"Accumulation of Zinc in Different Parts of Paddy Varieties as Influenced by Levels of Zinc Application in Vertisols"

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

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By

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CERTIFICATE – I

This is to certify that the thesis entitled ***"Accumulation of Zinc in Different Parts of Paddy Varieties as Influenced by Levels of Zinc Application in Vertisols"*** *submitted in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRICULTURE (Soil Science and Agricultural Chemistry)*** *of* ***Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur*** *is a record of the bonafide research work carried out by* ***Mr. Jitendra Patidar*** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help, received during the course of the investigation has been duly acknowledged by him.

Place: Jabalpur
Date 29/07/10

Dr. B.L. Sharma

(Chairman of the Advisory Committee)

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	**Dr. M.L. Kewat**	.....
Member	**Dr. H.L. Sharma**	.....

CERTIFICATE – II

This is to certify that the thesis entitled ***"Accumulation of Zinc in Different Parts of Paddy Varieties as Influenced by Levels of Zinc Application in Vertisols"*** *submitted by* ***Mr. Jitendra Patidar*** *to the* ***Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur*** *in partial fulfillment toward the requirement for the degree of* ***"Master of Science in Agriculture"*** *in the Department of* ***Soil Science and Agricultural Chemistry*** *has been approved by the Student's Advisory Committee and the External Examiner's after an oral examination of the same.*

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INTRODUCTION

Rice (*Oryza Sativa* L.) is the major staple food crop of India. It is widely grown in South-Eastern part of the country covering an area of 43.08 million hectares with an annual production of 92.6 million tonnes. Productivity of rice in India is 1.8 t ha^{-1}, which is quite low as compared to other rice growing countries like Japan (6.8 t ha^{-1}), Korea (6.1 t ha^{-1}), China (5.9 t ha^{-1}) and Indonesia (4.3 t ha^{-1}). In Madhya Pradesh 1.83 million hectare areas is under rice with an annual total production of 5.37 million tonnes with the average productivity of 1.06 t ha^{-1} is quite less than national average.

Zinc is an essential micronutrient for biological systems. One of the critical physiological roles of Zn in biological system is its role in protein synthesis and metabolism. In biological system Zn is required by largest number of proteins. It has been estimated that nearly 2800 human proteins are capable of binding Zn which corresponds to 10% of human proteome (Andreini et al., 2006). Almost 40 % of the Zn-binding proteins are transcription factors needed for gene regulation and the 60 % enzymes and proteins involved in ion transport (Andreini et al., 2006). Zn is also a critical micronutrient required for structural and functional integrity of biological membranes and for detoxification of highly aggressive free radicals (Cakmak, 2000). Any alteration in Zn homeostasis or any decrease in Zn concentration of human body will, therefore, result in number of cellular disturbances and impairments such as (1) immune dysfunctions and high susceptibility to infectious diseases, (2) retardation of mental development and (3) stunted growth of children (Black et al., 2008).

Zinc deficiency problem has been recognized as a very serious threat to human health, especially to child. Together with

vitamin A deficiency, Zn deficiency has been considered as the top priority problem facing the world currently by eight worldwide distinguished economist (including five Novel Laureates) at the Copenhagen Consensus Conference. Children are particularly sensitive to Zn deficiency. Zinc deficiency has been shown to be a major cause of child death in the world, and responsible for nearly 450,000 deaths in children under 5 years of age, that corresponds to 4.4% of the deaths of children less than 5 years of age globally (Black et al., 2008).

It is estimated that nearly half of the world population is affected from Zn deficiency as a consequence of low dietary intake of Zn. High consumption of cereal-based foods with low amount and bioavailability of Zn deficiency in human populations, especially in developing world. In most of the developing countries cereal grain, especially wheat and rice, contributes to about 70 % of the daily calorie intake.

Cereals are, however, inherently very low in concentrations of Zn to meet daily requirement of human (Cakmak, 2008). The Zn deficiency problem in cereal grains is aggravated by growing cereal crops on potentially Zn deficient soils. Soil Zn deficiency is also a well-documented problem that reduces crop production. Under Zn-deficient soil condition, plants show a high susceptibility to environmental stress factors such as drought stress and pathogenic infections, and develop severe symptoms such as leaf necrosis and stunting growth.

Micronutrients play much complex role in plant nutrition. Zn is a component of series of enzymes. It is required for the formation of certain microbial enzymes. The main function of zinc in plants is largely as activator of enzymes viz. carbonic anhydrase, Alcohol dehydrogenase, Glumatic dehydrogenase, L-lactic dehydrogenase, D-glyceraldehyde 3 phosphate dehydrogenase, malic dehydrogenase, D-lactic dehydrogenase, D-lactic cytochrome- C-reductase and aldolase. Zinc is also a

component of the enzyme system that leads to the formation of indole acetic acid from tryptophane which is found in plants and also in the activity of dehydropeptidase and glycoglycine dipeptidase, which play a specific role in the protein metabolism. Zinc is also a constituent part of dehydrogenase in yeast and of Galactose oxidase in moulds. Zinc help regulating auxin concentration in plant. It is a constituent of several enzymes with role in carbohydrate and protein synthesis, maintaining the integrity of membranes, regulating auxin synthesis and in pollen formation. It promotes flower setting and helps in proper development of fruits. It helps in carbohydrate transformation. The metal is found to regulate oxidation and reduction processes in plants. Zinc has a specific role in human and animal health. It is essential for DNA and protein synthesis, cell division and growth. Zinc is required for male and female reproduction and neurological function.

Zinc is also essential for immune function and its deficiency impairs resistance to infection. Zinc may be important in host defense against cancer. Marginal zinc deficiency in humans and animals can result in several undesirable consequences including dermatitis, reduced growth rates of infants and children impaired immune function, diminished learning ability, delayed male sexual development, prolonged wound healing, taste dysfunction, impaired dark adaptation, anorexia, diarrhoea, depressed mood, abnormal fetal growth ,prematurity, prenatal and difficulty in parturition.

The importance of genetic variability in plant species cannot be disregarded in seeking its adaptability to a specific environment. The absorption of the Nutrient is governed by a genome that is inherited. The experiences of various scientists have shown that the performance of a resistant variety is at optimum under nutrient stress conditions whereas others may completely fail to survive. In order to recommend a variety for Zn

deficient areas it is necessary to test the susceptibility or tolerance of some rice varieties to Zn deficiency.

If Zinc deficiency is not diagnosed and rectified timely, the problem will become alarming in the years to come because land has to be cultivated more intensively to have extra production to meet the requirement of increasing population. Looking to above study was undertaken with the following objectives-

- To study the effect of zinc level and methods of application on translocation of zinc in different plant parts of paddy varieties.
- To study the effect of yield and uptake of zinc by paddy varieties.
- To study in buildup of zinc in post harvest soils.

CHAPTER – II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Generally, nutrient deficiencies in soils and plants are monitored through fertilizer responses, field trials soil and plant analysis. Soil and plant analysis indicate only the possible occurrence of micronutrients deficiencies while the field trials provide information about the magnitude of increase in crop yield that could be attained with application of suitable fertilizers containing these nutrients as well as their optimum rates of application besides revealing their deficiency status in soils. The field trials, however, are the most important parameter for confirming the actual status of deficiency in soils and the benefits arising from fertilization of crops on such soils. Research work done on various aspects of zinc in soils and their role in crop production has been reviewed in this chapter.

2.1 Effect of Zn on yield attributes, yield and chemical composition of rice.

Sakal *et al.* (1993) conducted on Zn-deficient calcareous silt loam soils at 2 sites in Bihar assessed the response of rice cv. Sita to different application dates and rates of Zn. Applied Zn increased grain yield and plant uptake of Zn at both sites. At Pusa, yield was highest (5.41 t/ha) with 25 kg $ZnSO_4$ ha^{-1} applied at transplanting. At Dholi, yield was highest with 50 kg ha^{-1} applied at transplanting (4.04 t ha^{-1}), but this was not significantly different from applying 25 kg Zn ha^{-1} (yield 3.93 t ha^{-1}). Applying some of the Zn at tillering or panicle initiation, or using a $ZnSO_4$ foliar spray, decreased rice yield compared with basal application.

Yilmaz *et al.* (1997) studied the effect of six different zinc (Zn) application methods on grain yield and concentrations of Zn in whole shoots and grain was studied in rice cultivars grown on severely Zn-deficient calcareous soils (DTPA-extractable Zn:

0.12 mg kh^{-1} soil). Zinc application methods tested were: (a) control (no Zn application), (b) soil, (c) seed, (d) leaf, (e) soil + leaf, and (f) seed + leaf application. Irrespective of the method, application of Zn significantly increased grain yield in all cultivars. Compared to the control, increases in grain yield were about 26% with soil, soil + leaf, and seed + leaf, 20% with seed and 12% with leaf application of Zn. In a similar manner, biomass production (dry weight of above-ground parts) was increased by Zn treatments. The highest increase (10%) was obtained with the soil application and the lowest increase (4%) with leaf application. Significant effects of Zn application methods were also found on the yield components, i.e., effective tillers m^{-2}, grain number-penical^{-1}, and thousand grain weights. Effective tillers M^{-2} was affected most by Zn applications, particularly by soil and soil + leaf applications.

Qureshi (2001) conducted to study the effect of time and various levels of $ZnSO_4$ application on yield and yield components of fine rice variety Basmati-385. Six levels of $ZnSO_4$ including control (0, 10, 20, 30, 40, and 50 kg ha^{-1}) were applied before or after paddling. Time of application had no effect. It gave similar results either applied before or after paddling. The soil used in these studies was seemed to be deficient in Zn and the added Zn reports were positive. Number of tillers m-2, panicle bearing tillers m, spike length, number of spikelet's per panicle were affected significantly by the application of various levels of $ZnSO_4$. $ZnSO_4$ applied @10 kg or 20 kg ha^{-1} did not differ from each other significantly. 1000 grain weight and harvest index was not affected significantly by various $ZnSO_4$ levels and time of application. Straw and paddy yields were affected significantly by various $ZnSO_4$ levels. T_2 (10 kg $ZnSO_4$ ha^{-1}) and T_3 (20 kg $ZnSO_4$ ha^{-1}) gave the highest yield and were at par with cacti other This was concluded from the results that the application of $ZnSO_4$ at the rate of 10 kg ha^{-1} after or before

paddling was the most economical dose for obtaining higher yield.

Jena *et al.* (2006) conducted a field experiment on a clay loam soil to find out a better zinc practices for transplanted rice using the test variety MTU2067. The result revealed that soil application of 50 kg $ZnSO_4$ ha^{-1} followed by foliar spray of Zn-EDTA (equivalent to 0.2% $ZnSO_4$) and seeding root dip with ZnO (equivalent to 10 kg $ZnSO_4$ ha^{-1}) significantly increased the growth characters, yield attributes, grain and straw yield. Soil application of $ZnSO_4$ @ 50 kg/ha recorded 25 per cent increase in grain yield over control.

Bakhsh Kelarestaghi *et al.* (2006) revealed that application of 40kg ha^{-1} zinc sulphate could significantly improve many of these indices including; plant height, test weight ,grain and protein yield as well as harvest index, triticale had significantly higher zinc uptake efficiency (97%) in comparison to durum wheat.

Khan *et al.* (2007) studied the response of Zinc application in rice-wheat system. Two levels of zinc 5 and 10 kg ha^{-1} with control were studied with the basal dose of N, P_2O_5, and K_2O as 120-90-60 kg ha^{-1} in the form of urea, TSP, SOP and zinc sulphate during both the crops. Rice variety IRRI 6 and Wheat variety Naseer 2000, both were planted in R.C.B design with three replications. Zn application, significantly affected paddy grain yield, ranged from 3.9 to 5.9 t ha^{-1}, the highest yield was obtained from 10 kg Zn ha^{-1}. The number of tillers, spike m^{-2}, spike length, plant height and 1000 grain weight of paddy were also significantly affected over control with the same treatment. Wheat yield was also significantly affected by Zn levels ranged from 2.7 to 3.5 t ha^{-1} giving highest 31.6% over control at from 5 kg Zn ha^{-1}. Similarly Zn application also affected significantly to the yield parameters of wheat like the number of spike m^{-2}, number of spike/plant, spike length, plant height and 1000 grain

weight over control from the above said treatment of 5 kg Zn ha^{-1}. The concentration of zinc in soil and leaves was significantly affected by the application of zinc in rice and wheat, ranged from 0.45-1.18; 29.32-40.67 mg kg^{-1} in rice and 0.47-1.37, 22.6-367.37 mg kg^{-1} in wheat, respectively

Ali Khourgani and Bour (2008) studied at the field station of Azad Islamic university Iran. Nitrogen treatment had a significant effect on plant height, test weight, seed yield, biological yield, harvest index and protein content but Zn treatment had a significant effect on thousand seed weight and protein content.

Khan *et al.* (2008) reported that the Zinc sulphate increased the leaf Area Index, the total number of fertile tillers m^{-2} number of spikelets $spike^{-1}$, spike length, grains spike, test weight, grain yield, straw yield, biological yield and decreased harvest index. Most of the response trends were curvilinear although the decrease in harvest index was linear. All applications of zinc sulphate gave economic increases in margins over costs but the application of 5kg ha^{-1} gave the highest marginal rate of return. It is recommended that under calcareous soil conditions growers can expect good returns from the application of 5 kg zinc sulphate ha^{-1} at the time of sowing but if the grain price were to increase or the price of zinc sulphate were reduced economic responsed could be expected from higher levels of zinc sulphate.

2.2 Effect of Zn on yield grain and straw of paddy

Sharma *et al.* (1996) reported that the yield of rice significantly increased with the application of zinc in Zn deficient soil. They also observed an increased concentration of Zn in plant tissue, grain and straw and its uptake.

Sakal *et al.* (1993) conducted on Zn-deficient calcareous silt loam soils at 2 sites in Bihar assessed the response of rice cv. Sita to different application dates and rates of Zn. Applied Zn increased grain yield and plant uptake of Zn at both sites. At Pusa, yield was highest (5.41 t/ha) with 25 kg $ZnSO_4$/ha applied at transplanting. At Dholi, yield was highest with 50 kg/ha applied at transplanting (4.04 t/ha), but this was not significantly different from applying 25 kg/ha (yield 3.93 t/ha). Applying some of the Zn at tillering or panicle initiation, or using a ZnSO4 foliar spray, decreased rice yield compared with basal application.

Devarajan and Ramanathnan (1995) conducted field trials and red soil at Bhavnisagar, Tamil Nadu, rice Cv. IR 20 was given 0-100 kg $ZnSO_4$ ha^{-1} to every crop. Once in 3 crops or once in crops, they reported that grain yield was highest when Zn was applied $ZnSO_4$.

Sarkunan *et al.* (1996) also observed 22 percent improvement in rice yield with the application of 25 mg kg^{-1} Zn.

Tandon (1996) conducted a field experiment on a soil containing 0.93 ppm available Zn and 0.81 ppm available Fe at Kanpur, Uttar Pradesh, Rice cv. IR-20, Jaya, Pusa 2-21, and IET-1444 were given 0, 20, and 40 kg/ha of $ZnSO_4$ and $FeSO_4$. Fe and Zn applications generally increased grain yield. Jaya and IR-20 were not affected by Fe and Zn application. IET-1444 gave the highest grain yield of 4.48 tha^{-1} with 40 kg $FeSO_4$.

Khanda and Dixit (1996) conducted at Bhubaneshwar, Orissa, during summer 1991 and 1992 with 2 sources of zinc ($ZnSO_4$ and Zn-EDTA), 2 methods of application (soil and foliar) and/or 4 levels of nitrogen (0, 30, 60, 90 kg/ha) applied to rice cv, Sarathi. Combined application of zinc and nitrogen increased grain yield by 7.2% compared with nitrogen alone. Economic return was increased by combined N and Zn application, while among N rates the highest return per rupee invested was given

by 90 kg/ha. Uptake of nitrogen and zinc increased progressively with increased levels of nitrogen. Among the methods of application, soil application of zinc was superior to foliar spray.

Malakouti (1998) conducted a field trial with two levels of zinc and found that, zinc application increased grain yield by up to 20 and 25% in first and second trial respectively, over control and Zn concentrations in grain increased, mean grain yield was 4460 kg ha^{-1} in controls and 5143 kg ha^{-1} in plots given zinc fertilizers. Zinc application increased Zn content to 35 ppm, as compared with 25 ppm in control.

On the basis of three year continuous studies in rice-wheat rotation at Kaul (Haryana), Dhiman *et al.* (1998) revealed that application of 150% recommended dose of fertilizers to both the crops gave maximum grain yields of 11.16 t ha^{-1} in each year, which was 13.8 more than that of recommended dose (120 kg N + 60 kg P_2O_5 + 25 kg ha^{-1} Zn SO_4).

Alam *et al.* (2000) studied a pot experiment rice varieties Kashmir Basmati and IR-6 were compared for their response to Zn application under varied rates of applied P. At lower P rate cv. IR-6 responded to applied Zn significantly lesser than cv. Kashmir Basmati, but at higher P rates response to Zn for shoots and roots yield of cv. IR-6 was significantly higher than cv. Kashmir Basmati. Application of Zn improved root/top ratio at all rates of P and increase was more at lower compared to higher rates of applied P. Variety x Zn interaction was significant for top growth indicating a higher response of cv. IR-6 to applied Zn while the two varieties produced similar dry matter yield where Zn was not applied.

Debnath and Brahmachari (2001) reported that in an Inceptisol (available Zn, 0.5 ppm) the highest yield was recorded with the application of 30 kg ha^{-1} $ZnSO_4$ but the uptake of Zn in grain and straw was maximum with the highest level of $ZnSO_4$ in

soil. The residual effect of Zn application on the yield of rice was found to be best with 30 kg ha^{-1} $ZnSO_4$. Thus, the residual effect of applied Zn suggests that Zn application once in 2 or 3 years would be beneficial for maintaining adequate level of available Zn as well as yield potential of the soils.

Prasad *et al.* (2002) conducted a field experiment in Bihar for five year, to study the optimal frequency of zinc fertilizer application on zinc deficient soil in the rice-wheat cropping system. The result indicated that the rate of increase in yield of rice and wheat was 52.40 and 21.00 kg per kg zinc sulphate respectively and the per cent increase in yield of rice was 46.60 and 38.10 in wheat- rice and wheat cropping system and there was significant correlation with zinc removal.

Begum *et al. (2003)* studied the effects of rate and method of Zn application in transplant aus rice (cv. BR26). The Zn treatments increased significantly the grain and straw yield over control. Dipping seedling roots in 2% ZnO suspension for 24 hours gave the best economic return and its grain yield 3.80 t ha^{-1} which was statistically identical to the yield (3.82 and 3.81 t ha^{-1}) of soil application of 5 and 7.5 kg ZnO ha^{-1} respectively

Mehla (2004) conducted a field experiment to study the effect of Zn (at 5, 10 and 20 kg ha^{-1}) application frequency in rice (*Oryza sativa* cv. HKR 120) - wheat (*Triticum aestivum* cv. HD 2329) cropping system in 1989-92 at Kaul, Haryana, India. The grain yield of rice and wheat increased significantly with Zn application compared with the control. Rice exhibited more response to Zn than wheat. Zn at 5 kg ha^{-1} applied to rice every year was economical and resulted in high yields of both rice and wheat.

Sharma *et al.* (2005) studied the effect of levels and methods of zinc fertilization on yield, concentration and uptake of zinc by rice. Zinc was incorporated in the soil at the rate of 0,

5.6, 11.2 and 22.4 kg Zn per ha as zinc sulfate; sprayed on the plants at 1% and 2% zinc sulfate solution ; and roots of rice seedlings were dipped in 2% and 4% ZnO suspensions in water. Grain yield, zinc content and its uptake increased in all the experiments up to 22.4 kg Zn per ha. Soil applied zinc was significantly correlated with yield of rice (r=0.80) and zinc uptake (r = 0.89). Zinc content in 45 day old plants gave a significantly higher correlation with grain yield (0=0.84) than the zinc content of rice straw and grain at maturity.

Nathan *et al.* (2005) evaluated the Zn nutrition and grain yield response of rice as affected by Zn-fertilizer source and application time. Four field trials were conducted to evaluate several Zn sources. Zinc treatment included Zn solution sprayed at 1.1 to 2.2 kg Zn ha^{-1} and dry-granular Zn fertilizers broadcast at 11.2 kg Zn ha^{-1}. Zinc-fertilizer source, averaged across application times, significantly affected grain yield at all sites with Zn fertilization increasing yields by 12 to 180% compared with the unfertilized control. Zinc solution sprayed at 1.1 to 2.2 kg ha^{-1} generally produced yields that were comparable with yields from granular fertilizers applied at 11.2 kg Zn ha^{-1}.

Mehta *et al.* (2008) conducted a field experiment during kharif seasons of 2005-07 in Zn deficient medium black soil at Main Millet Research Station, Jamnagar. An experiment was comprised of three levels of $ZnSO_4$ viz., 0, 10 and 20 kg $ZnSo_4$ ha^{-1} as soil application and three treatments of foliar spray viz., control (no spray), 0.2% $ZnSO_4$ spray at tillering stage and 0.2% $ZnSO_4$ spray st pre-flowering stage were laid out in factorial randomized block design replicated thrice. The result revealed that there was an additional need for $ZnSO_4$ application @ 20 kg/ha at the time of sowing to pearl millet crop and one spray of 0.2% $ZnSO_4$ at pre-flowering stage to obtain the higher yield and net return.

2.2 Effect of Zn on concentration and uptake

Ismail *et al.* (1995) observed in a field experiment conducted in rabi 1992-93 at Dholi form Bihar in a Zn deficient highly calcareous sandy loam soil belonging to the great group calciorthent that application of Zn increased uptake of Zn (grain + straw) from 141.4 to 264.0 g ha^{-1}. The varieties UP-262, K-8804, HP 1102 and, K 9006 which appeared to be relatively more susceptible to zn deficiency removed considerably low amount of Zn from native source.

Savithiri *et al.* (1998) studied that concentration of Zn, Fe, Cu and Mn in the grain of 30 varieties. There were significant differences in micronutrient content and the varieties are grouped and listed according to the critical limit for the individual nutrients (13 p.p.m. for Zn, 100 p.p.m. for Fe, 3 p.p.m. for Cu and 30 p.p.m. for Mn), with those containing less than these amounts being classed as susceptible and those containing more as resistant to specific nutrient-deficient areas.

Sakal *et al.* (1999) conducted a pot experiment was carried out to test the tolerance of S rice varieties to zinc deficiency. Sita was highly susceptible to Zn deficiency and application of Zn markedly increased root CEC, Zn concentration and uptake. On the basis of yield response, root CEC, Zn concentration and uptake Rajendra Dhan, Ratna and Pusa 2-21 showed moderate tolerance; UPR-238 was tolerant to Zn deficiency and produced the maximum dry matter yield in the absence of Zn.

Yan *et al.* (1999) studied that rice yield was significantly increased and rice quality was improved by zinc fertilizer application.

Sharma and Bapat (2000) observed in a field experiment on wheat, three levels of zinc(0, 10, 20 kg Zn ha^{-1}) and four levels of phosphorus(0, 40, 80, 120 kg P_2O_5 ha^{-1}) were tested to find out their effect on the concentration of micronutrients(Zn,

Cu, Fe and Mn) in various parts of wheat plant at different stages of growth. The content of zinc in various plant parts increase with increasing levels of Zn. The yield of grain and straw increased significantly due to application of 10 kg Zn ha^{-1} by 12.9 and 11.4 percent, respectively, over control.

Khan *et al.* (2002) studied the effect of different levels of Zn viz., 0, 5, 10 and 15 kg^{-1} along with a basal dose of NPK (175 kg N, 110 kg P_2O_5 and 100 kg K_2O ha^{-1}) on the Zn content of soil and chemical composition of rice Zn content of soil, leaves, roots, grain and straw of rice increased significantly with an increase in an fertilization. Similarly, significant maximum N and K content of rice grain and straw were zinc was applied @ 15 kg Zn ha^{-1}.

Khan *et al.* (2002) conducted pot experiment to study the effect of different level of zinc (0,5,10 and 15 kg ha^{-1}) along with a basal dose of NPK analyzed that leaves, root, grain and straw of rice increase significantly with an increases level of zinc fertilizers. Zinc concentration was obtained in treatment receiving 150 kg zinc ha^{-1} both are straw and paddy (85.10 and 46.64 ppm) respectively and zinc content of rice leaves increase significantly with zinc addition both before flowering and after harvest over control. Maximum zinc accumulation was noted with 15 kg zinc ha^{-1} and also available zinc content of soil increase significantly with the addition of zinc over control at both panicle initiation and after harvest of rice.

Singh (2003) conducted in ten non-calcareous alluvial soils (India) to determine the critical level of soil Zn for predicting response of rice (*Oryza sativa* L.) to zinc application. The critical limit of Zn in rice soils below which plant response to Zn fertilization may be expected was found to be 2.1 ppm HCl-extractable Zn. In soils with values below this level, the plants showed typical symptoms of Zn deficiency and the percent mean grain, straw, husk and total dry matter yield (g per pot),

respectively. The rice husk had the highest concentration of Zn whereas the grain had the lowest. Zinc application significantly increased Zn concentrations in various plant parts in all the soils irrespective of the initial Zn status. In general, Zn responses were observed when plant Zn concentration was less than 24 ppm on a dry weight basis. The HCl-extractable soil Zn was positively correlated with the percentage yields of grain (r = 0.69*) and straw (r = 0.56).

Li-Qiang (2004) conducted a field experiment at Muyu, Jiangsu, China, with a light yellow clay soil. It contains 1.06 % of organic matter, 69.2 mg kg^{-1} of available nitrogen, 25.4 mg kg^{-1} of available phosphorus, 137 mg kg^{-1} of available potassium, and 0.58 mg kg^{-1} of available zinc, and a pH of 7.2. $ZnSO_4.7H_2O$ was applied as basic fertilizer at the rates of 0, (control) 15, 30, 45, and 60 kg ha^{-1}. It was reported that Zinc fertilizer promoted tillering ability. Zinc treatments gave 1.5 days earlier tillering compared with the control treatment in wheat, Zinc fertilizer promoted the accumulation of dry matter and increased leaf area. In fertilizer treatments, the leaf area in the three stages from the blooming date to 15 and 30 days after blooming was 3.8-14.86, 4.75-19.34, and 12.03-35.06% higher than that of the control. Compared with the control, yields in the 4 treatments increased by 3.57, 11.50, 12.32, and 9.77%, respectively.

Khan *et al.* (2005) Studies on pot experiment analyzed that the response of rice leaf to zinc content on rice leaf before flowering as show zinc treatment and soil series was significant. Maximum zinc content of 68.05 mg kg^{-1} was recorded in the treatment receiving zinc @ 1.5% which was significantly higher than the treatment receiving zinc @ 1.0 and 0.5 % . After flower zinc content of rice leaf showed similar trend of zinc content as recorded before flowering.

Sharma *et al.* (2005) studied the effect of levels and methods of zinc fertilization on yield, concentration and uptake of zinc by rice. Zinc was incorporated in the soil at the rate of 0, 5.6, 11.2 and 22.4 kg Zn per ha as zinc sulfate; sprayed on the plants at 1% and 2% zinc sulfate solution ; and roots of rice seedlings were dipped in 2% and 4% ZnO suspensions in water. Grain yield, zinc content and its uptake increased in all the experiments up to 22.4 kg Zn per ha. Soil applied zinc was significantly correlated with yield of rice (r=0.80) and zinc uptake (r = 0.89). Zinc content in 45 day old plants gave a significantly higher correlation with grain yield (0=0.84) than the zinc content of rice straw and grain at maturity.

Dixit *et al.* (2006) studied the individual and interactive effect of S and Zn on yield and uptake of nutrients by hybrid rice. Application of 60 kg S ha^{-1} recorded significantly higher grain and straw yield and sulphur uptake. Similarly significant response of rice to Zn addition was recorded upto 15 kg^{-1}. Increase in S and Zn was non significant and the highest grain and straw yield were recorded with the combined application of 60 kg S and 15 kg Zn oxide ha^{-1}. Nitrogen and phosphorus uptake in crop increased significantly with S and Zn additions in all treatments.

Dipankar *et al.* (2007) studied that the efficiency of Zn-organo complexes in supplying zinc was evaluated in a glasshouse experiment with maize as the test crop. Zinc concentration in plant increased Zn level and the highest Zn concentration was observed when Zn was applied as Zn-fulvate at the level of 10 mg Zn kg^{-1} soil. Dry matter production was increased with increasing Zn level until the attainment of critical zinc concentration of the plant. The highest dry matter was produced when critical Zn concentration in plant reached~39 mg kg^{-1} which was attained by the application of 10.0 mg Zn as $ZnSO_4$, 5.0 mg Zn as Zn-humate, 2.5mg Zn as Zn-humate-fulvate

and 1.0 mg Zn as Zn-fulvate kg^{-1} soil. Irrespective of zinc sources, zinc recovery was as follows: 0.25 mg Zn kg^{-1}> 0.5 mg Zn kg^{-1}> 1.0mg Zn kg^{-1}> 2.5 mg Zn kg^{-1}> 5.0 mg Zn kg^{-1} > 10.0 mg Zn kg^{-1} soil and irrespective of levels, the average zinc recovery by plant from different sources was as follows: Zn-FA> Zn-HA-FA>Zn-HA>$ZnSO_4$.

Varshney *et al.* (2008) conducted a field experiments in Typic Hapludoll to evaluate the efficiency of different rates and frequency of Zinc application on yield, Zinc concentration and uptake of hybrid rice-wheat sequence. They found that Zinc application significantly increased the grain yield, concentration as well as uptake by both the crops. The concentration of Zn was more in wheat grain as compared to straw while the reverse was true for rice; however, total Zinc removal by hybrid rice was more than twice as compared to wheat. Application of Zinc sulphate significantly increased the DTPA-extractable Zn in soil but the effect decreased with subsequent crop removal.

Jiang (2008) conducted two controlled-condition experiments were carried out, one with a wide range of constant Zn concentrations in the medium and one with a range of plant growth rate-related supply rates. In both experiments, increased Zn supply induced increased plant Zn uptake rate throughout crop development, when expressed as daily Zn uptake (µg day^{-1}) or as daily Zn uptake per gram of plant dry matter (µg g^{-1}). Zinc mass concentration (ZnMC) in all plant organs increased with an increase in Zn supply but to various degrees. At higher uptake levels, the ZnMC in stems increased most, while the ZnMC in hulled grains (brown rice) increased least. The increase in leaf ZnMC was generally small, but at toxic levels in the medium, leaf ZnMC increased significantly.

2.5 Effect of Zinc application on post harvest soil

Haldar and Mandal (1982) conducted a laboratory incubation experiments with three clay loam lowland rice soils (Haplustalf) to study the effect of application of three different levels of Cu (0, 1.25, 2.5 ppm) and Mn (0, 10, 20 ppm) in all possible combinations on the changes in the DTPA extractable Zn, Cu, F, Mn and Brays 2 extractable P in soil. The results showed that application of Cu decreased the content of extractable Zn, Fe, Mn and P in soils, the rate of decrease gradually declining with the progress of incubation period. Application of Mn also depressed the content of extractable Cu, Fe and P but increased that of extractable Zn.

Zinc deficiency in Vertisols has become wide spread due to intensive cropping coupled with cultivation of high yielding varieties and use of high analysis fertilizers. About 50% of soils of the district Indore have been reported deficient in zinc (Rathore *et al.*, 1995).

Murthy *et al.* (1997) observed that the total micro nutrient cations content showed irregular distribution with depth. The amount of DTPA-extractable cation decreased with depths. Soil development as basalt parent material were relatively richer in available micro-nutrient cation.

Trivedi *et al.* (1998) reported that at Navasri, Gujrat in Vertic ustochrept the DTPA Zn after harvest of rice increased from original value of 0.60 mg kg^{-1} to 0.87, 1.70 and 2.59 mg kg^{-1}, respectively with the application of 5.6, 11.2 and 16.8 kg Zn ha^{-1}.

However, Gupta *et al.* (2000) reported that after two cycles of rice- wheat rotation in sandy loam soil, the available Zn status increased from initial status by the combined use of urea and FYM, and also with the application of $ZnSO_4$ @ 62.5 kg ha^{-1} applied in each crop, as compare to inorganic alone.

Patil *et al.* (2003) analyzed sixty two surface soil samples representing different soil type, from rice fields of Konkan region of Maharashtra were studied for DTPA extractable Zn, Cu, Mn and Fe and their relationship with soil properties. Result indicated that DTPA-Zn was positively correlated with pH, organic carbon and clay. DTPA Cu and Mn were positively correlated with clay and CEC and Fe was negatively and significantly correlated with pH, $CaCO_3$ and clay.

Savithri (2005) reported that five cycles of field experiments involving maize followed by sunflower were conducted during 1996-2001 in a clay loam soil at Agricultural College and Research Institute, Coimbatore. The results indicated that application of zinc sulphate @ 37.5 kg ha^{-1} to first crop of maize followed by 12.5 kg ha^{-1} to all alternate sunflower crops increased the total yield of maize and sunflower together, showing beneficial resident effect of applied zinc to previous crop, which received cumulatively 25% less zinc sulphate as compared to 12.5 kg ha^{-1} to zinc sulphate applied to every crop in a sequence covering ten crops despite comparable yield were recorded among themselves. There was a build up of DTPA-Zn in the post harvest soil due to application of zinc sulphate, irrespective of levels, either to every crop or alternate crop over a period of time as against depletion of zinc observed in the treatments receiving only once and no zinc in the sequential experimentation.

Gupta *et al.* (2006) reported that A field experiment was conducted in sandy soil on mustard (*Brassica juncea*) with three levels of Zinc (Zn) viz. 0, 15 and 30 kg $ZnSo_4$/hac and three levels of saline water irrigation (S) viz. 0.81, 8.05 and 12.09 dSm^{-1}. Basal dose of N, P and K were @ 80 kg N/ha, 60 kg P_2O_5/ha, 40 kg K_2O/hac respectively. Post harvest analysis of soil samples revealed that the DTPA-extractable zinc increased significantly, with increase in zinc levels and decreased

significantly with increase in saline water irrigation levels. The pH, EC, cation (Ca^{2+}, Mg^{2+}, Na^{+}) and anion (SO_4^{2-}, Cl^{-}, HCO_3^{-}, CO_3^{2-}) of soil samples ,after harvest, increased with increase in saline water irrigation levels , There was no effect observed in these with increase in zinc levels except potassium (K^{+}).

CHAPTER – III

MATERIALS AND METHODS

MATERIAL AND METHODS

A field experiment was conducted under collaboration of ICAR coordinated research project on micronutrients, Department of Soil Science and Agriculture Chemistry, College of Agriculture JNKVV, Jabalpur to study the **"Accumulation of zinc in different parts of paddy varieties as influenced by levels of zinc application in Vertisols"**. Observations on Plant height, number of effective tillers, test weight and yield of grain & straw were recorded and samples were analyzed for Zn content. Post harvest soil samples (0-20 cm) were also collected from the experimental plots for chemical analysis.

3.0 Details of the experimental material

3.1 Climate

Jabalpur has a semi-arid subtropical climate. It is situated in 23.9° North latitude and 79.58° East longitude. Its altitude is 411.78 meters above mean sea level. The annual average rainfall is about 1375 mm with intermittent dry spells. The maximum and minimum temperature ranged between 46.6 and **21.0°** C respectively. The weekly metrological data as recorded at meteorological observatory JNKVV, Research Station, Jabalpur are presented in (Table 3.1):

Table 3.1: Meteorological data (weekly) during crop growth period (2009-10)

Months	Standard Weeks	Temperature (°C)		Relative humidity		Wind Velocity (km/hr)	Rain fall (mm)	Sun-shine hours
		Max.	Min.	Max.	Min.			
July	27	34.8	24.1	88	56	5.9	067.0	3.7
	28	31.0	24.4	88	75	6.8	65.0	1.6
	29	30.7	23.8	91	78	6.8	355.3	4.0
	30	29.8	23.8	90	71	9.1	19.2	3.4
Aug.	31	32.1	23.7	87	59	8.1	000.0	5.8
	32	32.2	23.5	89	70	7.4	180.0	3.8
	33	29.7	23.4	89	76	6.8	28.4	5.5
	34	32.9	23.2	91	65	5.4	30.8	6.2
	35	31.3	23.0	94	74	4.0	109.8	3.8
Sept.	36	30.1	22.5	92	80	7.1	358.0	4.9
	37	30.2	22.2	90	65	6.6	83.8	9.6
	38	34.0	23.2	85	52	3.9	000.0	10.0
	39	34.9	22.3	84	46	4.9	000.0	8.5
Oct.	40	32.5	22.8	91	61	5.9	42.8	5.7
	41	32.1	18.9	87	43	3.7	000.0	9.0
	42	32.7	16.2	87	31	2.1	000.0	9.2
	43	31.9	11.7	84	23	1.9	000.0	9.6
	44	31.6	11.1	87	26	1.6	000.0	9.2
Nov.	45	31.0	16.4	86	39	2.4	2.5	6.6
	46	28.2	18.0	89	69	4.6	53.2	4.1
	47	24.5	8.0	96	34	1.9	000.0	8.7
	48	26.8	7.5	92	31	1.3	000.0	9.0
Dec.	49	27.6	9.7	90	39	1.0	000.0	7.6
	50	28.1	11.8	94	46	1.8	000.0	6.7
	51	25.0	9.9	94	55	2.9	20.2	7.6
	52	24.7	8.6	92	44	2.0	5.2	8.4

3.2 Field Experiment:

The present study was conducted on Paddy crop under micronutrient scheme. The experiment was carried out with 5 Zn levels and 20 Paddy varieties in split plot design. Zn levels were applied to paddy crop within the scope and objectives as depicted in the introduction.

The soil of experimental site was clay in texture, neutral in reaction, non calcareous, medium in organic carbon, available nitrogen, phosphorus, and potassium and low in DTPA extractable Zn (table 3.2).

Table 3.2: Physico-chemical properties of soil of experimental site

S. No.	Properties	Value
1	Sand	25.3 %
2	Silt	17.9 %
3	Clay	56.8 %
4	Soil texture	Clay
5	Soil pH (1:2)	7.3
6	Electrical conductivity	0.2 dSm^{-1}
7	Calcium carbonate	45.5 g kg^{-1}
8	Organic carbon	6.7 g kg^{-1}
9	DTPA extractable Zn	0.57 mg kg^{-1}
10	Available Nitrogen	268 kg ha^{-1}
11	Available Phosphorus	14.9 kg ha^{-1}
12	Available Potassium	314 kg ha^{-1}

3.3 Experimental detail:

The experiment was conducted taking 5 Zn level and 20 Varieties in split plot design with three replications. The treatments were randomly allocated in each replication. The details of treatments are given below.

Location	:	Research Farm, JNKVV, Jabalpur (M.P.)
Replication	:	03
Total treatment combination	:	100
Design	:	Split plot design
Treatment		
Varieties of rice	:	20
Zn level	:	5
Plot size	:	3m. × 1.5m.
Space between replication	:	1m.
Space between plots	:	0.5m.
Crop	:	Rice
Date of sowing	:	09 July 2010

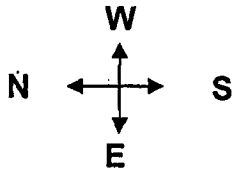

Fig 3.1: Lay out plant of experiment

RI

4		3		3		5		2	
3		2		2		3		1	
2	V_1	1	V_4	5	V_{13}	1	V_{19}	4	V_{20}
1		5		4		2		3	
5		4		1		4		5	
4		4		1		2		5	
1		5		2		3		4	
5	V_{14}	1	V_5	5	V_{10}	4	V_8	2	V_2
3		2		3		1		3	
2		3		4		5		1	
4		1		4		3		2	
3		4		3		2		3	
5	V_6	3	V_{12}	2	V_{15}	1	V_9	5	V_3
1		2		5		5		4	
2		5		1		4		1	
2		2		4		2		1	
5		3		3		3		5	
3	V_7	4	V_{18}	2	V_{17}	4	V_{16}	2	V_{11}
4		1		5		5		3	
1		5		2		1		4	

RII

5		1		3		1		3	
3		3		2		3		2	
2	V_{19}	2	V_{11}	4	V_9	5	V_1	1	V_{10}
1		4		1		4		5	
4		5		5		2		4	
2		2		5		3		3	
4		1		4		1		2	
5	V_{15}	4	V_5	2	V_{12}	2	V_{14}	1	V_7
3		3		1		4		5	
1		5		3		5		4	
3		2		2		1		2	
2		5		3		2		4	
1	V_{16}	3	V_{13}	5	V_6	3	V_8	3	V_3
4		4		1		5		1	
5		1		4		4		5	
2		5		4		5		4	
3		2		2		4		2	
4	V_4	4	V_{17}	5	V_{20}	2	V_2	1	V_8
		3		1		3		5	
15		1		3		1		3	

RIII

2		2		4		5		3	
3		4		3		1		1	
4	V_{14}	1	V_{17}	5	V_{18}	4	V_{19}	4	V_8
1		3		2		2		5	
5		5		1		3		2	
2		2		4		5		5	
4		1		1		1		2	
1	V_1	3	V_{16}	5	V_{10}	3	V_4	1	V_{11}
5		4		2		4		4	
3		5		3		2		3	
2		2		5		2		1	
1		3		2		1		5	
3	V_9	1	V_6	1	V_{15}	5	V_{20}	3	V_{13}
5		4		4		3		4	
4		5		3		4		2	
4		2		2		1		2	
1		5		3		4		4	
5	V_5	1	V_{12}	1	V_7	5	V_2	5	V_3
2		3		5		3		3	
3		4		4		2		1	

Table 3.3: Treatments of experiment

Treatments	
Zn level (kg ha^{-1})	
T_1 NPK(120:80:40) control	
T_2 NPK + 10 Kg Zn	
T_3 NPK + 20 Kg Zn	
T_4 NPK + 20 kg Zn + 0.5% spray of $ZnSO_4$ (preflowering, flowering and milking stage)	
T_5 NPK + 0.5% spray of $ZnSO_4$ (preflowering, flowering and milking stage)	
Rice varieties	
1. Chandrahasini	11. Samleshwari
2. Pusa Basmati	12. Dubraj
3. Sufari - 17	13. Mahamaya
4. Swarna	14. P.K.V. – HMT
5. Purnima	15. Shyamla
6. Danteshwari	16. MTV – 1010
7. Indira Sona	17. Vandana
8. Indira Sugandhit Dhan- 1	18. Kranti
9. IR - 36	19. Madhuri
10. Bambleshwari	20. Karma Masuri

3.4 Observations

The plant height and number of effective tillers were measured at harvest stage. Plant samples were collected at flowering stage. Yield of grain and straw were recorded at harvest. Grain and straw samples were collected from each plot and these samples were digested in di-acid mixture (1:2.5 $HClO_4$:HNO_3) and analyzed for Zn content on atomic absorption spectrophotometer. The post harvest soil samples (0-20 cm) were also collected for analysis of DTPA extractable Zn in the soil.

3.5 Soil and plant analysis

Soil and plant samples were prepared and analyzed by using standard methods of analysis as given below:

3.5.1 Soil analysis

The soil samples were air dried and crushed with wooden pestle and mortar and sieved through 2 mm sieve. The material passed through the sieve was used for determination of various factors.

3.5.1.1Soil pH:

Soil pH was determined by glass electrode method in 1 : 2 soil : water suspension (Govindrajan, 1970).

3.5.1.2 Electrical conductivity:

Electrical conductivity was measured in the supernatant liquid of 1:2 soil : water suspensions by solu-bridge method (Jackson, 1965).

3.5.1.3 Organic carbon

Organic carbon was determined by rapid titration method of Walkley and Black as described by Jackson (1965).

3.5.1.4 Calcium carbonate

Analysis of calcium carbonate was carried out by the rapid titration method as described by Jackson (1965).

3.5.1.6 DTPA extractable Zinc

The DTPA (pH 7.3) extractable Zinc extracted by 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M triethanol amine (TEA) were analyzed on atomic absorption spectrometer (Lindsay and Nrovell, 1978).

3.5.2 Plant analysis for Zinc

One gram of plant material was taken in 100 ml conical flask, 10 ml mixture of diacid (2.5:1 of AR grade HNO_3 : $HClO_4$ respectively) was added to each flask and whole mass was digested on a hot plate to get white solution. The digestate was transferred in 50 ml volumetric flask and volume was made up to

the mark with distilled water and analyzed on atomic absorption spectrometer (Jackson, 1965).

3.6 Statistical analysis

The data of field observations and chemical analysis were put to statistical analysis to draw the conclusions and to test the significance of the treatments under study.

Skeleton of analysis of variation

S.No.	Source of variance	d. f.	S.S	M.S.S.	F
1	Replication	2			
2	Variety	19			
3	Error (A)	38			
3	Zn level	4			
4	Zn × Variety	76			
5	Error (B)	160			
6	Total	299			

CHAPTER – IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

The result obtained from the experimental field and laboratory analyses are presented in this chapter. The effect of zinc application on yield attributes like plant heights, number of effective tillers, test weight and yield of rice grain and straw have been studied.

The results on chemical composition, nutrient uptake by paddy crop and availability of zinc in post harvest soil samples after paddy have also been given in this chapter.

4.1 The effect of Zn application on yield attributes.

Various indices viz. yield attributes like plant height, number of effective tillers, and test weight of paddy were recorded and presented in this chapter.

4.1.1 Plant height

The data presented in table 4.1 reflected that the plant height of paddy increased significantly with the application of Zinc over control up to 20 kg Zn ha^{-1}. The maximum height of paddy plant (69.5 cm) was observed at 20kg Zn + o.5% spray of $ZnSO_4$ level. The level of Zn 20 and Zn 20 + 0.5% spray was at par in increasing the plant height. Spray of $ZnSo_4$ was non significant effect on plant height. The varietal effects were found to be statistically significant. The minimum height (46.14 cm) observed in variety Swarna and maximum height (105.17 cm) was found in variety Sufari-17. The interaction effects between Zn × variety was found to be statistically non significant.

Table 4.1: Effect of Zn application on plant height of different paddy varieties

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	58.73	62.33	63.10	63.27	59.40	61.37
Pusa Basmati	62.03	65.37	66.82	67.52	62.17	64.78
Sufari – 17	101.40	106.02	107.15	108.85	102.43	105.17
Swarna	39.77	49.43	50.35	50.53	40.63	46.14
Purnima	49.03	52.17	54.89	55.43	49.77	52.26
Danteshwari	52.23	60.00	61.68	62.00	53.17	57.82
Indira sona	68.57	71.40	72.88	73.52	69.10	71.09
ISD – 1	59.77	67.23	68.50	68.78	60.47	64.95
IR – 36	52.70	57.60	58.82	59.73	53.77	56.52
Bambleshwari	67.83	70.13	71.00	71.65	68.23	69.77
Samleshwari	62.47	68.10	69.55	70.12	63.90	66.83
Dubraj	76.97	85.63	86.85	87.31	77.13	82.78
Mahamaya	71.23	77.53	78.92	79.14	71.87	75.74
P.K.V. – HMT	48.87	51.80	52.57	52.95	49.00	51.04
Shyamla	50.47	55.13	56.25	57.57	51.75	54.23
MTV – 1010	60.17	68.33	69.55	73.07	60.93	66.41
Vandana	87.00	89.37	90.38	90.90	87.53	89.04
Kranti	60.63	68.20	69.52	71.01	61.45	66.16
Madhuri	61.77	66.27	67.65	68.30	61.90	65.18
Karma Masuri	48.43	54.83	57.97	58.28	49.50	53.80
Mean	62.00	67.34	68.72	69.50	62.70	

	Var.	Zn	Var. x Zn
SEm±	0.81	0.32	0.14
CD 5%	2.27	0.90	NS

4.1.2 Number of effective tillers

The data presented in table 4.2 showed that the number of effective tillers increased significantly with level of Zn up to 20 kg Zn ha^{-1}. It increased from 6.52 at control to 8.07 per plant with the application of 20 kg Zn ha^{-1}. The effect of Zn spray was

Table 4.2: Effect of Zn application on number of effective tillers of different paddy varieties

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	5.93	7.20	7.80	7.85	6.03	6.96
Pusa Basmati	6.65	7.42	8.04	8.07	6.67	7.37
Sufari – 17	5.20	5.73	6.60	6.63	5.22	5.88
Swarna	4.78	5.18	5.53	5.54	4.80	5.17
Purnima	4.97	5.97	6.13	6.13	4.97	5.63
Danteshwari	7.62	8.43	8.99	9.00	7.62	8.33
Indira sona	5.00	5.63	6.00	6.00	5.03	5.53
ISD – 1	5.93	6.65	7.41	7.47	5.97	6.69
IR – 36	8.00	9.43	10.10	10.10	8.03	9.13
Bambleshwari	7.87	9.30	10.00	10.03	7.87	9.01
Samleshwari	5.63	6.87	7.43	7.45	5.67	6.61
Dubraj	4.67	5.30	5.67	5.67	4.70	5.20
Mahamaya	5.12	5.52	5.87	5.87	5.13	5.50
P.K.V. – HMT	6.98	7.76	8.49	8.57	7.20	7.80
Shyamla	6.20	7.37	7.92	7.93	6.23	7.13
MTV – 1010	9.67	11.43	12.33	12.33	9.73	11.10
Vandana	8.65	9.42	10.04	10.07	8.67	9.37
Kranti	8.00	9.60	10.23	10.27	8.10	9.24
Madhuri	8.40	9.43	10.37	10.43	8.47	9.42
Karma Masuri	5.20	6.10	6.43	6.47	5.27	5.89
Mean	6.52	7.49	8.07	8.09	6.57	

	Var.	Zn	Var. x Zn
SEm±	0.26	0.13	0.57
CD 5%	0.71	0.36	NS

non significant on number of effective tillers in paddy. The varietal response was found to be statistically significant. Minimum tillers were found in variety Swarna (5.17 per plant) and maximum in variety MTV – 1010 (11.10 per plant). The interaction effect of Zn x variety was statistically non significant in increasing tillers in paddy crop.

4.1.3 Test weight

It is observed from table 4.3 that the test weight (Thousand grain weight) of paddy grain increased significantly with the application of zinc. It increased from 19.13 gm at control to 23.05 gm at 20 kg Zn ha^{-1}. The effect of 0.5% spray of $ZnSO_4$ was non significant over soil application of zinc. The varietal effect was observed to be statistically significant. Minimum test weight was found in variety Swarna (17.53 gm) and maximum in variety MTV-1010 (25.92 gm). The interaction effect of Zn x variety was statistically non significant in increasing test weight of paddy grain.

Table 4.3: Effect of Zn application on test weight of different paddy varieties

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	19.36	22.25	22.71	22.93	21.39	21.73
Pusa Basmati	18.08	21.16	24.63	25.52	20.11	21.90
Sufari – 17	19.20	21.09	21.49	23.29	18.69	20.75
Swarna	14.48	17.81	18.60	19.05	17.69	17.53
Purnima	21.35	22.16	22.16	25.10	21.79	22.51
Danteshwari	20.19	21.61	21.96	22.01	20.77	21.31
Indira sona	20.63	21.52	21.72	22.39	21.27	21.50
ISD – 1	20.28	21.84	21.87	23.53	21.48	21.80
IR – 36	18.04	23.32	25.25	25.36	20.44	22.48
Bambleshwari	19.64	23.56	24.98	26.12	21.62	23.18
Samleshwari	19.36	21.41	21.99	24.69	18.57	21.21
Dubraj	17.44	17.49	17.61	19.91	17.48	17.99
Mahamaya	18.87	25.65	27.03	27.71	25.41	24.93
P.K.V. – HMT	17.00	18.60	19.10	19.80	17.25	18.35
Shyamla	19.61	22.59	24.83	27.31	21.67	23.20
MTV – 1010	22.21	26.00	27.47	28.79	25.15	25.92
Vandana	23.38	25.60	26.73	27.32	25.11	25.63
Kranti	22.03	25.34	27.79	28.11	24.79	25.61
Madhuri	17.63	21.96	25.08	25.17	20.80	22.13
Karma Masuri	17.19	18.85	19.35	19.97	17.55	18.58
Mean	19.13	21.88	23.05	24.13	20.80	

	Var.	Zn	Var. x Zn
SEm±	0.91	0.47	2.12
CD 5%	2.55	1.32	NS

4.2 Effect of Zn application on yield of different varieties of paddy.

4.2.1 Grain Yield

The data presented in table 4.4 reflected that yield of paddy grain increased significantly with the application of Zinc over control. The maximum yield of grain (4.89 t ha^{-1}) was observed at 20 kg Zn ha^{-1} level; whereas non significant increased in yield was observed with 20 kg Zn + 0.5% spray of $ZnSO_4$. Spray also has non significant effect over control.

Table 4.4: Effect of Zn application on grain yield (t ha^{-1}) of different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5 % Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	4.19	4.31	4.63	4.75	4.22	4.42
Pusa Basmati	3.93	4.44	4.82	4.97	4.02	4.44
Sufari – 17	3.99	4.45	5.07	5.13	4.04	4.53
Swarna	3.11	3.48	3.65	3.75	3.23	3.44
Purnima	3.90	4.12	4.38	4.41	4.00	4.16
Danteshwari	4.51	4.80	4.89	4.89	4.57	4.73
Indira sona	3.26	3.65	4.00	4.04	3.38	3.67
ISD – 1	3.36	4.05	4.66	4.74	3.54	4.07
IR – 36	4.44	5.07	5.79	5.83	4.69	5.16
Bambleshwari	4.81	5.23	5.63	5.77	4.95	5.28
Samleshwari	3.74	4.32	4.74	4.76	3.83	4.28
Dubraj	3.50	4.00	4.38	4.53	3.60	4.00
Mahamaya	3.67	4.12	4.37	4.30	3.86	4.06
P.K.V. – HMT	4.43	4.68	4.83	4.86	4.51	4.66
Shyamla	4.15	4.33	4.50	4.58	4.23	4.36
MTV – 1010	4.81	5.13	6.12	6.19	4.93	5.44
Vandana	3.81	4.32	4.94	5.20	3.87	4.43
Kranti	4.47	5.12	5.86	5.91	4.68	5.21
Madhuri	4.82	5.27	5.69	5.77	4.97	5.30
Karma Masuri	3.84	4.39	4.79	4.86	3.91	4.36
Mean	4.04	4.46	4.89	4.96	4.15	

	Var.	Zn	Var. x Zn
SEm±	0.16	0.03	0.15
CD 5%	0.45	0.09	NS

Fig-4.1 Effect of Zinc application on MTV-1010 variety of paddy

Fig-4.2 Effect of Zinc application on Pusa Basmati variety of paddy

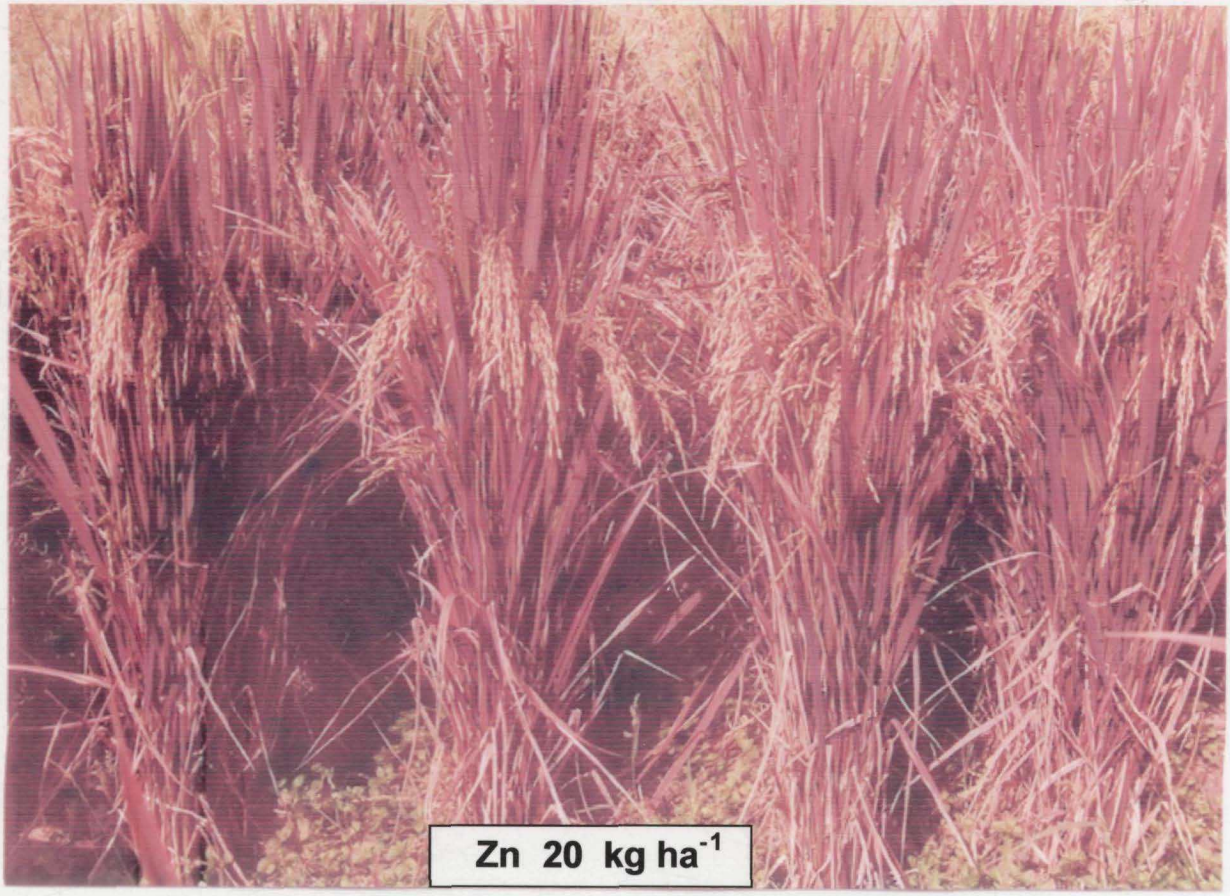

Fig. 4.3 Effect of zinc application on Shyamla variety of paddy

The varietal effects were found to be statistically significant in increasing. The minimum yield (3.44 t ha^{-1}) was found in variety Swarna and maximum yield (5.44 t ha^{-1}) was found in variety MTV–1010. Zinc and varietal interaction effect was found to be non significant on yield.

4.2.2 Straw yield

The data presented in table 4.5 showed that the application of zinc resulted in a significant increase in yield of straw over control up to 20 kg Zn ha^{-1}. 20 kg Zn + 0.5% spray of $ZnSO_4$ was statistically at par with the preceding level i.e. 20 kg

Table 4.5: Effect of Zn application on straw yield (t ha^{-1}) of different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	6.46	6.11	7.05	7.51	6.18	6.66
Pusa Basmati	4.30	4.72	5.08	5.03	4.56	4.74
Sufari – 17	6.55	8.18	8.84	8.36	7.75	7.93
Swarna	4.31	4.64	5.03	5.21	3.37	4.51
Purnima	5.37	5.62	6.13	6.60	5.70	5.88
Danteshwari	6.39	6.16	7.34	7.71	7.11	6.94
Indira sona	5.12	5.46	6.39	6.41	5.47	5.77
ISD – 1	4.94	6.05	6.99	7.04	6.45	6.29
IR – 36	4.36	5.27	6.21	5.99	4.57	5.28
Bambleshwari	5.82	6.86	7.31	7.99	7.06	7.01
Samleshwari	6.26	7.77	8.06	7.92	7.19	7.44
Dubraj	4.60	5.03	5.37	5.73	4.82	5.11
Mahamaya	5.96	6.53	7.21	7.58	6.35	6.72
P.K.V. – HMT	4.29	3.96	5.14	5.41	4.50	4.66
Shyamla	5.30	5.29	5.97	6.34	5.76	5.73
MTV – 1010	6.98	7.35	8.27	8.76	7.56	7.78
Vandana	6.21	6.96	7.45	7.27	6.24	6.83
Kranti	6.57	6.95	7.38	7.52	6.80	7.04
Madhuri	5.70	6.43	7.09	6.81	5.86	6.38
Karma Masuri	4.70	5.29	6.23	6.36	5.34	5.58
Mean	5.51	6.03	6.73	6.88	5.93	

	Var.	Zn	Var. x Zn
SEm±	0.23	0.12	0.56
CD 5%	0.64	0.35	NS

Zn ha^{-1}. Spray of $ZnSO_4$ has non significant effect on yield of paddy straw. Straw yield varied from 5.51 t ha^{-1} at control to 6.73 t ha^{-1} with the application of 20 kg Zn. The varietal effects were found to be statistically significant. Minimum yield (4.51 t ha^{-1}) was observed in Swarna variety and maximum yield (7.93 t ha^{-1}) was found in Sufari-17 variety. The interaction effect was found to be statistically non significant on effecting yield of paddy straw.

4.3 Effect of Zn application on Zn content in grain, husk and straw of paddy

4.3.1 Zn content in rice

Zinc application exhibited a positive effect on zinc concentration in rice grain. It increased significantly with the increasing levels of Zn. It increased from 8.84 at control to 17.57 mg kg^{-1} with the application of 20 kg Zn + 0.5% spray of $ZnSO_4$. Foliar spray of Zn also increased the Zn content in grain from 8.84 at control to 11.0 mg kg^{-1} with 0.5% foliar spray of $ZnSO_4$. Maximum content of zinc was observed in Indira Sona (14.26 mg kg^{-1}) while minimum in variety Chandrahasini (10.42 mg kg^{-1}). Zn x v Interaction effect on zinc content was found to be significantly positive. Zn content in all the varieties increased with the increasing levels of Zn our control. The maximum content of Zn was observed in variety PKV-HMT (19.97 mg kg^{-1}) with the application of 20 kg Zn + 0.5% foliar spray of $ZnSO_4$. While minimum was found in variety Vandana (7.42 mg kg^{-1}) at control (Table-4.6).

Table 4.6: Effect of Zn application on Zn content (mg kg^{-1}) in grains of different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	7.74	9.61	11.32	14.20	9.23	10.42
Pusa Basmati	7.90	11.58	14.70	17.30	9.78	12.25
Sufari – 17	8.43	11.56	15.37	17.45	10.29	12.62
Swarna	9.03	11.36	13.27	15.83	11.11	12.12
Purnima	9.97	12.51	13.87	18.10	10.70	13.03
Danteshwari	9.10	11.19	14.30	18.31	10.61	12.70
Indira sona	10.93	14.23	15.70	17.20	13.24	14.26
ISD – 1	11.47	13.98	15.51	16.36	11.36	13.74
IR – 36	7.72	11.97	13.36	19.54	10.33	12.59
Bambleshwari	8.87	11.19	15.17	19.37	10.18	12.96
Samleshwari	8.20	11.75	13.75	18.10	10.67	12.49
Dubraj	10.63	12.03	14.94	17.04	11.88	13.30
Mahamaya	8.64	13.12	14.77	17.33	10.77	12.93
P.K.V. – HMT	8.67	13.06	15.96	19.97	13.18	14.17
Shyamla	8.73	13.20	14.43	16.00	11.81	12.84
MTV – 1010	9.03	13.09	16.33	18.67	13.17	14.06
Vandana	7.42	9.08	11.00	15.27	10.33	10.62
Kranti	7.72	11.07	13.12	18.50	10.19	12.12
Madhuri	8.53	11.34	14.87	19.13	9.74	12.72
Karma Masuri	8.00	11.85	13.22	17.67	11.52	12.45
Mean	8.84	11.94	14.25	17.57	11.00	

	Var.	Zn	Var. x Zn
SEm±	0.728	0.239	0.985
CD 5%	2.18	1.45	2.84

4.3.2 Zn content in husk

It is observed from table-4.7 that the Zinc concentration in paddy husk increased significantly and progressively due to application of Zinc. The Zn content in husk increased significantly with the application of 20 kg Zn + 0.5% spray of $ZnSO_4$ over control. zinc increased from 41.29 mg kg^{-1} at control to 64.51 mg kg^{-1} at 20 kg Zn + 0.5% spray of $ZnSO_4$ which was significantly higher over 20 kg Zn ha^{-1}. The application of 0.5% spray of $ZnSO_4$ allows (59.23 mg kg^{-1}) also significantly increased Zn content in husk. Maximum zinc content was

observed in husk of variety Sufri-17 (55.42 mg kg^{-1}) while minimum in variety Indira sona (50.44 mg kg^{-1}). The interaction was also found to be statistically significant. Zinc content in all the variety increased with the increasing levels of Zn over control. The maximum content of Zn was observed in variety samleshwari (66.42 mg kg^{-1}) with the application of 20 kg Zn + 0.5% foliar spray of $ZnSO_4$. While minimum was found in variety *Mahamaya (39.39 mg kg^{-1}) at control.*

Table 4.7: Effect of Zn application on Zn content (mg kg^{-1}) in husk of different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	41.06	49.67	55.94	64.40	57.25	53.66
Pusa Basmati	43.26	51.01	56.52	65.65	59.21	55.13
Sufari – 17	42.56	50.71	54.88	66.19	62.79	55.42
Swarna	43.65	44.32	56.31	63.82	63.32	54.28
Purnima	41.49	42.98	45.98	65.11	59.38	50.99
Danteshwari	40.55	45.74	50.70	64.25	57.61	51.77
Indira sona	40.32	44.60	50.35	64.38	52.55	50.44
ISD – 1	41.42	47.60	50.05	63.65	52.39	51.02
IR – 36	40.71	48.47	53.64	65.31	58.74	53.37
Bambleshwari	42.48	49.64	56.40	64.73	62.45	55.14
Samleshwari	40.51	44.52	56.01	66.42	57.56	53.00
Dubraj	41.32	45.37	55.12	63.43	60.54	53.16
Mahamaya	39.39	45.57	52.43	64.36	57.36	51.82
P.K.V. – HMT	41.33	46.48	56.54	62.47	61.46	53.66
Shyamla	40.55	45.59	52.45	64.05	55.78	51.68
MTV – 1010	40.42	44.46	55.38	65.35	62.39	53.60
Vandana	41.49	46.28	57.42	63.94	59.71	53.77
Kranti	40.42	44.35	56.39	64.57	62.49	53.64
Madhuri	41.21	45.44	57.36	63.95	59.32	53.45
Karma Masuri	41.61	45.94	56.29	64.22	62.26	54.06
Mean	41.29	46.44	54.31	64.51	59.23	

	Var.	Zn	Var. x Zn
SEm±	0.659	0.373	1.537
CD 5%	1.98	2.27	4.42

4.3.3 Zn content in straw

Data presented that in table 4.8 observed that the Zn content in rice straw increased with increasing levels of Zn significantly. It increased from 16.58 mg kg^{-1} at control to 43.30

Table 4.8 Effect of Zn application on Zn content (mg kg^{-1}) in straw of different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	15.88	28.01	39.45	45.51	40.82	33.93
Pusa Basmati	18.45	30.76	41.85	45.36	41.65	35.61
Sufari – 17	16.61	27.10	40.25	46.45	42.03	34.49
Swarna	18.62	29.79	38.31	41.50	37.29	33.10
Purnima	19.23	33.84	40.91	46.44	41.32	36.35
Danteshwari	14.15	27.56	35.14	40.18	35.25	30.46
Indira sona	13.52	25.71	36.40	42.09	36.34	30.81
ISD – 1	14.94	29.08	38.11	44.64	39.59	33.27
IR – 36	17.27	28.31	36.91	40.43	36.10	31.80
Bambleshwari	16.79	27.00	38.98	43.07	42.57	33.68
Samleshwari	14.60	28.55	36.09	38.61	35.73	30.71
Dubraj	17.08	30.32	40.20	44.12	40.51	34.45
Mahamaya	17.29	31.55	38.19	43.45	40.99	34.29
P.K.V. – HMT	17.97	33.40	42.70	45.69	42.51	36.45
Shyamla	19.63	33.19	43.58	44.82	42.68	36.78
MTV – 1010	15.08	28.10	38.52	43.22	42.74	33.53
Vandana	14.36	25.78	39.66	41.83	34.39	31.21
Kranti	16.43	29.57	40.05	45.93	43.66	35.13
Madhuri	15.89	28.48	36.75	39.50	38.31	31.78
Karma Masuri	17.84	30.91	38.99	43.12	38.58	33.89
Mean	16.58	29.35	39.05	43.30	39.65	

	Var.	Zn	Var. x Zn
SEm±	0.63	0.25	1.10
CD 5%	1.75	0.69	3.10

mg kg^{-1} at 20 kg Zn + 0.5% spray of $ZnSO_4$. Application of 0.5% spray of $ZnSO_4$ also increased the Zn content significant in paddy straw over control. It increased from 16.58 mg kg^{-1} at control to 39.65 mg kg^{-1} with foliar application allow. Maximum zinc content (36.78 mg kg^{-1}) was observed in variety Shyamla while minimum in variety Danteshwari (30.46 mg kg^{-1}). The interaction effect was found to be statistically significant in increasing Zn content in paddy straw. Zinc content in all the variety increased with the increasing levels of Zn over control. The maximum content of Zn was observed in variety kranti (45.93 mg kg^{-1}) with the application of 20 kg Zn + 0.5% foliar spray of $ZnSO_4$. While minimum was found in variety Danteshwari (14.15 mg kg^{-1}) at control.

4.4 Total Zn uptake

The data presented in table 4.9 indicates that total uptake of zinc increased significantly due to application of Zn. It increased from 126.60 g ha^{-1} to 384.91 g ha^{-1} with the application of no Zn and 20 kg Zn + 0.5% spray of $ZnSO_4$ respectively. Uptake of zinc was also significantly increased due to foliar application of 0.5% spray of $ZnSO_4$. Significant different has been observed in respect of uptake of Zn by various varieties. The minimum uptake (199.72 g ha^{-1}) was found in variety Swarna and maximum in variety Kranti (350.35 g ha^{-1}). The interaction effect was found to be statistically non significant in increased the total zinc uptake.

Table 4.9 Effect of Zn application on Zinc uptake by different varieties of paddy

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	134.71	212.51	330.67	409.79	291.80	275.90
Pusa Basmati	111.48	197.79	283.06	313.38	228.88	226.91
Sufari – 17	144.06	240.76	373.99	438.11	324.62	304.31
Swarna	113.13	183.13	249.83	287.24	165.28	199.72
Purnima	141.95	241.49	310.26	386.06	279.11	271.78
Danteshwari	132.24	223.12	327.76	399.27	298.88	276.25
Indira sona	103.91	193.18	295.45	339.06	243.88	235.10
ISD – 1	113.43	232.88	338.10	391.58	295.60	274.32
IR – 36	109.70	210.52	307.09	355.06	213.16	239.11
Bambleshwari	140.33	243.79	369.59	456.24	351.01	312.19
Samleshwari	121.65	272.93	357.29	391.21	299.88	288.59
Dubraj	112.09	194.73	271.12	314.94	234.00	225.38
Mahamaya	134.48	260.74	340.16	403.58	302.37	288.27
P.K.V. – HMT	115.96	193.06	296.91	344.56	250.54	240.21
Shyamla	141.04	232.34	325.36	355.71	296.99	270.29
MTV – 1010	151.32	274.87	415.71	492.44	385.40	343.95
Vandana	119.78	217.13	347.02	383.44	255.33	264.54
Kranti	142.86	297.52	429.65	495.33	386.40	350.35
Madhuri	132.96	242.08	344.45	380.65	272.31	274.49
Karma Masuri	114.99	215.95	306.19	360.58	250.63	249.67
Mean	126.60	229.03	330.98	384.91	281.30	

	Var.	Zn	Var. x Zn
SEm±	9.35	4.70	21.03
CD 5%	26.10	13.13	NS

4.5 Effect of Zn application on Zn content in plant parts at flowering stage of paddy

It is observed (Table-4.10) that concentration of zinc in stem, leaf and penical at flowering stage increased significantly with increasing levels of zinc. It increased from 23.79 to 40.32 mg kg^{-1} in stem, 24.52 to 45.38 mg kg^{-1} in leaf and 14.47 to 32.87 mg kg^{-1} in penical. Maximum Zn content (36.22 mg kg^{-1}) was observed in leaf followed by stem (31.41 mg kg^{-1}) and penical (23.03 mg kg^{-1}) that at following stage leas Zn was translocatad to penical and stem. The varietal effects were found to be

statistically significant. Minimum zinc content was observed in stem of Chandrahasini (29.44 mg kg^{-1}) and maximum in Shyamla (34.67 mg kg^{-1}). Minimum zinc content in leaf of Karma Masuri (33.86 mg kg^{-1}) was observed while maximum was found in IR-36 (40.79 mg kg^{-1}). The content of Zn in panicle of PKV-HMT was found maximum (25.02 mg kg^{-1}) and minimum in Vandana penical (20.83 mg kg^{-1}).

Table 4.10 Effect of Zn application on Zn content (mg kg^{-1}) in plant parts (stem, leaf & penical) at different varieties of paddy at flowering stage

Zn level	stem	leaf	penical
0 kg Zn ha^{-1}	23.79	24.52	14.47
10 kg Zn ha^{-1}	30.38	34.32	20.64
20 kg Zn ha^{-1}	31.94	38.15	26.34
Zn20 kg Zn +0.5% spray of $ZnSO_4$	40.32	45.38	32.87
0.5% spray of $ZnSO_4$	30.61	28.71	20.84
Average	31.41	36.22	23.03
SEm±	0.66	0.44	0.25
CD 5%	1.91	1.41	0.69
Varieties			
Chandrahasini	29.44	34.22	24.61
Pusa Basmati	30.95	35.27	23.36
Sufari – 17	30.74	39.49	21.78
Swarna	32.17	35.69	24.10
Purnima	31.73	36.14	22.90
Danteshwari	31.48	35.06	22.27
Indira sona	30.84	40.20	23.33
ISD-1	32.40	36.09	24.18
IR – 36	31.59	40.79	23.91
Bambleshwari	31.06	38.59	22.60
Samleshwari	32.18	36.49	24.10
Dubraj	34.24	38.42	24.44
Mahamaya	31.56	36.07	22.58
P.K.V.– HMT	34.09	39.20	25.02
Shyamla	34.67	38.67	24.94
MTV – 1010	32.53	36.42	24.63
Vandana	30.96	36.51	20.83
Kranti	32.47	35.73	24.03
Madhuri	30.66	34.14	22.11
Karma Masuri	29.40	33.86	22.91
Average	31.76	36.85	23.43
SEm±	0.80	0.26	0.56
CD 5%	2.22	0.72	1.56

4.6 Effect of Zn application on Zn concentration in post harvest soil

Data presented in table 4.11 shows that the application of zinc exerted positive influence on extractable zinc in post harvest soil samples. It exhibited a progressive and significant increase from 0.58 mg kg^{-1} at control to 5.80 mg kg^{-1} at 20 kg Zn ha^{-1} + 0.5% spray of $ZnSO_4$. The varietals effect was non significant. The interaction effect of Zn x variety was also found to be statistically non significant affecting the Zn content in post harvest soil sample.

Table 4.11 Effect of Zn application on Zn content (mg kg^{-1}) in post harvest soil sample

Varieties	Zn levels (kg ha^{-1})					
	Zn0	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn	Mean
Chandrahasini	0.58	3.57	5.52	5.80	0.69	3.23
Pusa Basmati	0.55	3.38	5.44	5.74	0.64	3.15
Sufari – 17	0.59	3.47	5.30	5.61	0.62	3.12
Swarna	0.55	3.32	5.26	5.56	0.61	3.06
Purnima	0.59	3.58	5.61	5.89	0.68	3.27
Danteshwari	0.57	3.61	5.58	5.87	0.66	3.26
Indira sona	0.59	3.67	5.69	6.00	0.65	3.32
ISD – 1	0.59	3.44	5.39	5.70	0.64	3.15
IR – 36	0.58	3.71	5.66	5.90	0.66	3.30
Bambleshwari	0.59	3.47	5.55	5.88	0.64	3.23
Samleshwari	0.57	3.35	5.36	5.74	0.63	3.13
Dubraj	0.58	3.63	5.73	5.99	0.67	3.32
Mahamaya	0.57	3.31	5.39	5.73	0.62	3.12
P.K.V. – HMT	0.59	3.66	5.62	5.92	0.66	3.29
Shyamla	0.56	3.29	5.28	5.63	0.63	3.08
MTV – 1010	0.58	3.57	5.52	5.83	0.67	3.23
Vandana	0.57	3.62	5.64	5.95	0.63	3.28
Kranti	0.56	3.52	5.53	5.86	0.67	3.23
Madhuri	0.59	3.50	5.44	5.71	0.68	3.18
Karma Masuri	0.59	3.40	5.42	5.72	0.68	3.16
Mean	0.58	3.50	5.50	5.80	0.65	

	Var.	Zn	Var. x Zn
SEm±	0.057	0.022	0.010
CD 5%	NS	0.062	NS

4.7 Effect of Zn application on Percent use efficiency of zinc based on Zn uptake by different paddy varieties

The data present in table 4.12 indicated that the zinc use efficiency was affecting by application of zinc. The use efficiency of Zn increased with only spray level of Zn in all the varieties. Maximum use efficiency was found (55.62 %) with application of 10 kg Zn ha^{-1} and minimum (33.14%) with the application of 20 kg Zn + 0.5% foliar spray of $ZnSO_4$. The maximum use efficiency (63.39%) was observed in variety Chandrahasini with the application of 10 kg Zn ha^{-1}

Table 4.12 Effect of Zn application on percent use efficiency of zinc based on Zn uptake in different paddy varieties

Varieties	Zn levels (kg ha^{-1})			
	Zn10	Zn20	Zn20+0.5% Spray of Zn	0.5% Spray of Zn
Chandrahasini	63.39	40.74	32.87	46.17
Pusa Basmati	56.36	39.38	35.57	48.71
Sufari – 17	59.84	38.52	32.88	44.38
Swarna	61.78	45.28	39.39	68.45
Purnima	58.78	45.75	36.77	50.86
Danteshwari	59.27	40.35	33.12	44.25
Indira sona	53.79	35.17	30.65	42.61
ISD – 1	48.71	33.55	28.97	38.37
IR – 36	52.11	35.72	30.90	51.46
Bambleshwari	57.56	37.97	30.76	39.98
Samleshwari	44.57	34.05	31.10	40.57
Dubraj	57.56	41.34	35.59	47.90
Mahamaya	51.58	39.53	33.32	44.48
P.K.V. – HMT	60.06	39.06	33.65	46.28
Shyamla	60.70	43.35	39.65	47.49
MTV – 1010	55.05	36.40	30.73	39.26
Vandana	55.17	34.52	31.24	46.91
Kranti	48.02	33.25	28.84	36.97
Madhuri	54.92	38.60	34.93	48.83
Karma Masuri	53.25	37.56	31.89	45.88
Mean	**55.62**	**38.50**	**33.14**	**45.99**

CHAPTER – V

DISCUSSION

DISCUSSION

The present investigation was carried out for studying the influence of zinc on growth, yield and uptake of Zn on paddy and zinc availability in Vertisols. The results have been presented in the preceding chapter and the significant findings are discussed here in the light of available literature.

5.1 Effect of zinc application on yield attributes and yields of paddy.

Under deficient condition the crops are likely to respond to application of zinc as the same is the constituent of various enzymes and also regulates the auxin content in plants, hence the plant growth and involved in photosynthesis and metabolism of plant. Zinc maturity is adversely affected due to its deficiency.

Result of the present study on effect of zinc on yield attributes of paddy crop are presented in table 4.1 to 4.5. The yield attributes like plant height, number of effective tillers and test weight significantly increased with application of zinc up to 20 kg ha^{-1} over control. It is evident from table 4.1 to 4.5 that plant height increased by 10.8% at harvest stage with application of 20 kg zinc ha^{-1} while with foliar application only 1.1% increase on plant height was observed. While effective tillers and test weight increased by 23.7% and 26.1% with the application of 20 kg zinc ha^{-1} respectively over control. Qureshi M.I. (2001) and Khan *et al.* (2007) have also observed significant increase in number of tillers, plant height and test weight with the application of Zn.

The yield of paddy increased significantly due to application of Zn. The maximum grain yield was recorded where application of 20 kg Zn ha^{-1} was applied (Table 4.4 and fig. 5.1.1). The yield of paddy grain increased significantly by 21.0%

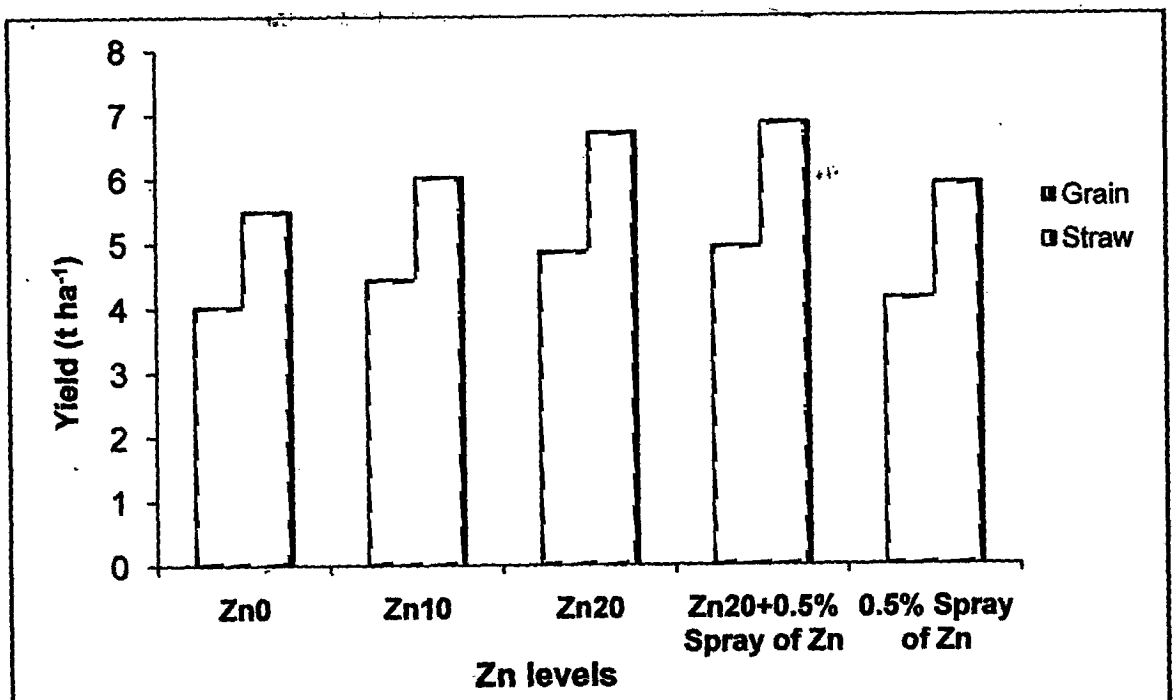

Fig. 5.1.1 Effect of Zn application on yield of paddy

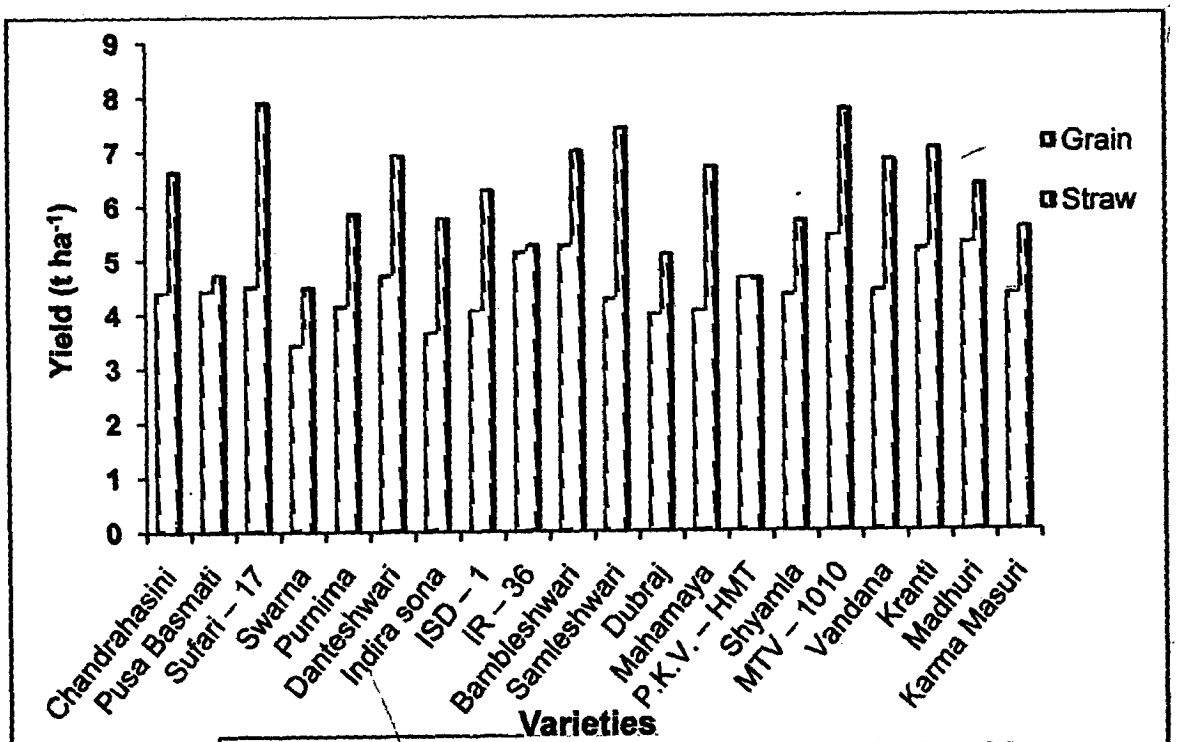

Fig. 5.1.2 Effect of Zn application on yield of paddy varirties

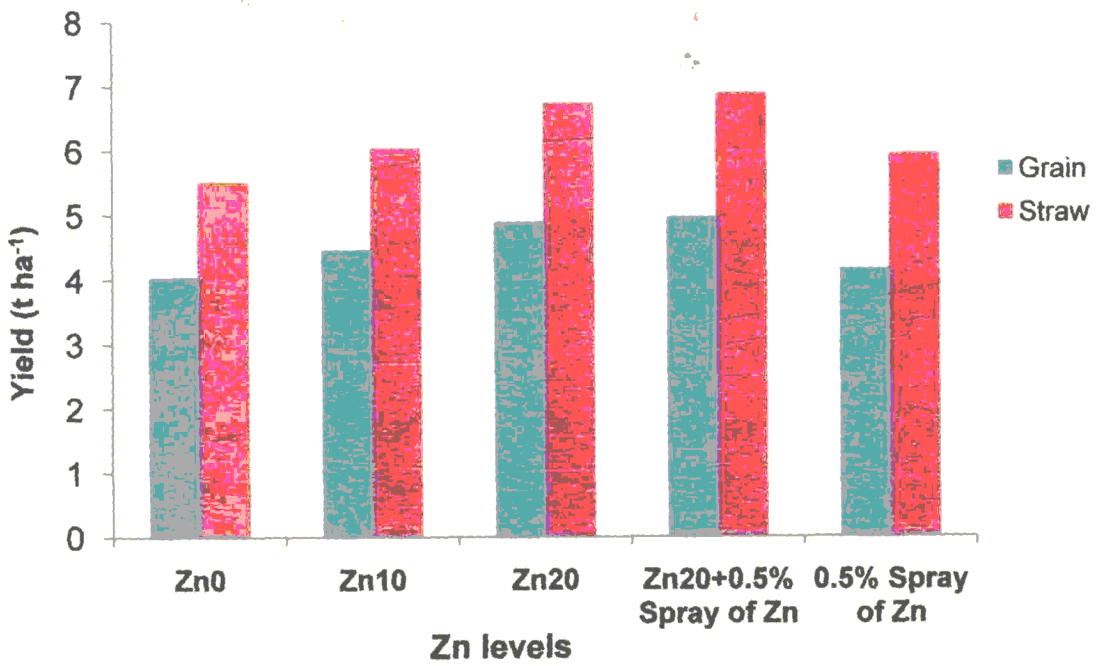

Fig. 5.1.1 Effect of Zn application on yield of paddy

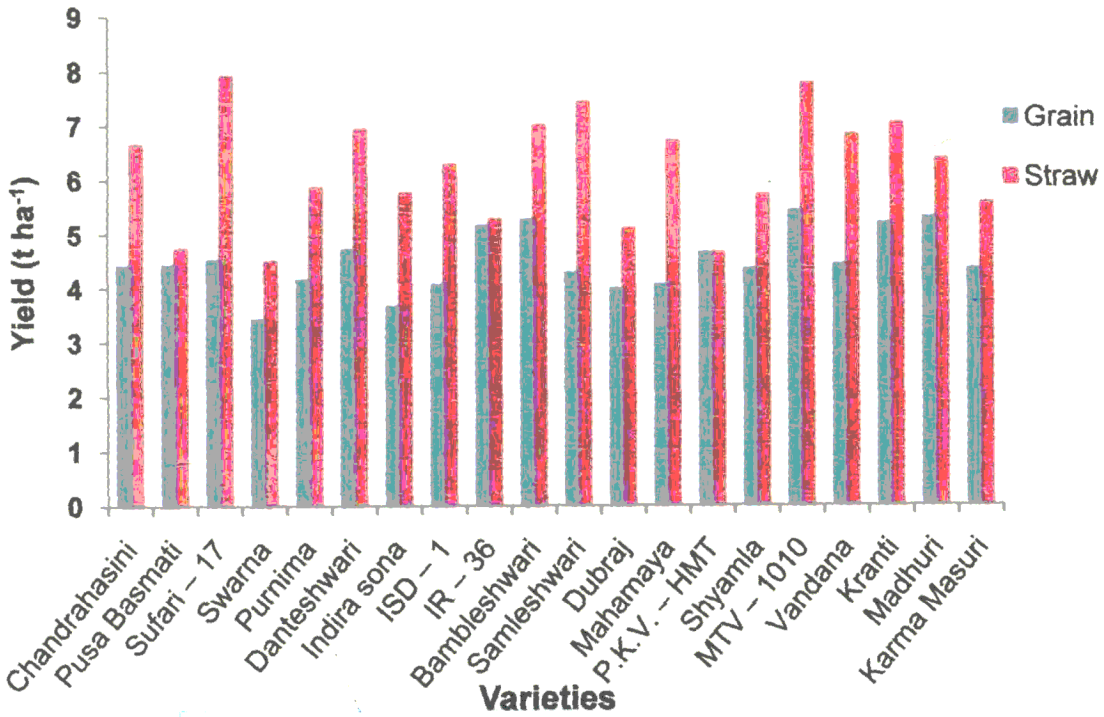

Fig. 5.1.2 Effect of Zn application on yield of paddy varirties

with application of 20 kg Zn ha^{-1} over control and foliar spray of $ZnSO_4$ increased the yield only by 2.7%

Similarly straw yield of paddy was also found to be increased due to increasing levels of zinc. It increased by 22.1% with zinc level at 20 kg ha^{-1} and also increased by 7.6% with the application of foliar spray of $ZnSO_4$ over control. The maximum straw yield was recorded at 20 kg Zn + 0.5% sprays of $ZnSO_4$ (Table 4.5 and fig. 5.1.1).

The increase in yield may be attributed due to beneficial effect of zinc on growth parameters viz., tillers, plant height, and test weight of crop. The increased yield with application of zinc may also be due to increased concentration of zinc in different plant parts at various growth stages as reported by Bakhsh Kelarestaghi. (2006).

Sakal *et al.* (1993) reported that grain yield of rice increased significantly as compared to control. Malakouti (1998) reported that zinc application increased the grain yield of wheat by 20 to 25% over control. Yan *et al* (1999) studied that rice yield significantly increased and quality was improved by zinc fertilizer application.

The yield of different paddy varieties increased significantly due to application of zinc. The maximum grain yield was recorded in variety MTV-1010 where application of 20 kg Zn ha^{-1} was given (Table 4.4 and fig.5.1.2). The yield of paddy variety MTV-1010 Increased by 58.13% in over Dubraj

Similarly straw yield of different paddy varieties was also found to be increased due to increasing levels of zinc. The maximum straw yield was recorded in variety Sufari-17 (Table 4.5 and fig 5.1.2). It increased by 75.8% in over Swarna.

Tandon (1996) have reported the increase in grain yield of different varieties of rice increased with application of zinc in soils of Kanpur.

5.2 Effect of zinc application on zinc concentration of rice

The concentration of zinc in grain (rice and husk) and straw increased with the application of zinc (Table 4.6, 4.7 & 4.8 and Fig. 5.2,1 & 5.2.2). The zinc concentration increased by 61.1% in rice grain, 31.5% in husk and 135.5% in straw, with the application of 20 kg Zn ha^{-1} over control. Similarly the concentration of zinc in grain (rice and husk) increased by 23.2% & 18.78% and in straw by 10.8% with the application of 20 kg Zn ha^{-1} + 0.5% spray of $ZnSO_4$ respectively over 20 kg Zn ha^{-1} and the concentration of zinc was also increased in grain (rice and husk) by 24.4% & 43.4% and in straw 139.1% with 0.5% foliar spray of $ZnSO_4$ over control. The above results are in agreement with Varshney *et al.* (2008) who have reported that concentration of zinc increased with the application of zinc in grain and straw of rice.

Yilmaz *et al* (1997) reported that the application methods of Zn were significanty increased concentration of Zn in rice in Zn-deficient calcareous soil.

The maximum Zn concentration in grain (19.97 mg kg^{-1}) was observed in variety PKV-HMT which was about 169.1% higher than Vandana and the maximum Zn concentration in husk (66.42 mg kg^{-1}) was observed in variety Samleshwari which was about 68.6%higher than Mahamaya.

Rai *et al.* (2003) also reported the highest zinc concentrations (37.7 mg g^{-1}) in Jayanti variety of rice grown on six high-yielding rice varieties in calcareous soils.

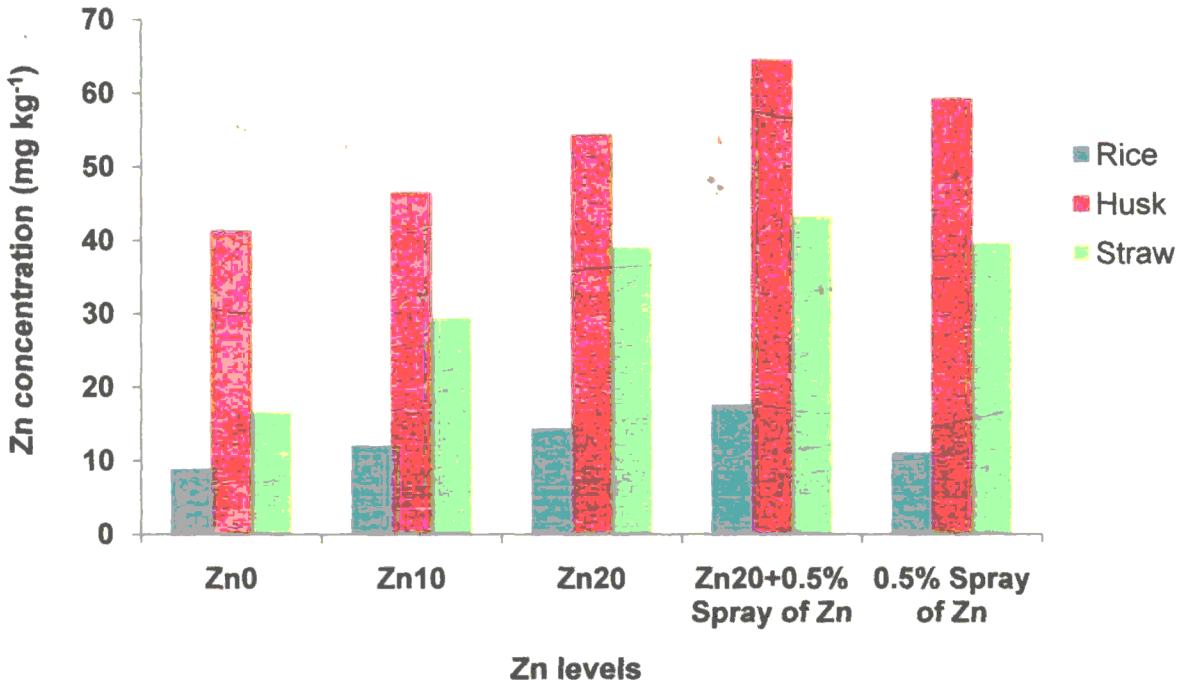

Fig. 5.2.1 Effect of Zn application on concentration of zinc in paddy

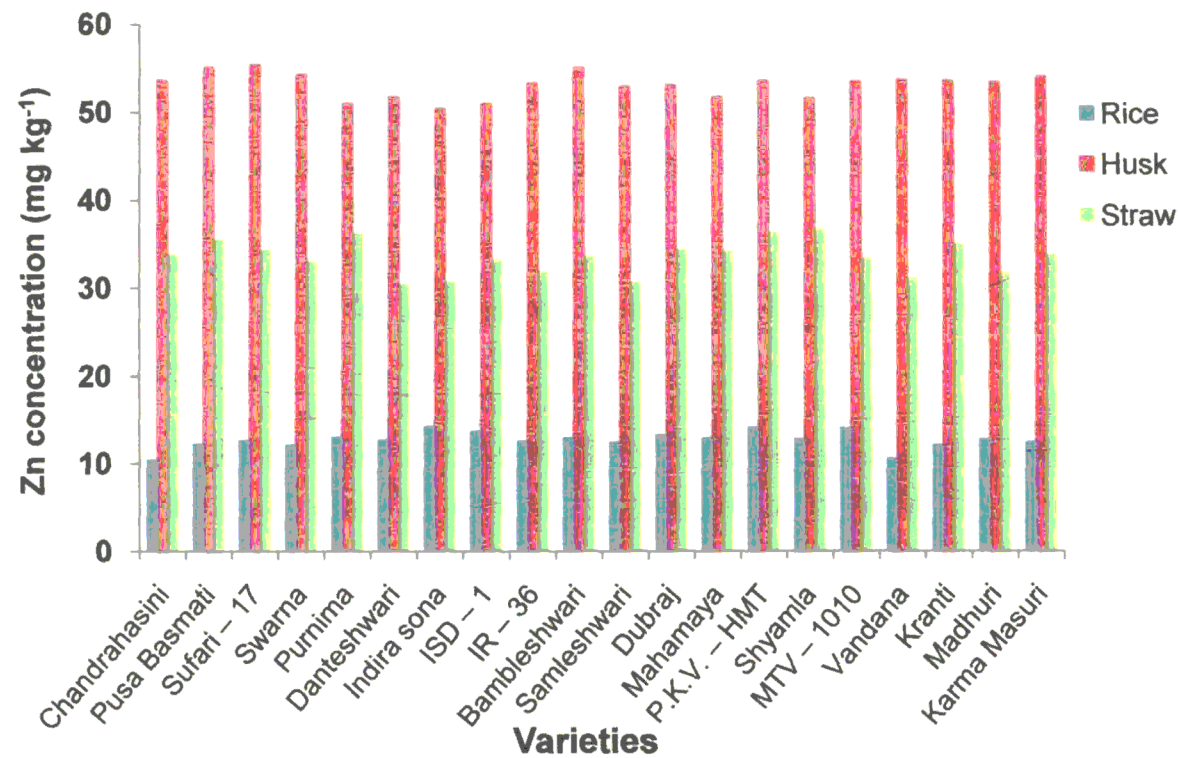

Fig. 5.2.2 Effect of Zn application on concentration of zinc in paddy varieties

5.3 Effect of Zn application on total uptake of nutrient in paddy crop

The effects of Zn on the uptake of nutrient have been presented in table 4.9 and fig-5.3.1 & 5.3.2 the results indicate that total uptake of Zn increased with application of Zn. The Zn uptake increased by 204% with application of 20 kg Zn + 0.5% spray of $ZnSO_4$ over the control (fig. 5.3.1) and similarly increased the Zn uptake by 122.1% with foliar spray of $ZnSO_4$. The uptake of nutrient is a function of yield and its concentration in crop, hence application of Zn increased uptake of Zn due to increased yield as well as Zn concentration of the crop.

The maximum Zn uptake was observed in Variety Kranti (495.33 gha^{-1}) which was 376.7% more in comparison to Indira sona (fig. 5.3.2).

Similar findings have been reported by Sharma and Bapat (2000) in Vertisols of Jabalpur, and Sharma *et al* (2005) have also reported that increasing in uptake due to application of zinc.

Varshney *et al* (2008) have also reported the increase in Zn content and uptake significantly with increasing level of Zn in Typic Hapludoll.

5.4 Effect of Zn application on different plant parts of paddy crop

The concentration of Zn in different plant parts (stem, leaf and penical) increased with the application of zinc (Table 4.10 and fig. 5.4.1). The zinc concentration increased by 69.4% in stem, 92.9% in leaf and 123.7% in penical with the application of 20 kg Zn + 0.5% foliar sprays of $ZnSO_4$ over control. Similarly the concentration of zinc increased by 28.6% in stem, 22% in leaf and 44% in penical with the application of 0.5% foliar spray of $ZnSO_4$ over control. Similar findings have been reported by Sharma and Bapat (2000) the content of zinc in various plant

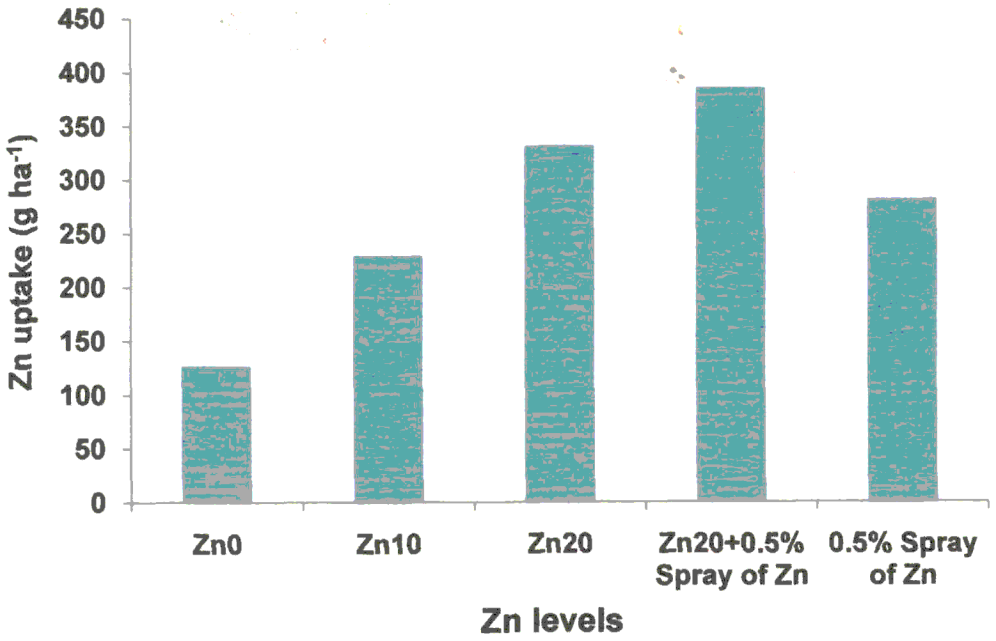

Fig. 5.3.1 Effect of Zn application on total Zn uptake by paddy

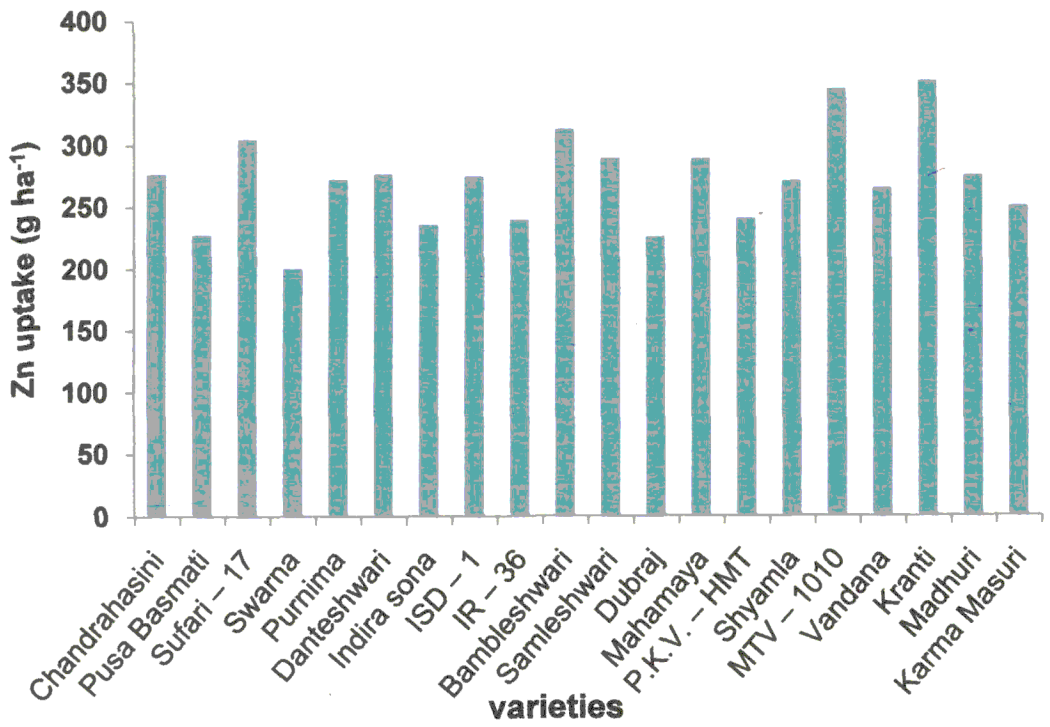

Fig. 5.3.2 ZN uptake by different varieties of paddy

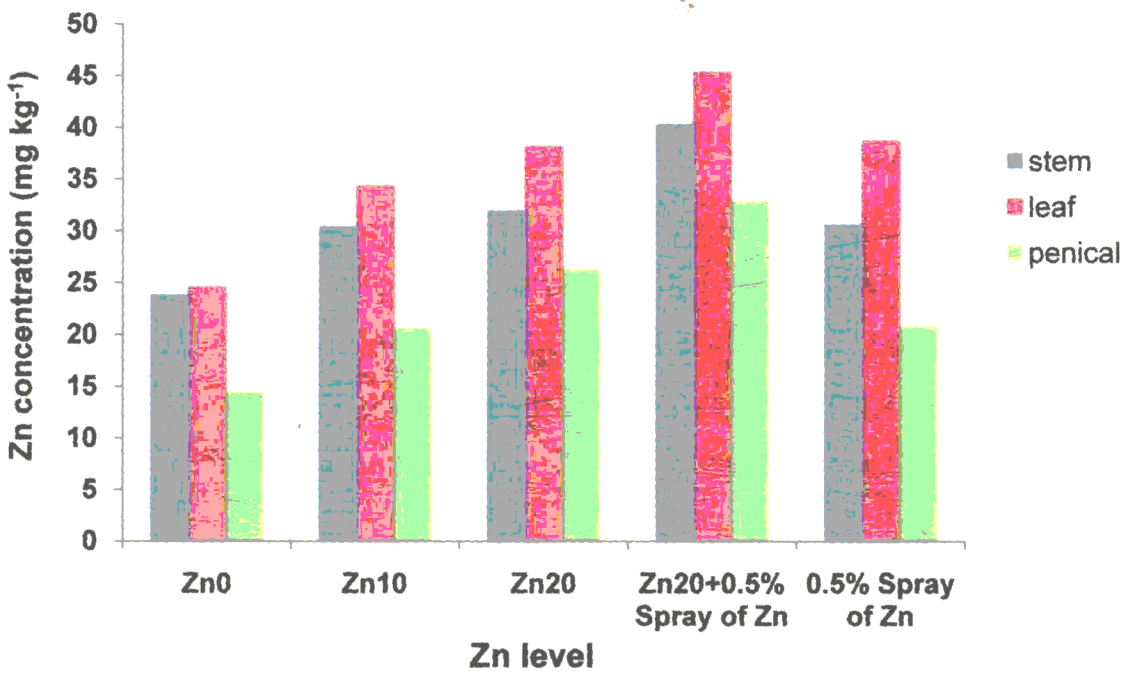

Fig. 5.4.1 Effect of Zn application on concentration of zinc in different plant parts of paddy

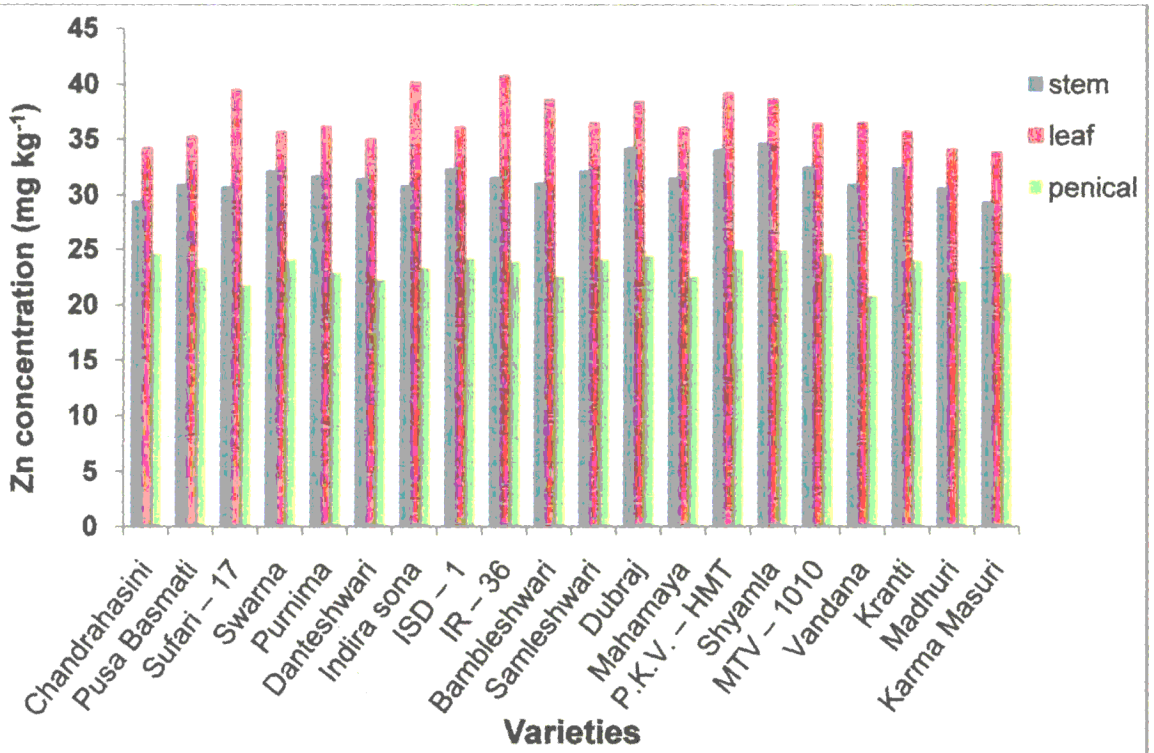

Fig. 5.4.2 Effect of Zn application on concentration of zinc in different plant parts of paddy varieties

parts increase with increasing levels of zinc at different stages of growth.

5.5 Effect of Zn application on DTPA extractable zinc

The application of zinc exerted an increased effect on DTPA extractable zinc in post harvest soil (Table 4.11). It increased in post harvest sample by 848.2% with the application of 20 kg Zn ha^{-1} over control. Similar findings have been reported by Haldar and Mandal (1982) in three clay loam lowland rice soil.

Trived et al. (1998) reported that after harvest of rice increased from original value respectively with the application of zinc.

5.6 Effect of Zn application on Zn use efficiency of paddy crop

The maximum use efficiency was observed by 55.6% with the application 10 kg Zn ha^{-1} and use efficiency decreased by 38.5% with the application of 20 kg Zn ha^{-1} and also use efficiency was decreased by 33.14% with foliar spray of $ZnSO_4$ over soil application of 20 kg Zn ha^{-1}. Varshney *et al* (2008) reported the efficiency of different rates and frequency of Zn application on yield, zinc concentration and uptake of rice.

CHAPTER – VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

SUMMARY, CONCLUSION AND SUGGESTION FOR FURTHER WORK

6.1 Summary

A field experiment was conducted to assess the effect of zinc on growth, yield and uptake of zinc in relation to yield and nutrition of paddy crop. The effect was also assessed on zinc content in post harvest soils.

Zn at the rate of 0, 10 kg ha^{-1}, 20 kg ha^{-1}, 20 kg ha^{-1} + 0.5% spray and 0.5% spray was applied to different paddy varieties in three replications and effect of Zn application was observed . Significant findings of the present study are summarized below.

6.1.1 Yield attributes and yields of paddy

The positive significant influence of zinc application was noticed on yield attributes like plant height, number of tillers and test weight of rice. Maximum increase in all yield attributes as well as in grain yield was observed with the application of 20 kg Zn ha^{-1}+0.5% spray of $ZnSO_4$. Maximum grain yield (4.96 t ha^{-1}) of rice was recorded in the Plots receiving application of 20 kg Zn ha^{-1}+0.5% spray of $ZnSO_4$ while it was minimum (4.04 t ha^{-1}) under no Zn. Minimum & maximum grain yield was observed in variety Dubraj (3.44 t ha-1) & MTV-1010 (5.44 t ha-1). Respectively Straw yield also increased with the increasing levels of zinc the differences amongst the treatments touches the level of significance.

6.1.2 Content and nutrient uptake by rice

The content of Zn increased from 8.84 to 17.57, 41.29 to 64.51 and from 16.58 to 43.30 mg kg^{-1} in grain (rice, husk) and straw respectively with the application of 20 kg Zn ha^{-1}+0.5% spray of $ZnSO_4$ over control. Minimum & maximum content of Zn

in rice, husk and straw was observed in variety Chandrahasini, Indira Sona, Danteshwari & PKV-HMT, Sufri-17, Shyamla respectively.

The uptake by rice crop increased from 126.60 g ha^{-1} to 384.91 g ha^{-1} with application of 20 kg Zn ha^{-1}+0.5% spray of $ZnSO_4$ over the control .Minimum & maximum uptake was observed by variety Swarna & Kranti respectively.

6.1.3 DTPA extractable Zn

The application of zinc exerted a positive significant influence on DTPA Zn in post harvest soil samples. On an average the zinc content increased significantly from 0.58 under control to 5.80 mg kg^{-1} with 20 kg Zn ha^{-1}+0.5% spray of $ZnSO_4$.

6.2 Conclusions

1. Application of 20 kg Zn ha^{-1} was found superior for getting the maximum grain yield of rice over control. Zn concentration in rice, husk and straw and its uptake increased significantly with the application of Zn.
2. Foliar spray of $ZnSo_4$ increased uptake and concentration of zinc in rice.
3. Zinc content in post harvest soil samples increased significantly with the increasing levels of Zn.
4. Use efficiency of zinc decrease with increasing levels of zinc.
5. Zinc content in different plant parts increase with increasing levels of zinc at flowering stage.

6.3 Suggestions for further work

The availability of zinc does not exceed 5 to 10% of applied zinc in soil and most of the applied zinc is converted to unavailable forms. Hence, it is suggested to study the response

of crops to zinc to get maximum benefit to applied fertilizer and explore the means to increase the efficiency of applied Zn.

There is wide sprayed deficiency of zinc in soils hence research on screening the varieties which one efficient take up zinc from Zn-deficient soils.

Studies should be carried out to enhance the absorption of Zn in paddy varieties to cop up with zinc deficiency in human being.

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