a Ritz ville fine sandy loam. After 5 years no significant differences were found from plots receiving upto 4.5 Kg /ha., over plots receiving no zinc fertilizer.

Brown *et al.*, (1964) found that 2.5 ppm of zinc as ZnSO₄ was adequate for 6 or 7 successive crops. When 12.5 ppm of zinc was added, 10 successive crops were grown in the green house on a previously zinc deficient soil without zinc deficiency recurring. Dithizone-extractable zinc declined gradually with cropping and when it reach 0.55 ppm, there was a plant response to further addition of zinc.

Takkar *et al.*, (1975) studied the effect direct and residual available zinc on yield, zinc concentration and it s uptake by wheat and groundnut crops. Different rates of zinc application (11,22,33,44 & 55 Kg/ha.) had built up different levels of residual available zinc, and significantly increased the zinc content from deficient to sufficient levels. These levels of zinc had resulted in significant increase of zinc concentration and its uptake by wheat and groundnut which in turn significantly increased the yield of these crops. The residual available zinc decreased, though remained significantly higher than control after the harvest of every crop. Application rates of 11,22,23,33,44 & 55 Kg zinc/ha. provided residual zinc for atleast 5,7,9,11 & 13 crops respectively.

Samui and Bhattacharyya (1976) observed in a plot trials that paddy yield increased with increasing zinc sulphate rates upto 20 Kg/ha. were not affected by P and were the highest (200 g/plot) with 60 Kg P₂O₅ + 20 Kg ZnSO₄/ha., compared with 174.8 g without P & Zn; yield significantly decreased with higher rates of P + Zn. Fresh fodder yields of berseem in the following seaseon increased by the residual effect of 60 Kg P₂O₅, 10 Kg ZnSO₄ and especially 60 Kg P₂O₅+ 30 Kg ZnSO₄/ha.

Agarwala *et al.*, (1980) reported that 18 field trials were conducted at 15 diff. locations in central and eastern U.P. to examine crop response to zinc fertilization. Wheat, rice and maize plants grown with less than 0.39 ppm dithizone extractable zinc in non -

calcareous soils and less than 0.74 ppm zinc in alkaline soils exhibited foliar symptoms of zinc deficiency and responded to zinc application. The paddy yield was increased by 50 % (about 11.5 q/ha) at three location and that of wheat was increased by 30 % (8.5 q/ha) at 9 locations. The magnitude of the yield response to zinc application was largely a function of the native soil zinc but was also determine by the soil pH and calcareousness. Both wheat and rice showed response to residual zinc during the following three cropping seasons but the magnitude of response to residual zinc declined.

Bhardwaj and Prasad (1981) reported that among the four levels of soil applied zinc sulphate, viz., 0, 10, 20 and 40 Kg /ha., tried on rice, 20 Kg/ha., gave highest paddy grain yield. The residue from 40Kg ZnSO₄ /ha. applied to rice gave maximum grain yield of the following wheat crop. No residual effect was found on subsequently grown III and IV crops.

Takkar and Nayyar (1982) conducted a field trial on a zinc-deficient highly sodic soil of Ghabdan series to evaluate the Ca and Zn needs of the rice-wheat system. Treatments incl. three rates of Ca (G₀, G₂₅, G₅₀ percent gypsum requirement of soil) and three rates of Zn (Zn₀, Zn₁₁, Zn₂₂ Kg Zn/ha). These were applied only to rice -I and rice -V crops. Gypsum (Ca) application significantly and markedly increased the yield, Ca and Zn uptake in rice and wheat crops. Zn application significantly improved the soil and plant zinc but the yield of rice-I, wheat -II, and wheat -IV crops were poorer then in Ca application treatment. When Zn and Ca applied together, they markedly and successively increased the yield and Zn uptake revealing the deficiencies of both Ca and Zn. A repeat application of Zn and Ca to rice -V was recommended to counter the adverse effect of high residual sodium carbonate for optimum crop growth in rice-wheat cropping system. The result suggested that treatment G₅₀, Zn₂₂ was the best followed by G₃₀, Zn₁₁ or G₂₅, Zn₂₂.

Indulkar and Malewar (1989) observed that irrespective of sources, 4Kg Zn/ha directly to rice and subsequently to chickpea significantly improved the grain and straw yields of both the crops in rotation compared with the control. The farmyard manure in combination with all sources of inorganic zinc increased the residual zinc and in turn additive effect in grain legume was recorded. Zn @ 4Kg /ha raised the status of DTPA-Zn considerably even after rice -chickpea crop rotation.

Patnaik and Raj (1999) conducted a field experiment with rice in Zn deficient soil to study the direct, residual and cumulative effects of Zn in rice-rice cropping system soil application of ZnSO₄ increased the grain yield of rice response of grain yield after 4 seasons

(1 direct and 3 residuals) was highest (21.9 %) with 50 Kg ZnSO₄/ha when compared to other levels. The yield response with ZnSO₄/ha was highest (19.9 %) even after 8 seasons indicating strong residual effects. Application of 75 Kg ZnSO₄ (50 Kg initially and 25 Kg at 5th seasons) gave the high cumulative (8 seasons response) effect. The yield increased was 5.1t/ha over control. Application of 12.5 Kg ZnSO₄/ha in Zn deficient soil was not sufficient to get optimum yields. Zn content in the index leaf samples increased with the increase in the ZnSO₄ application. Zn content also remained above the critical level even after 7 seasons in the treatments, where ZnSO₄ was applied initially, indicating that ZnSO₄ has strong residual effect. Soil available Zn after the harvest of each season crop also indicated strong residual effect. The uptake in the Zn sulphate treated plots was significantly more than the control plots.

3.2 Agroclimatic condition of the research farm

The climate of the Toral zone is sub tropical in nature with distinctive characteristics of high rainfall, high humid dry and a prolonged winter. There are practically two dominant seasons in a year - an extended winter or dry-rainy season and a long rainy season. The winter, in most of the years sets in after middle of October with a fall in night temperature and is extended upto March very high rainfall, cool temperature and dry clear sunny day with occasional heavy rainfall and high humidity are the characteristics of winter season. The wet or rainy season is characterized by hot and humid weather, heavy precipitation by south west monsoon with cloudy overcast days and fewer hours of bright sunshine. The monthly mean data prevailing to the treated of experimental plots is presented in the Table 3.1

3.2.1. Rainfall

The rainfall with the onset of kharif season of 1999 was high and an amount of 862.6 mm and 1081.9 mm was received during the month of July and August. In the post-monsoon season, comparatively small amount of rainfall was received at the onset of 2000 and in the winter rainfall was received during winter months of November, December and January. The rainfall data is presented in table 3.1

3.2.2. Temperature

Mean of maximum and minimum temperature during both the years of experimentation is very recorded and is presented in table 3.1. Rise of temperature is seen during from the month of June upto October. Highest maximum temperatures were recorded in March and October (31.7°C) and in April (30.6°C) and highest minimum temperature (24.1°C) was recorded in August during crop growth. The average maximum temperature ranged from 26.2°C to 31.7°C in 1999 and 22.9°C to 31.4°C in 2000. The temperature (maximum and minimum) began to rise from February onwards. The average minimum temperature varied from 11.3°C to 24.1°C and 8.3°C to 19.8°C during the years of 1999 and 2000, respectively. January and February were the colder months (8.8°C). Minimum temperature was highest in August (24.1°C) during 1999 and in April (18.8°C) during 2000.

MATERIALS & METHODS

The investigations reported in this manuscript were carried out during the Kharif seasons of 1999 and the rabi seasons of 1999-2000 to study the effect of zinc on rice cultivars and its residual effect on wheat. The details of the experimental materials used, methods followed and the statistical techniques adopted during the course of investigations have been discussed in this chapter.

3.1. Experimental Location

The field experiments were conducted at the Instructional Farm, Bidhanchandra Krishiviswa Vidyalaya, North Bengal campus, Pundibari, Kooch Behar (West Bengal) for two consecutive seasons at the same locations during the kharif season of 1999 and rabi season of 1999-2000. The Farm is located at 26°19'N. latitude and 89°23' E. longitude and at an altitude of 43 meters above mean sea level.

3.2 Agroclimatic condition of the research farm

The climate of the Terai zone is sub tropical in nature with distinctive characteristics of high rainfall, high humidity and a prolonged winter. There are practically two dominant seasons in a year- an extended winter or dry rabi season and a long rainy season. The winter, in most of the years sets in after middle of October with a fall in night temperature and is extended upto March very light rainfall, cool temperature and dry clear sunny day with occasional heavy rainfall and high humidity are the characteristics of winter season. The wet or rainy season is characterised by hot and humid weather, heavy precipitation by south west monsoon with cloudy overcast days and fewer hours of bright sunshine. The monthly mean data prevailing to the period of experimentation is presented in the Table 3.1

3.2.1. Rainfall

The rainfall with the onset of kharif season of 1999 was high and an amount of 862.6 mm and 1081.9 mm was received during the month of July and August, 1999 respectively lent conversely small amount of rainfall was received at the onset of 2000 and almost no rainfall was received during winter months of November, December and January. The rainfall data is presented in table 3.1.

3.2.2 Temperature

Both the maximum and minimum temperature during both the years of experimentation were recorded and presented in table 3.1 Rise of temperature was observed from the month of June upto October. Highest maximum temperatures were recorded in June and October (31.7°C) 1999 and in April 2000 (31.4°C) and highest minimum temperature (24.1°C) was recorded in August during rice growth. The average maximum temperature ranged from 26.2°C to 31.7°C in 1999 and 22.9°C to 31.4°C in 2000. The temperature (maximum and minimum) began to rise from February onwards. The average minimum temperature varied from 11.3°C to 24.1°C and 8.8°C to 18.8°C during the years of 1999 and 2000, respectively. January and February were the colder months (8.8°C). Minimum temperature was highest in August (24.1°C) during 1999 and in April (18.8°C) during 2000.

Table 3.2 Physico-Chemical properties of soil.

3.2.3 Relative Humidity

The monthly mean maximum relative humidity varied from 92 to 97% and 88 to 97% during the years of experimentation of 1999 and 2000, respectively. The minimum relative humidity varied from 53 to 79% in 1999 and 46 to 59% in 2000. Lower percent of relative humidity was recorded during December, 1999 and in March, 2000.

3.2.4 Bright Sunshine Hours

The monthly sunshine hours varied from 3.4 to 8.6 hours and 6.7 to 8.4 hours during the years of 1999 and 2000, respectively. The highest sunshine hour was recorded in the month of November, 1999 (8.6) and in the month of February, 2000 (8.4) and the minimum sunshine hours was observed in the month of July, 1999 (3.4) and January, 2000 (6.7)

3.3.5. Experimental Soil

The topography of the land, where the investigations were undertaken, was medium in situation endowed with good drainage facility. The soil of the experimental field were sandy loam in texture, a true representative of the region. Composite soil samples from all the experimental plots were collected and analysed before starting the experiment. The physico-chemical properties of the soil are given in table 3.2.

Table 3.1. Metrological monthly mean data prevailing to the periods of experimentation.

Year 1999						
Month	Temperature(°C)		Humidity (%)		Rainfall (mm)	Sunshine
	Max.	Min.	Max.	Min.		
June	31.7	23.6	92	74	745.2	5.2
July	30.7	24.0	96	79	862.6	3.4
August	30.8	24.1	95	78	1081.9	3.8
September	31.1	23.0	95	74	261.7	5.7
October	31.7	21.4	97	72	445.6	7.0
November	29.5	15.9	96	56	000.0	8.6
December	26.2	11.3	95	53	000.0	8.4

Year 2000						
Month	Temperature (°C)		Humidity (%)		Rainfall (mm)	Sunshine (hr)
	Max.	Min.	Max.	Min.		
January	22.9	8.8	97	53	0.0	6.7
February	24.3	8.8	95	46	20.7	8.4
March	28.8	14.2	88	46	15.5	7.4
April	32.00	20.00	71	45	307.8	-

Table 3.2 Physico - Chemical properties of soil.

A. Mechanical composition of soil (0-15 cm)

Particulars	Particles size distribution (%)	Method employed
Sand	62.34	Bouyoucoshy hydrometre (Piper, 1950)
Silt	20.85	
Clay	16.81	

B. Physical Properties of soil (0-90 cm)

Particulars	Soil profile depth (cm)					Method of employed
	0-15	15-30	30-45	45-60	60-90	
i) Bulk density (gm ³)	1.45	1.42	1.41	1.38	1.38	Core sample (Piper, 1950)
ii) Field capacity (%)	37.43	36.24	31.81	20.74	15.24	Field sample (Piper, 1950)

C. Chemical properties of soil (0-15 cm)

Particulars	Value	Method employed
(i) pH (soil:water::1:2.5)	5.80	pH meter
(ii) Organic Carbon (%)	1.02	Walkley & black method
(iii) Cation exchange Capacity CEC (me/100g)	16.72	Ammonium acetate methods (Jackson, 1967)
(iv) Total nitrogen (%)	0.10	Modified Kjeldahl method (Jackson, 1967)
(v) C:N	10.20	
(vi) Available Phosphorous (kg/ha)	16	Bray's No. 1 method (Jackson, 1967)
(vii) Available Potassium (kg/ha)	128.23	Flame Photometer method (Jackson, 1967)

3.4 Previous cropping history of the experimental plot

A cropping sequence of rice- mustard was practised in the experimental site for last three years before this experimentation.

3.5 Experimental details

3.5.1. Agricultural operation

Proper care was taken for management of all the experimental plots beginning from transplanting/sowing to harvest for the experimentation during both the seasons namely kharif (rice) and rabi (wheat). The details of the field operations are given in table 3.3.

3.5.2. Sowing of seeds in seed bed

Seeds were soaked overnight in plain water for easy germination in seed bed. Seeds were sown by broad casting.

3.5.3. Land preparation

One deep ploughing by tractor followed by two ploughings by power tillage to obtain a good tilth. The weeds and stubbles were removed and cleaned. Levelling was done and drainage cum irrigation channels were made.

3.5.4. Harvesting and threshing

Harvesting of the experimental plots were done discarding the border rows. Threshing was done with the help of pedal thresher. The straw and grains were separately dried in the sun and after proper cleaning and drying, grains and straws of each plots were weighed and then yield was calculated.

3.3 Details of general field operations

3.3.1 Field operations in the rice plots

Operations	Kharif rice (1999)
i) Sowing of seeds in seed bed	8.6.99
ii) Land preparation	20.6.99
iii) Preparation of bounds, channels and beds	2.7.99
iv) Application of : <ul style="list-style-type: none"> a) Zinc sulphate b) Fertilizer 	5.7.99 5.7.99
v) Transplanting	7.7.99
vi) Interculture operation	22.7.99
vii) Top dressing : <ul style="list-style-type: none"> a) The first one b) The second one 	29.7.99 21.8.99
viii) Harvesting and processing	27.10.99 15.11.99 17.11.99

3.3.2 Field operations in the wheat plots

Operations	Wheat (1999 - 2000)
i) Final Land preparation	13.12.99/14.12.99
ii) Preparation of bunds, channels and beds	15.12.99
iii) Basal application of fertilizers	20.12.99
iv) Date of sowing	20.12.99
v) Top dressing	18.01.2000
vi) Irrigation	11.01.2000
vii) Harvesting	07.04.2000
viii) Threshing	12.04.2000

3.5.5 Particulars about the cultivars used in the experiment

The cultivars used in the experiment were IET 4786, IR 68, Lalat, IRT 1809, Biplab, MTU 7029, Ajaya, MW 10, IR 50 and IET 10384. The necessary information regarding the cultivars are as follows:

Ajaya : It was released by central variety Release committee in 1992. It is a derivative of the cross between IET 4141 and CR 98- 7216. The duration of the crop is 125-130 days. The type of grain is long bold.

IR 68 : It is a derivative of IR19660 - 73 -4 & IR 2415-90-4-3-2, than back crossed with IR 5853- 162-1 -2-3. It was released by IRRRI in 1988. The duration of the variety is 120-125 days and the type of grain is long slender.

Lalat : It is a derivative of OBS 677 x IR 2071 x VIKRAM x W 1273. It takes 125- 130 days to mature and the type of grain is long slender.

IET 1809 :

Biplab : It takes 125 days to mature . The type of grain is bold.

MTU 7029 : It is a cross between Vasista in to Mahsuri. It was released in 1982 in A.P. Plants are semi-dwarf. The crop duration is 110-115 days and the type of grain is long bold.

IET 4786 : It is a derivative of CR 10-114 x CR-10-15. The duration of the crop is 112-115 days and the type of grain is long slender.

MW 10 : It takes 110-115 days to matured and the type of grain is medium bold.

IR 50 : It is derivative of IR 2153-14-1-6-2 x IR 28 x IR 30. The crop duration is 110-115 days and grain type is long bold.

IET 10384 : It is a short duration variety and takes 105-110 days to mature.

3.5.6 Design and, layout

3.5.6.1.

Effect of three levels of zinc applied as zinc sulphate (main plot treatment) with ten different cultivars (sub-plot treatment) of rice were studied in a split-plot design with three replications having sub-plot size of 4m x 3m during kharif season of 1999 with assured drainage system. Altogether there

were thirty treatment combinations. The three levels of zinc sulphate were 0, 25 and 50kg ZnSO₄/ha. The ten cultivars of rice were IET 4786 (V₁), IR 68 (V₂), IET 9947 (V₃) IET 1809 (V₄), Biplab (V₅), MTU 7029 (V₆), Ajaya (V₇), MW 10 (V₈), IR 50 (V₉), and IET (10384) (V₁₀) respectively. The three doses of zinc sulphate were applied in the three main plots and ten cultivars of kharif rice were randomly distributed in the sub-plots.

There were 90 plots which were provided with 25 cm height ridged on all the sides of sub-plots. To provide drainage from each plot, adequate number of drainage channels were also constructed.

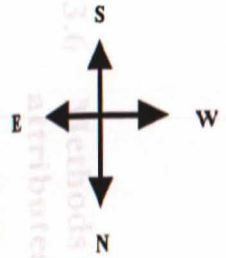
The treatment combinations were as follows.

REPLICATION-III	Zn ₀ V ₁	Zn ₂₅ V ₅	Zn ₅₀ V ₆
	Zn ₀ V ₅	Zn ₂₅ V ₃	Zn ₅₀ V ₄
	Zn ₀ V ₇	Zn ₂₅ V ₆	Zn ₅₀ V ₂
	Zn ₀ V ₈	Zn ₂₅ V ₇	Zn ₅₀ V ₇
	Zn ₀ V ₁₀	Zn ₂₅ V ₄	Zn ₅₀ V ₁
	Zn ₀ V ₉	Zn ₂₅ V ₈	Zn ₅₀ V ₅
	Zn ₀ V ₄	Zn ₂₅ V ₉	Zn ₅₀ V ₈
	Zn ₀ V ₂	Zn ₂₅ V ₂	Zn ₅₀ V ₃
	Zn ₀ V ₃	Zn ₂₅ V ₁	Zn ₅₀ V ₉
	Zn ₀ V ₆	Zn ₂₅ V ₁₀	Zn ₅₀ V ₁₀

The plots received uniformly a dose of 30:30:30::N: P₂O₅ :K₂O kg/ha as based in the form of urea, single super phosphate and murate of potash respectively. Another 30 kg of nitrogen per hectare was top dressed in two equal splits at 21 and 42 days after transplanting (DAT).

The plan of experiment is shown in Fig 3.5

REPLICATION-I	Zn ₀ V ₁	Zn ₂₅ V ₅	Zn ₅₀ V ₆	Zn ₀ V ₅	Zn ₂₅ V ₃	Zn ₅₀ V ₄	Zn ₀ V ₇	Zn ₂₅ V ₆	Zn ₅₀ V ₂
	Zn ₀ V ₈	Zn ₂₅ V ₇	Zn ₅₀ V ₇	Zn ₀ V ₁₀	Zn ₂₅ V ₄	Zn ₅₀ V ₁	Zn ₀ V ₉	Zn ₂₅ V ₈	Zn ₅₀ V ₅
REPLICATION-II	Zn ₀ V ₄	Zn ₂₅ V ₉	Zn ₅₀ V ₈	Zn ₀ V ₂	Zn ₂₅ V ₂	Zn ₅₀ V ₃	Zn ₀ V ₃	Zn ₂₅ V ₁	Zn ₅₀ V ₉
	Zn ₀ V ₆	Zn ₂₅ V ₁₀	Zn ₅₀ V ₁₀						



REPLICATION-I

REPLICATION-II

REPLICATION-III

Zn ₅₀ V ₅	Zn ₂₅ V ₂	Zn ₀ V ₁
Zn ₅₀ V ₃	Zn ₂₅ V ₄	Zn ₀ V ₃
Zn ₅₀ V ₁	Zn ₂₅ V ₅	Zn ₀ V ₇
Zn ₅₀ V ₇	Zn ₂₅ V ₇	Zn ₀ V ₆
Zn ₅₀ V ₂	Zn ₂₅ V ₆	Zn ₀ V ₂
Zn ₅₀ V ₄	Zn ₂₅ V ₃	Zn ₀ V ₅
Zn ₅₀ V ₆	Zn ₂₅ V ₁	Zn ₀ V ₄
Zn ₅₀ V ₉	Zn ₂₅ V ₁₀	Zn ₀ V ₉
Zn ₅₀ V ₈	Zn ₂₅ V ₉	Zn ₀ V ₈
Zn ₅₀ V ₁₀	Zn ₂₅ V ₈	Zn ₀ V ₁₀

Zn ₀ V ₂	Zn ₂₅ V ₃	Zn ₅₀ V ₃
Zn ₀ V ₆	Zn ₂₅ V ₄	Zn ₅₀ V ₃
Zn ₀ V ₃	Zn ₂₅ V ₂	Zn ₅₀ V ₁
Zn ₀ V ₄	Zn ₂₅ V ₁	Zn ₅₀ V ₇
Zn ₀ V ₇	Zn ₂₅ V ₇	Zn ₅₀ V ₂
Zn ₀ V ₁	Zn ₂₅ V ₅	Zn ₅₀ V ₆
Zn ₀ V ₅	Zn ₂₅ V ₆	Zn ₅₀ V ₄
Zn ₀ V ₉	Zn ₂₅ V ₄	Zn ₅₀ V ₁₀
Zn ₀ V ₁₀	Zn ₂₅ V ₉	Zn ₅₀ V ₈
Zn ₀ V ₈	Zn ₂₅ V ₁₀	Zn ₅₀ V ₉

Zn ₀ V ₄	Zn ₂₅ V ₅	Zn ₅₀ V ₇
Zn ₀ V ₆	Zn ₂₅ V ₆	Zn ₅₀ V ₃
Zn ₀ V ₈	Zn ₂₅ V ₈	Zn ₅₀ V ₂
Zn ₀ V ₁₀	Zn ₂₅ V ₂	Zn ₅₀ V ₅
Zn ₀ V ₉	Zn ₂₅ V ₁	Zn ₅₀ V ₆
Zn ₀ V ₇	Zn ₂₅ V ₉	Zn ₅₀ V ₈
Zn ₀ V ₂	Zn ₂₅ V ₁₀	Zn ₅₀ V ₉
Zn ₀ V ₁	Zn ₂₅ V ₇	Zn ₅₀ V ₁
Zn ₀ V ₃	Zn ₂₅ V ₄	Zn ₅₀ V ₄
Zn ₀ V ₅	Zn ₂₅ V ₃	Zn ₅₀ V ₁₀

Sub-plot size : 4m x 3m

Treatments :

Main plot : Zinc

Zn₀ : Control

Zn₂₅ : Zinc sulphate @ 25 kg/ha

Zn₅₀ : Zinc sulphate @ 50 kg/ha

Sub-plot : Cultivars of rice

V₁ : IET 4786

V₂ : IR 68

V₃ : IET 9947

V₄ : IET 1809

V₅ : Biplab

V₆ : MTU 7029

V₇ : Ajaya

V₈ : MW 10

V₉ : IR 50

V₁₀ : IET 10384

3.5 Layout plan of experiment

3.6 Methods for recording yield, yield components and other attributes of rice

Twelve sq.m. (4m x 3m) area discarding border rows, was selected which was reserved for yield assessment and the following observations were taken in each plot.

3.6.1 Grain yield

Plants from 12 m² area were harvested at ground level. They were then threshed, winowed and sun dried separately for each treatment (Plot-wise) and the grain yields were calculated at 14 % moisture basis.

3.6.2 Straw yield

After threshing the straw bundles were allowed to dry in the field for about 2 to 3 days and then the yield of straw was recorded for each plot. Both grain and straw yields of each plot were converted in terms of q/ha.

3.6.3 Number of panicles/square meter

An area of 1m x 1m qas marked out at random from where number of panicles were counted.

3.6.4 Number of filled grains per panicle

Ten panicles were selected at random from each plot and were brought to the laboratory. They were then dried and threshed carefully. From those panicles filled grains and chaffy grains were counted.

3.6.5 Test weight of grain

One thousand filled grains were counted and were sun dried. Their weights were taken separately for each plot.

3.6.6 Height of the plants

Ten plants were selected at random in each plot and heights were measured from ground level to the tip of the panicles. After this, average height of per plant was calculated.

3.7 Statistical interpretation of results

The statistical analysis of data, collected as described earlier, were done by calculating values of C.D. at 5% critical difference at 5% level of significance) as described by Gomez, Cox and Cochran (1955) and Paun and Sukhatme (1967).

3.7.1 Methodology to determine the response of grain yield due to zinc application in preceding kharif rice

The equality of response effects due to two treatments is tested by Fisher test at 5% level of significance. For identification of susceptible tolerance variety the specification of 95% confidence limits are considered with law as

- i) variety whose response is \geq upper control limit (UCL) i.e. $\bar{x} + 1.96 \times SE(\bar{x})$ is taken as susceptible
- 2) Variety as response is \leq lower control limit (LCL) i.e. $\bar{x} - 1.96 SE(\bar{x})$ is taken as tolerance.

3.7.2 Methods for recording yield, yield components and other attributes of wheat

Six sq.m. (3 m x 2 m) area discarding border rows, was selected for yield assessment and the following observations were taken.

All plant matter was harvested at ground level. Harvesting area (HA) is recorded in sq.m. 100 spikes from harvested plant matter were selected at random. Fresh weight (FS) of the selected spikes was taken. After drying at 75 to 80 C for two days, dry weight (DS) of the spikes was recorded.

After removal of 100 spikes, the fresh weight (FB) of the remaining plant matter was recorded. The bundle is then sun dried sufficiently to facilitate the threshing. Fresh grain weight from each bundle (TU) was recorded. A sample of approximately 30gm from each grain sample was taken and fresh eight was recorded (WG). After oven drying at 75 to 80 C for 16 hrs the dry weight (DG) was recorded.

All weights were recorded in grain. The yield and yield components were determined by the following formula used by Dr. K.D. Sanyal, (Senior Agronomist, Wheat/Agronomy programme, CIMMYT)

$$3.7.3 \text{ Biomass (kg/ha)} = \frac{\frac{DS}{FS} (FB+FS)}{HA} \times 10$$

$$3.7.4 \text{ Grain yield (kg/ha)} = \frac{\frac{DG}{WG} \times TG \times \frac{(FB+FS)}{FB}}{HA} \times 10$$

$$3.7.5 \text{ Harvest Index} = \frac{\text{Grain yield at 0 \% moisture}}{\text{Dry Biomass}}$$

$$3.7.6 \text{ Spikes per m}^2 = \frac{FB + FS}{FS} \times \frac{100}{HA}$$

$$3.7.7 \text{ Grain per m}^2 = \frac{\text{Grain yield (kg/ha) at 0 \% H}_2\text{O}}{1000 \text{ Kernel weight}} \times 100$$

3.7.8 Grain per spike = $\frac{\text{Grains/m}^2}{\text{Spikes/m}^2}$

3.7.9 Test weight of grain

One thousand grains were counted and sundried. Their weights were taken separately for each plot.

3.7.10 Height of the plants

Height of plant was recorded by randomly selecting ten plants in each plot and average was recorded. The heights were measured from ground surface to terminal spiketets and it was done just before harvesting.

There was no significant difference in the number of matured panicles per square metre due to the application of different levels of zinc sulphate (Table 4.1).

4.1.1.1 Effect of cultivars

Treatment differences due to the different rice cultivars were found to be significant it was revealed from the Table 4.1 that the highest number (1.46) of matured panicles per square metre associated with the variety NTLI 7079 (N.) whereas the lowest number (0.99) was obtained from the variety IPI 1009 (N.).

4.1.1.2 Effect of irrigation between zinc and rice cultivars

The interaction effect between zinc and rice cultivars on the number of matured panicles per sq. m was statistically significant. The highest number (1.60) of matured panicles per sq. m was recorded with the zinc sulphate NTLI 7079 (N.) which yielded 78.56 g/m² zinc sulphate. The lowest number (0.97) was obtained with the variety IPI 1009 (N.) in the control plot.

4.1.2 Number of filled grains per panicle

4.1.2.1 Effect of zinc

Number of filled grains per panicle was not greatly influenced by the zinc application of the cultivars (Table 4.2). The effect of zinc sulphate on panicle filled grains was highly significant where zinc sulphate was applied at 75 kg/ha of zinc sulphate. However, it was not significant especially with 25 kg/ha of zinc sulphate.

4.1.2.2 Effect of cultivars on the yield of rice

Number of filled grains per panicle was significantly due to the use of different rice cultivars. Data found in Table 4.2, clearly indicated that the maximum number of filled

Table 4.1 Effect of zinc and rice cultivars on a number of matured panicles/m²

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	297.33	250.33	266.67	271.00
IR 68 (V ₂)	264.00	287.33	272.00	274.00
IET 9947 (V ₃)	279.00	236.33	257.67	258.00
IET 1809 (V ₄)	287.00	213.00	214.33	205.00
Biplab (V ₅)	357.00	321.00	328.00	335.00
MTU 7029 (V ₆)	320.67	364.33	351.67	346.00
Ajaya (V ₇)	199.33	224.00	209.00	211.00
MW 10 (V ₈)	324.00	287.67	303.00	305.00
IR 50 (V ₉)	333.67	371.33	327.00	344.00
IET 10384 (V ₁₀)	301.33	261.33	285.00	283.00
Mean	286.33	281.50	281.50	283.11

Effect of	SEm (±)	C.D. (0.05)
Zinc	3.854	NS
Variety (V)	8.0896	22.953
Zn x Cultivars	14.0116	39.755

Table 4.2 Number of filled grains per panicle

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	71.00	67.33	73.00	70.44
IR 68 (V ₂)	28.00	49.33	46.00	41.11
IET 9947 (V ₃)	57.00	56.00	58.67	57.22
IET 1809 (V ₄)	40.67	50.00	54.67	48.44
Biplab (V ₅)	54.33	43.33	50.00	59.22
MTU 7029 (V ₆)	61.00	69.43	65.67	65.33
Ajaya (V ₇)	58.33	62.00	59.33	59.89
MW 10 (V ₈)	58.33	43.00	58.33	53.22
IR 50 (V ₉)	49.67	54.67	50.00	51.44
IET 10384 (V ₁₀)	78.67	76.33	72.00	75.67
Mean	55.70	57.13	58.77	57.20

Effect of	SEm (±)	C.D. (0.05)
Zinc	0.3153	1.237
Variety (V)	0.95925	2.721
Zn x Cultivars	1.6614	4.714

grains/panicle (76) was recorded with cultivar IET 10384 (V₁₀), cultivar IR 68 (V₂) resulted in the lowest number (41) of filled grains.

4.1.2.3 Effect of interactions

Interaction between zinc and rice cultivars was found to be significant (Table 4.2). Among the treatments highest number of filled grains per panicle was recorded when variety IET 10384 (V₁₀) was treated with no zinc in the plots. The lowest number of filled grains per panicle was recorded with the variety IR 68 (V₂) in the control plots.

4.1.3 Test weight of grains

4.1.3.1 Effect of zinc

The test weight of rice grain was not significantly influenced due to the soil application of zinc as zinc sulphate. Data from the Table 4.3 indicated that the plots which were fertilised with 50 Kg of ZnSO₄/ha recorded maximum test weight (27.38 g). The control plots recorded minimum test weight of grains (27.18 g).

4.1.3.2 Effect of rice cultivars

Treatment differences due to different rice cultivars were found to be statistically significant. The highest test weight of grains was recorded with the cultivar Ajaya (V₇) and followed by IET 10384(V₁₀) and MTU 7029 (V₆). But the cultivar IR 68 (V₂) recorded the lowest test weight of grains.

4.1.3.3 Effect of interactions

Interaction effect due to zinc and rice cultivars was found to be non significant (Table 4.3).

4.2 Yield

4.2.1 Grain yield

4.2.1.1 Effect of zinc on the yield of rice

Grain yield was not significantly influenced by the soil application of zinc as zinc sulphate (Table 4.4). However, the results showed an increasing trend of grain yield due to application of zinc during wet season. The results showed that the application of 25 Kg ZnSO₄/ha recorded the highest mean grain yield (26.80 q/ha i.e., 1.72 percent increase over control) and the plots fertilised with 50 kg ZnSO₄/ha recorded mean grain yield to the tune of 26.73 q/ha.

Table 4.3 Effect of zinc and rice cultivars on test weight (g)

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	27.61	27.83	27.85	27.64
IR 68 (V ₂)	25.54	25.54	26.16	25.75
IET 9947 (V ₃)	27.22	26.91	27.54	27.22
IET 1809 (V ₄)	28.57	28.06	28.11	28.25
Biplab (V ₅)	25.81	26.08	26.36	26.08
MTU 7029 (V ₆)	28.05	27.98	28.23	28.09
Ajaya (V ₇)	28.62	28.57	28.59	28.60
MW 10 (V ₈)	26.87	26.25	26.70	26.61
IR 50 (V ₉)	25.34	26.05	25.91	25.77
IET 10384 (V ₁₀)	28.18	27.88	28.33	28.13
Mean	27.18	27.18	27.38	27.25

Effect of	SEm (±)	C.D. (0.05)
Zinc	6.2306	NS
Variety (V)	0.1335	0.379
Zn x Cultivars	0.2313	NS

Table 4.4 Effect of zinc and rice cultivars on grain yield (q/ha) of rice

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	28.20	21.77	28.00	25.98
IR 68 (V ₂)	11.86	22.67	19.067	17.87
IET 9947 (V ₃)	31.90	22.56	25.67	26.71
IET 1809 (V ₄)	14.50	18.66	23.17	18.78
Biplab (V ₅)	35.60	29.00	32.50	32.37
MTU 7029 (V ₆)	33.90	38.00	36.50	36.13
Ajaya (V ₇)	27.78	30.16	27.50	28.48
MW 10 (V ₈)	25.90	23.77	25.70	25.12
IR 50 (V ₉)	26.60	35.00	23.90	28.50
IET 10384 (V ₁₀)	27.67	26.40	25.33	26.47
Mean	26.39	26.80	26.73	26.64

Effect of	SEm (±)	C.D. (0.05)
Zinc	0.80060	3.143
Variety (V)	1.42035	4.0301
Zn x Cultivars	2.46013	6.9802

Table 4.5 Table 4.4 Effect of zinc and rice cultivars on straw yield (q/ha) of rice

4.2.1.2 Effect of cultivars on the yield of rice

Grain yield was significantly influenced due to the effect of rice cultivars (Table 4.4). It was revealed from the table that the highest grain yield (36.13 q/ha) was recorded with rice cultivar MTU 7029 (V_6) where as the lowest grain yield (17.87 q/ha) was obtained from the variety IR 68 (V_2). However, the yield of cultivar Biplab (V_5) was statistically at par with cultivar MTU 7029 (V_6).

4.2.1.3 Effect of interaction between zinc and rice cultivars

The interaction between zinc and rice cultivars had a significant effect on grain yield of wet season rice in rice-wheat cropping system (Tab- 4.4).

Highest grain yield (38.00 q/ha) was recorded with rice cultivars MTU 7029 (V_6) when treated with 25 Kg $ZnSO_4$ /ha. The lowest grain yield of 11.87 q/ha was recorded with the variety IR 68 (V_2) in the control plots.

It was interesting to note from the results due to the interaction effect that some cultivars of rice responded (V_2, V_4, V_6) positively due to application of zinc sulphate and some did not respond ($V_1, V_3, V_5, V_8, V_{10}$).

4.2.2 Straw Yield

4.2.2.1 Effect of Zinc

Straw yield was not markedly influenced by the soil application of zinc as zinc sulphate (Table 4.5).

However, the results revealed an increasing trend of straw yield due to application of zinc during wet season. The results also showed that the application of 50 Kg $ZnSO_4$ /ha recorded the highest mean straw yield (38.86 q/ha i.e. 4.6 percent increase over control) and the plots fertilised with 25 Kg $ZnSO_4$ /ha recorded mean straw yield to the tune of 37.68 q/ha.

4.2.2.2 Effect of cultivars

Straw yield was significantly influenced due to the effect of rice cultivars (Table 4.5). It was revealed from the table that the highest mean straw yield (59.91 q/ha) was recorded with rice cultivar MTU 7029 (V_6) where as the lowest straw yield (21.43 q/ha) was obtained from the variety IR 68 (V_2).

4.2.2.3 Effect of interaction

The interaction between zinc rice cultivars had a significant effect on straw yield of wet season rice in rice-wheat cropping system (Table 4.5).

Table 4.5 Table 4.4 Effect of zinc and rice cultivars on straw yield (q/ha) of rice

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	38.28	39.60	38.83	38.90
IR 68 (V ₂)	22.60	22.93	18.76	21.43
IET 9947 (V ₃)	45.54	40.26	43.53	43.11
IET 1809 (V ₄)	22.62	25.19	29.00	25.60
Biplab (V ₅)	39.60	43.06	48.51	43.73
MTU 7029 (V ₆)	53.46	61.49	64.79	59.91
Ajaya (V ₇)	28.87	32.34	31.35	30.85
MW 10 (V ₈)	35.15	34.32	36.46	35.31
IR 50 (V ₉)	39.60	36.63	37.40	37.88
IET 10384 (V ₁₀)	44.80	40.92	39.93	41.88
Mean	37.05	37.68	38.86	37.86

Effect of	SEm (±)	C.D. (0.05)
Zinc	0.5624	2.9509
Variety (V)	1.3724	2.9135
Zn x Cultivars	1.7786	7.9910

Table 4.6 Effect of zinc and rice cultivars on grain yield response (%)

Sub plot treatment Cultivars	Main plot treatment					Mean of yield response
	Zn ₀	Zn ₂₅		Zn ₅₀		
	Grain yield (q/ha)	Grain yield (q/ha)	Yield response (%)	Grain yield (q/ha)	Yield response (%)	
IET 4786 (V ₁)	28.20	21.80	-22.80	28.00	-0.71	-11.75
IR 68 (V ₂)	11.87	22.70	91.00	19.10	61.00	76.00
IET 9947 (V ₃)	31.90	22.60	-29.24	25.70	-19.52	-24.38
IET 1809 (V ₄)	14.50	18.70	28.75	23.20	59.79	44.27
Biplab (V ₅)	35.60	29.00	-18.53	32.50	-8.71	-13.62
MTU 7029 (V ₆)	33.90	38.00	12.09	36.50	7.66	9.87
Ajaya (V ₇)	27.77	30.20	8.64	27.50	-0.97	3.83
MW 10 (V ₈)	25.90	23.80	-8.10	25.70	-0.77	-4.43
IR 50 (V ₉)	26.60	35.00	31.50	23.90	-10.15	10.71
IET 10384 (V ₁₀)	27.70	26.40	-4.69	26.00	-6.14	-5.42
Mean (x̄)	26.39	26.80	8.869	26.81	8.148	8.508

For zinc sulphate @ 25 kg per hectare

Variety whose response is $> \bar{x} + 1.96 SE = 8.869 + 1.96 \times 11.227 = 35.87$ is taken as susceptible

Variety whose response is $< \bar{x} - 1.96 SE = 8.869 - 1.96 \times 11.227 = -13.135$ is taken as tolerant

For zinc sulphate @ 50 kg per hectare

Variety whose response is $> \bar{x} + 1.96 SE = 8.148 + 1.96 \times 9.00 = 25.788$ is taken as susceptible

Variety whose response is $< \bar{x} - 1.96 SE = 8.148 - 1.96 \times 9.00 = -9.49$ is taken as tolerant

Table 4.7 Residual effect of zinc applied to previous wet season rice cultivars on
Highest straw yield (64.79q/ha) was recorded with rice cultivar MTU 7029 (V₆) when treated with 50 Kg ZnSO₄/ha. The lowest straw yield of (18.76 q/ha) was obtained from the cultivar IR68 (V₂) treated 50 Kg ZnSO₄/ha.

4.3 Grain yield response percentage in rice cultivars due to the application of zinc sulphate

Percent response of grain yield (Table 4.6) over the control showed that IR 68 (V₂) gave highest response (76%) while least response was observed in Lalat (V₃) and others responded in between.

Considering the treatment of ZnSO₄ (25Kg /ha), the identification of susceptible and tolerant varieties was shown that IR 68 (V₂), IR 50 (V₉) are susceptible and IET 4786 (V₁), Lalat (V₃) and Biplab (V₅) were tolerant. It was revealed from the (Table 4.6) that the soil application of 50 Kg ZnSO₄/ha showed the varieties IR 68 (V₂), IET 1809 (V₄) were susceptible and variety Lalat (V₃) and variety IR 50 (V₉) were tolerant cultivars to zinc.

However, for finer (i.e. pin-pointed) identification, both the treatment effects were brought simultaneously under the analysis and on joint consideration of identification for both treatments, the conclusion might be reached that cultivars IR 68 (V₂), IET 1809 (V₄) are susceptible and cultivar Lalat (V₃) is tolerant to zinc application.

Experiment No. 2

4.2 Title of the experiment

Studies on the residual effect of zinc on wheat in the soils of preceding rice crops on succeeding wheat during dry season in rice-wheat cropping system.

4.2.1 Yield components

4.2.1.1 Number of Ear head /m²

4.2.1.1.1 Effect of residual zinc

Earhead/m² of wheat succeeding crop during dry season was insignificantly influenced due to the residual zinc applied in the soil at the time of wet season rice cultivation. The results revealed that the highest number of earhead/m² (545.40) was recorded due to the residual effect of soil application of zinc sulphate @50 Kg/ha as basal in the wet season rice.

Table 4.7 Residual effect of zinc applied to previous wet season rice cultivars on earhead per sq. m² of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	484.67	525.00	580.00	529.89
IR 68 (V ₂)	492.33	509.33	559.33	520.33
IET 9947 (V ₃)	579.67	623.33	595.67	599.56
IET 1809 (V ₄)	464.67	425.67	415.67	435.33
Biplab (V ₅)	547.33	565.00	538.67	550.33
MTU 7029 (V ₆)	572.00	512.00	469.00	517.67
Ajaya (V ₇)	559.33	579.33	556.67	565.11
MW 10 (V ₈)	562.33	641.33	590.67	598.11
IR 50 (V ₉)	511.67	389.33	601.67	500.89
IET 10384 (V ₁₀)	372.00	441.33	546.67	453.33
Mean	514.60	521.77	545.90	527.06

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	13.66	-	10.03
Variety (V)	26.84	53.84	10.80
Zn within V	45.14	90.57	-
V within Zn	46.48	93.26	-

Table 4.8 Residual effect of zinc applied to previous wet season rice cultivars on grains/earhead of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	18.67	17.67	17.00	17.78
IR 68 (V ₂)	16.00	16.33	16.00	16.11
IET 9947 (V ₃)	15.00	15.00	17.33	15.78
IET 1809 (V ₄)	18.00	20.00	22.67	20.22
Biplab (V ₅)	15.00	15.00	18.33	16.11
MTU 7029 (V ₆)	14.00	16.00	19.00	16.33
Ajaya (V ₇)	15.33	16.67	16.67	16.22
MW 10 (V ₈)	17.67	15.33	17.00	16.67
IR 50 (V ₉)	16.00	22.00	15.00	17.67
IET 10384 (V ₁₀)	19.00	17.00	18.00	18.00
Mean	16.47	17.10	17.70	17.09

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	0.347	-	7.87
Variety (V)	0.647	1.30	8.03
Zn within V	1.09	2.189	-
V within Zn	1.12	2.248	-

The number of earhead/m² obtained from the soil treated with ZnSO₄ @50 Kg/ha as basal exhibited an increase of 5.99 % over controlled plots of preceding rice.

4.2.1.1.2 Effect of rice cultivars

The residual effect of zinc in the soils of preceding 10 rice cultivars has significantly influenced the number of earhead/m² (Table 4.7). The results obtained from the experiment clearly indicated that the highest number (599.56) of earhead/m² was obtained in the soils where rice cultivar Lalat (V₃) was transplanted and lowest number (435.33) obtained from the plots where IET 1809 (V₄) was transplanted in the preceding season.

4.2.1.1.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect of earhead/m² of wheat between residual zinc and rice cultivars was found to be statistically significant.

4.2.1.2 Grains/earhead

4.2.1.2.1 Effect of residual zinc

Grains/earhead of wheat succeeding crop during dry season was not significantly affected because of the residual zinc applied in the preceding wet season rice in a rice-wheat crop rotation (Table 4.8). The results distinctly indicated that the highest number of grains/earhead was obtained owing to the residual effect of soil application of zinc sulphate @ 50 Kg/ha as basal in the preceding rice. The number of grains/earhead obtained from the soil treated with ZnSO₄ @ 50 Kg/ha as basal reflected an increase of 7.47 % over controlled-plots of preceding rice.

4.2.1.2.2 Effect of rice cultivars

The number of grains/earhead was significantly augmented due to the residual effect of zinc in the soils of preceding 10 rice cultivars (Table 4.8). The results showed that the highest number of grains/earhead (20.22) was recorded in the soils where rice cultivars IET 1809 (V₄) was transplanted.

4.2.1.2.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect between residual zinc and rice cultivars on grains/earhead of wheat was found to be significant when wheat variety 'Sonalika' was sown during dry season as a succeeding crop.

4.2.1.3 Test weight

4.2.1.3.1 Effect of residual zinc

Thousand grain weight of wheat succeeding crop during dry season was significantly influenced. And this is due to the residual effect of zinc applied in the preceding wet season rice in a rice-wheat crop rotation. From the Table 4.9 it is revealed that the test weight (37.89) of wheat grain was highest of due to the residual effect of soil application of zinc @ 25 Kg/ha as basal in the preceding rice. The wheat crop raised in the soils with 50 Kg ZnSO₄/ha as basal did not reveal significant difference in test weight over control plots of preceding rice.

4.2.1.3.2 Effect of rice cultivars

The test weight of wheat was not significantly influenced (Table 4.9). The results revealed that the highest test weight (38.13 g) was recorded from the plot where rice-cultivar IET 10384 (V₁₀) was transplanted. However, the lowest test weight was (37.28 g) recorded from the soils where rice-cultivar IET 4786 (V₁) was transplanted.

4.2.1.3.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect between residual zinc and rice cultivars on test-weight of wheat resulted in an influence which was statistically significant.

4.2.2 Grain yield

4.2.2.1 Effect of residual zinc

Grain yield of wheat as succeeding crop during dry season in rice-wheat cropping system was significantly influenced due to the residual zinc applied in the preceding wet season rice crop in a rice wheat rotation (Table 4.10). The results showed that the highest grain yield of wheat (35.82 q/ha) was obtained due to the residual effect of zinc sulphate application @ 50 Kg/ha as basal in the preceding rice. The wheat crop raised in the soils with 25 Kg ZnSO₄/ha as basal showed an increase of 4.6% yield over controlled plots.

4.2.2.2 Effect of rice cultivars on succeeding wheat

Wheat grain yield was significantly differed due to the residual effect of zinc in the soils of preceding 10 rice cultivars (Table 4.10). The results showed that the highest grain yield (36.14q/ha) was recorded from the soils where MW 10 (V₈) rice cultivar was transplanted.

However, the lowest yield of wheat (30.90 q/ha) was obtained from the soils where IET 10384 (V₁₀) rice cultivar was transplanted.

Table 4.9 Residual effect of zinc applied to previous wet season rice cultivars on test weight (g) of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	36.82	36.96	38.05	37.28
IR 68 (V ₂)	38.27	37.68	37.92	37.96
IET 9947 (V ₃)	37.65	38.08	37.26	37.66
IET 1809 (V ₄)	37.60	36.88	37.58	37.35
Biplab (V ₅)	38.10	37.94	37.89	37.95
MTU 7029 (V ₆)	37.57	38.33	37.02	37.64
Ajaya (V ₇)	37.40	38.49	37.98	37.96
MW 10 (V ₈)	37.29	37.90	36.81	37.33
IR 50 (V ₉)	37.84	38.21	37.89	37.98
IET 10384 (V ₁₀)	38.50	38.37	37.52	38.13
Mean	37.70	37.89	37.60	37.72

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	0.061	0.168	0.62
Variety (V)	0.205	0.412	1.15
Zn within V	0.340	0.683	-
V within Zn	0.356	0.714	-

Table 4.10 Residual effect of zinc applied to previous wet season rice cultivars on grain yield (q/ha) of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	33.20	34.88	36.62	34.90
IR 68 (V ₂)	30.68	31.44	33.87	32.00
IET 9947 (V ₃)	32.45	35.49	38.16	35.67
IET 1809 (V ₄)	31.49	32.51	34.26	32.75
Biplab (V ₅)	31.76	31.18	37.46	33.68
MTU 7029 (V ₆)	30.37	31.96	33.05	31.79
Ajaya (V ₇)	32.17	33.78	35.42	33.79
MW 10 (V ₈)	34.83	36.02	37.58	36.14
IR 50 (V ₉)	30.37	32.53	35.24	32.71
IET 10384 (V ₁₀)	27.38	28.81	36.50	30.90
Mean	31.47	32.92	35.82	33.40

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	0.457	1.268	5.3
Variety (V)	1.105	2.16	7.02
Zn within V	1.843	4.56	NS
V within Zn	1.913	2.89	NS

4.2.2.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect between residual zinc and rice cultivars on grain yield of wheat was found to be significant (Table 4.10).

4.2.3 Biomass yield

4.2.3.1 Effect of residual zinc

Biomass yield of wheat as succeeding crop during dry season was markedly influenced owing to the residual zinc applied in the preceding wet season rice in a rice-wheat rotation (Table 4.11). The results showed that the highest biomass yield of wheat (97.32 q/ha) was obtained because of the residual effect of soil application of zinc sulphate @ 50Kg/ha as basal in preceding rice. The wheat crop raised in the soils with 25 Kg zinc sulphate/ha as basal reflected an increase of 2.25 % biomass yield over controlled plots of preceding rice.

4.2.3.2 Effect of rice cultivars

The biomass yield of wheat was significantly increased due to the residual effect of zinc in the soils of preceding 10 rice-cultivars (Table 4.11). The results revealed that the highest biomass yield (103.04 q/ha) was recorded in the soils where rice cultivar Lalat was transplanted. However, the lowest yield of biomass (84.20q/ha) was obtained from the soils where rice cultivar was IET 1809 (V₄) was transplanted.

4.2.3.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect between residual zinc and rice cultivars of preceding rice plots was found to be statistically significant when wheat variety 'Sonalika' was sown during dry season as a succeeding crop. It was observed from the Table 4.11 that the plots of Zn tolerant rice variety showed significant increase of wheat biomass yield. However, the soils of susceptible rice cultivars did not respond well.

4.2.4 Harvest index

4.2.4.1 Effect of residual zinc

Harvest index of succeeding wheat crop during dry season was significantly influenced because of the residual zinc applied during wet season rice crop (Table 4.12). The results showed that the highest harvest index (0.369) of wheat was obtained due to the residual effect of soil application of zinc sulphate @ 50 Kg/ha as basal during wet season rice cultivation. The difference between harvest index of wheat obtained under the treatment of zinc sulphate @ 25 Kg/ha and control was not significantly influenced.

Table 4.11 Residual effect of zinc applied to previous wet season rice cultivars on biomass yield (q/ha) of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	92.23	98.61	106.92	99.25
IR 68 (V ₂)	87.38	88.54	96.23	90.72
IET 9947 (V ₃)	99.18	106.01	103.92	103.04
IET 1809 (V ₄)	88.74	81.14	82.72	84.20
Biplab (V ₅)	98.39	97.40	97.13	97.64
MTU 7029 (V ₆)	93.04	96.25	89.67	92.99
Ajaya (V ₇)	97.85	95.54	98.95	97.45
MW 10 (V ₈)	98.90	108.94	100.76	102.87
IR 50 (V ₉)	91.09	82.68	93.31	89.03
IET 10384 (V ₁₀)	73.87	86.24	103.61	87.91
Mean	92.07	94.14	97.32	94.51

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	1.721	NS	7.05
Variety (V)	3.670	7.362	8.24
Zn within V	6.152	12.342	-
V within Zn	6.356	12.753	-

Table 4.12 Residual effect of zinc applied to previous wet season rice cultivars on harvest index of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V ₁)	0.360	0.353	0.342	0.352
IR 68 (V ₂)	0.351	0.355	0.351	0.352
IET 9947 (V ₃)	0.327	0.334	0.367	0.343
IET 1809 (V ₄)	0.357	0.400	0.415	0.390
Biplab (V ₅)	0.322	0.327	0.385	0.345
MTU 7029 (V ₆)	0.326	0.332	0.368	0.342
Ajaya (V ₇)	0.328	0.353	0.357	0.346
MW 10 (V ₈)	0.358	0.330	0.374	0.354
IR 50 (V ₉)	0.333	0.393	0.377	0.368
IET 10384 (V ₁₀)	0.373	0.334	0.354	0.354
Mean	0.343	0.351	0.369	0.355

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	0.0082	0.23	8.9
Variety (V)	0.0091	0.018	5.5
Zn within V	0.016	0.032	-
V within Zn	0.0157	0.0315	-

4.2.4.2 Effect of rice cultivars

The harvest index of wheat was markedly increased due to the residual effect of zinc applied in the soils of preceding 10 rice cultivars (Table 4.12). From the table it was obvious that the highest harvest index (0.390) was recorded in the soils where rice-cultivar IET 1809 (V₄) was transplanted, while the lowest harvest index (0.342) was obtained from the plots where MTU 7029 (V₆) was transplanted.

4.2.4.3 Effect of interaction between residual zinc and rice cultivar

The interaction effect between residual zinc and rice cultivars of preceding rice plots on harvest index of wheat was observed to be statistically significant when wheat variety 'Sonalika' was sown during dry season as a succeeding crop.

4.2.5 Plant height

4.2.5.1 Effect of residual zinc

The plant height of wheat succeeding crop during dry season was significantly influenced due to the effect of residual zinc applied in the preceding wet season rice crop in rice-wheat cropping system (Table 4.13). The results showed that the highest plant height of wheat was recorded (97.47 cm) due to the residual effect of zinc sulphate application @ 50 Kg/ha as basal in the preceding rice. But no significant difference regarding plant height is obtained from the two treatments like zinc sulphate (0) and zinc sulphate (25 Kg/ha).

4.2.5.2 Effect of rice cultivars

The plant height of wheat was significantly increased due to the residual effect of zinc in the soils of preceding 10 rice cultivars (Table 4.13) from the table it is obvious that the highest plant height (98.70 cm.) was recorded in the soils where rice cultivars IET 4786 (V₁) was transplanted. However, the lowest plant height (93.97 cm.) was obtained from the plots where rice cultivar MW10 (V₉) was transplanted.

4.2.5.3 Effect of interaction between residual zinc and rice cultivars

The interaction effect between residual zinc and rice cultivars on plant height during harvesting was found to be statistically significant.

Table 4.13 Residual effect of zinc applied to previous wet season rice cultivars on plant height (cm) of wheat during dry season in rice-wheat cropping system

Treatment	Zn ₀	Zn ₂₅	Zn ₅₀	Mean
IET 4786 (V₁)	98.60	98.80	98.70	98.70
IR 68 (V₂)	97.70	96.27	95.73	96.57
IET 9947 (V₃)	95.10	97.60	100.50	97.73
IET 1809 (V₄)	96.50	98.70	98.40	97.87
Biplab (V₅)	100.20	96.00	98.20	98.13
MTU 7029 (V₆)	97.00	99.00	98.20	98.13
Ajaya (V₇)	97.10	96.90	101.80	98.60
MW 10 (V₈)	94.90	94.00	93.00	93.97
IR 50 (V₉)	94.60	93.90	96.20	94.90
IET 10384 (V₁₀)	94.60	95.70	94.00	94.77
Mean	96.63	96.71	97.47	96.94

Effect of	SEm (±)	C.D. (0.05)	C.V. (%)
Zinc	0.189	0.523	0.57
Variety (V)	0.793	1.59	1.73
Zn within V	1.309	2.627	-
V within Zn	1.373	2.754	-

DISCUSSIONS

From the above results it was obvious that the yield of rice cultivars played an important role in the variation of grain yield of wet season rice in rice-wheat-cropping system under acidic terai Agro-climatic condition. The effect of rice cultivars on grain yield was attributed to increased number of panicle bearing tillers and higher number of filled grains per panicle.

This result corroborated the findings of several workers. (Ramadass and Krishnasamy, 1992 ; Balasundaram *et al.*, 1981; Saravanan and Ramanathan, 1988; Velu and Savithri, 1985).

Production of crops is a result of co-ordinated interplay of the hereditary factors and environmental conditions upon the internal physiological processes of the plant, (Sahu, 1967). In view of the physiological significance of zinc and its poor presence in the soils all over the world, in general it appears that there is enough scope of improvement of crops through zinc fertilization in rice based cropping system and its residual effect to the succeeding crops.

5.1 Experiment No. 1

Title of the experiment

Studies on the effect of zinc on wet season rice in rice-wheat cropping system.

Yield components, yield and yield response

The cultivar MTU 7029 (V₆) recorded the highest grain yield during the wet season in rice-wheat cropping system and the performance of Biplab (V₅) was at par with MTU 7029 (V₆). The soil application of zinc in the form of zinc sulphate had no significant effect on the grain yield during wet season of experimentation (Table 4.4). As the grain yield of rice depends on the three yield components, viz., number of matured panicles per square metre, number of filled grains per panicle and thousand grain weight, so matured panicles per square metre and number of filled grain per panicle mainly contributed in variation on grain yield by the cultivars.

It was revealed from the Table 4.7 and 4.8 that the soil application of zinc in the form of zinc sulphate did not register any remarkable influence on the yield and yield components of rice during the wet season in acidic (pH 5.8) submerged soils of experimentation. This

result may be possible due to inclusion of both susceptible and tolerant cultivars in the sub-plot treatments. Further, such results of zinc applied in the form of zinc sulphate as basal may be due to non-availability of applied zinc in submerged soil. Yosida (1975c) observed that the availability of both soil zinc and applied zinc is much lower in submerged soils than in upland soils.

The number of matured panicles per unit area in rice is influenced by hereditary, environmental (seasonal) and nutritional conditions. Thus, the number of matured panicles per square metre differed due to the effect of rice cultivars. Rai and Murty (1977), Saha (1994) opined alike.

The difference in number of filled grains per panicle and test weight due to the effect of cultivars was also observed by various workers (Brown *et al.*, (1972), (Mandal and Chatterjee, 1973b; Rao *et al.*, 1984).

From the results presented in Table 4.6, it was evident that the different rice cultivars had played a crucial role in the variation of response. These variations of response could be ascribed to their genomic difference. The results of this study also revealed that cultivar Lalat (V₃) showed poor response under Zn stress condition while rice cultivars IR 68 (V₂) and IET 1809(V₄) showed considerable response.

Thus it may be concluded that rice cultivar Lalat appeared to be tolerant to zinc and might be able to thrive well on soils prone to zinc deficiency and on the other hand adequate zinc fertilization to the soils is an essential pre requisite for obtaining higher grain yields response in susceptible cultivars viz., IR 68 (V₂) and IET1809 (V₄) under zinc deficiency condition because of their low capability in utilising native and applied zinc. Similar response on grain yield due to zinc application in different lines of rice cultivars was observed in a continuous cropping experiment at IRRI (Yoshida *et al.*, 1973). The differences in grain yield response of rice cultivars may be considered owing to the different abilities of varieties to absorb and translocate zinc (Bergmann 1992; Yoshida, 1981).

5.2 Experiment No. 2

Title of the experiment

Studies on the residual effect of zinc on wheat in the soils of preceeding rice crop on succeeding wheat during dry season in rice-wheat cropping system.

Grain yield of wheat during dry season significantly increased due to the residual effect of zinc (as $ZnSO_4$) application as basal in the preceding wet season rice. It was observed from the Table 4.10 that an increase of 13.82 and 4.6 percent over control was recorded due to soil residual effect of soil application of 50 Kg and 25 Kg $ZnSO_4$ /ha in the preceding rice crop. Increase in grain yield of wheat due to residual zinc in a rice-wheat cropping system was also observed by Prasad *et al.*, (1981), Sharma and Das (1982), Boawn *et al.*, (1960); Brown *et al.*, (1964), Bhardwaj and Prasad, (1981), Takkar and Nayyar (1982). Grain and Biomass yield of wheat significantly differed (Table 4.10 and 4.11) due to the residual effect of zinc in the soils of preceding 10 rice cultivars treatments in the sub-plots. This happened mainly due to the fact that the number of ear head per square metre as usual had a close relationship with the grain yield per unit area. The wheat yield differences among the soils (plots) where 10 rice cultivars grown during the preceding wet season, were mainly due to their differences in number of ear head per unit area and number of grains per ear and greater utilisation of residual zinc. This finding was also observed by Sharma *et al.*, (1979). This may be due the more receptivity of stigma and thus more number of grains per year. The lower wheat grain yield in dry season may be resulted due to much more utilisation of applied zinc by the preceding tolerant rice cultivars. However, higher wheat grain yield in rice wheat cropping system was obtained from the soils (plots) where susceptible rice cultivars were transplanted, might be due to the less utilisation of applied zinc to the previous wet season rice. The significant contribution of residual zinc towards the wheat grain yield in rice-wheat cropping system was also observed by several workers (Savithri 1978; Brown 1972).

SUMMARY AND CONCLUSION

Rice and wheat are the most important food crops in the world, on the consideration of both, the area under the crop and the number of people depending on it.

To study the effect of zinc on rice cultivars and its residual effect on wheat, a field experiment was designed in split-plot at the teaching farm of Pundibari during 1999 (wet season rice) and 1999-2000 (wheat during dry season). The treatments consisted three level of zinc i.e., main plot treatments 0, 25 and 50 Kg ZnSO₄/ha (symbolized as Zn₀, Zn₂₅, Zn₅₀ respectively); ten different rice cultivars as sub-plot treatments viz., IET 4786, IR68, Lalat, IET 1809, Biplab, MTU 7029, Ajaya, MW10, IR 50 and IET 10384 (symbolized as V₁, V₂, V₃, V₄, V₅, V₆, V₇, V₈, V₉ and V₁₀ respectively) during wet season and wheat (Variety Sonalika) was sown in the plots as succeeding crops without further application of zinc in a rice-wheat cropping system.

Different levels of zinc sulphate had no significant influence on growth attributes and yield of wet season rice. However, soil application of zinc as zinc sulphate showed an increasing trend. Application of 25 Kg. ZnSO₄/ha recorded the highest mean grain yield (26.80 q/ha i.e., 1.72 percent increase over control) and the plots fertilised with 50 Kg. ZnSO₄/ha recorded mean grain yield to the tune of 26.73 q/ha. Grain yield was significantly influenced due to the effect of rice cultivars. The highest grain yield (36.13 q/ha) recorded with rice cultivar MTU 7029 was associated with higher number of matured panicles per square metre. The decrease in yield was associated with decrease in the yield components. It was also evident that the different rice cultivars had played a crucial role in the variation of response. These variations of response could be attributed to their genomic difference. The results indicated that IR68 and IET 1809 were susceptible and cultivars Lalat and IR 50 were tolerant cultivars to zinc. So adequate zinc fertilization to the soils is an essential pre-requisite for obtaining higher yields in susceptible cultivars viz., IR68 and IET 1809.

Grain yield of wheat during dry season (1999-2000) as succeeding crop in rice-wheat cropping system significantly increased due to the residual effect of zinc. The results indicated that an increase of 13.82 and 4.6 percent over control was recorded due to soil residual effect application of 50 Kg and 25 Kg ZnSO₄/ha in the preceeding rice crop. However, higher wheat grain yield in rice wheat cropping system was obtained from the soils

(plots) where susceptible rice cultivars were transplanted and it might be associated with the less utilisation of applied zinc to the previous wet season rice.

Keeping in view the results obtained from the experiment as summarised above, it may be concluded as follows :

1. That application of zinc as $ZnSO_4$ improved yield components and yield of zinc susceptible rice cultivars in *tarai* soils.
2. Wheat sown as succeeding crops after susceptible rice cultivars in rice wheat cropping system achieved higher grain yield.
3. That 25 Kg $ZnSO_4/ha$ applied as basal in the wet season rice may be recommended for cultivation of susceptible rice cultivars in rice-wheat cropping system where wheat variety Sonalika is recommended.

FUTURE SCOPE OF RESEARCH

- Agarwala, S. C., Mehrotra, N.K., Ahmad, S. and Sharma, C.P. (1980) Crop response to zinc sulphate in rice. *Indian J. Agron.* 27: 1-4.
- In the present investigation only one source of zinc namely zinc sulphate in three different levels was applied in ten different rice cultivars during wet season to study the effect on yield components and yield of wet season rice and its residual effect on wheat during dry season. There is a further scope to include more number of rice cultivars of three different durations namely, early, medium and long. Besides the rice cultivars other methods of zinc application namely basal and foliar may be included. No attempt has been made in the present investigation to measure the pattern of uptake of zinc by rice as well as residual zinc in soil and uptake of residual zinc by the succeeding wheat crop. This experiment was carried out during wet and dry season. There is a scope to investigate such trials for atleast three years to recommend the amount of zinc to be applied in wet season rice and to screen the susceptible rice cultivars.
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