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SOIL FERTILITY, PRODUCTION POTENTIAL AND NUTRIENT UPTAKE EFFICIENCY UNDER RICE (*Oryza sativa* L.) AS INFLUENCED BY INTEGRATED USE OF ZINC AND FYM

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Abstract: *A field experiment was conducted during 2014–2015 at experimental farm of Udai Pratap College, Varansi, to assess the possibility of improving soil properties and productivity of Rice (Oryza Sativa). The treatments were consisted by various combinations of Zink and FYM such as control (T_1), 5kg. Zink/ha. (T_2), 10Kg. Zink/ha. + 10T. FYM/ha. (T_4), 15Kg. Zink/ha. (T_5), 20 Kg. Zink/ha. + 10 T FYM/ha. (T_6), 20 Kg. Zink/ha. (T_7). Application of 20 Kg Zn ha.+10T. FYM recorded significantly higher organic carbon available NPK and S. content over other combination. Application of 20 Kg Zn ha.+10T. FYM significantly increased the total porosity and reduced BD of soil as compare to other treatment. The use of organic manure significantly decreased soil pH. and EC. as compare to Zink alone. Significantly higher plant height, No. of Tiller, grain and straw yield recorded with application of 20 Kg. Zink/ha.+10T. FYM/ha. Results indicated that application of zink with FYM improved soil fertility as well as crop productivity at all level of zink application. It is also found that increasing level of zink increase crop productivity. The application FYM with zink maximized yield of rice and improved soil fertility.*
Keyword: *Rice, zink, FYM, fertility, productivity.*

Introduction: Rice (*Oryza sativa* L.) is the staple food of more than 65 % of the world population. It is the grown with the second highest wide production after maize, producing more than one fifth of the calories consumed by the human species of the world. In recent year's use of fertilizers coupled with intensive cropping have accelerated the exhaustion of micro-nutrient reserves of soils. It has, thus, become imperative to use the matching doses of required NPK and Zinc along with FYM. Besides, increasing the productivity of rice, supplementation of micro-nutrients in fertilizer schedule also is a significant factor to improve the quality of grain to overcome certain malnutrition problems in dietary system of human beings. Accordingly its productivity, quality and profitability have become an integral part of our National Food System. In India, among micro-nutrients, Zn deficiency is the most widespread under the area of high yielding crop varieties particularly in low land rice [1]. Therefore, it was worthwhile to study the effect of Zn, Fe and FYM growth, yield and the content of N, P, K, Zn and Fe in grains of different rice varieties.

Under Zn deficient soil condition, the growth and quality of rice grain and human health is affected [2,1]. The rice plant is commonly deficient in Zn as the requirement of Zn in rice is high [3]. The Zn removal by hybrid rice is more twice as compared to wheat [4]. Though the Zn requirement of crop varied with their cultivars, type of soil, and their deficiency status and sources of Zn, application of Zn @ 11 kg ha^{-1} has been proved to be optimum for wheat to relatively in the fine textured loamy soil [5]. To ameliorate Zn deficiency, the Zn-fertilizers are being used but the Zn availability to the plant is less due to very high Zn fixation. The addition of farmyard manure (FYM) significantly increased the DTPA extractable Zn and Fe in the soil under rice-wheat cropping system [6]. Under such a situation, the use of fertile and organic manures in an integrated manner is essential to maintain soil health and sustainable production [7]. Integrated plant nutrient supply (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. Therefore, suitable combination of Zn and FYM levels need to be developed under rice-wheat sequence. Hence, the present investigation was undertaken to study the effect of FYM and Zn application on soil properties, yield and uptake of Zn by rice grown in inceptisols of Varanasi. The major objective of this experiment was to evaluate the effects of Zn & FYM on the promotion of plant growth (rice) and improvement in soil properties by means of field experiment.

Materials and Methods

A field experiment was conducted in *kharif* season (2014-2015) at agricultural form of U.P. Autonomous College, Varanasi developed on alluvium deposited. The soil of experimental site was sandy clay loam in texture, slightly saline and non-alkaline in reaction. The initial physico-chemical properties of experimental soil were bulk density 1.36 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.40, EC 0.55 dS m^{-1}, organic carbon 0.48 %, water holding capacity 41.5 %, available nitrogen 233.0 kg ha^{-1}, available phosphorus 15.0 kg ha^{-1}, available potassium 237.2 kg ha^{-1} and available sulphur 9.5 kg ha^{-1}. The various treatments applied to rice crop were Control (T_1), 5 kg Zn ha^{-1} +RDF* (T_2), 10 kg Zn ha^{-1}+RDF* (T_3), 10 kg Zn ha^{-1}+ RDF*+ 10 t FYM ha^{-1} (T_4), 15 Kg Zn ha^{-1}+ RDF* (T_5), and 20 kg Zn ha^{-1}+ RDF*+10 t FYM ha^{-1} (T_6), 20 Kg Zn ha^{-1}+ RDF* (T_7). The treatments were triplicated in randomized block design (RBD). The recommended dose for rice was 120-60-40 kg N-P_2O_5-K_2O ha^{-1}. NPK and FYM were applied as per schedule of treatments. Nitrogen from urea was given as 50% basal, 25% after 45 days of transplanting and 25% after 60 days. The full dose of P and K through single super phosphate and muriate of potash were applied at time of sowing as basal dressing respectively. Zink was applied as per treatments described above through $ZnSO_4$ at time of transplanting. The composition of FYM was 0.5% N, 0.2 % P_2O_5, 0.5% K_2O. The required quantities of FYM were applied 15 days before sowing as per treatment. Soil samples from 0-15 cm depth were collected in plastic bag from individual plots at 30 DAT and after harvest of the crop. One soil sample of each plot was air- dried, processed to pass through 2 mm round hole sieve and analysed for oxidizable organic carbon (1*N* $K_2Cr_2O_7$), available N (0.32% alkaline$KMnO_4$ oxidizable), P(0.5 M $NaHCO_3$ extractable), K (1 *N* neutral ammonium acetate extractable) and S (0.15% $CaCl_2$) following the methods described by Walkley and Black method [8,9,10,11]. Soil pH was determined in 2:1 soil: water suspension with the help of glass electrode in digital pH meter and electrical conductivity of soil was measured in the supernatant liquid of soil water suspension (1:2) by conductivity bridge [12]. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured [13]. The available zinc in soil was determined by DTPA method through atomic absorption spectrophotometer [14].

Field was prepared by cross harrowing followed by planking and puddling. Around each plot bonds were made to control water in the plots. Healthy seedlings of 21 days old rice plant (var. - Moti) was transplanted with a spacing of 20X10 cm. Five plants are marked randomly in each replicated plot and height was measured from base of plant to the tip of the upper most fully matured and stretched leaf before emergence of ear and from the base of plant to tip of ear after it emergence for calculating mean plant height at 30 and 120 days after transplanting (DAT). Number of tillers per meter in row length at different growth stages (30 DAT and at maturity) of crop were recorded. Dry matter of plants is taken at 60 DAT by cutting the plants in one meter row length in each plots then kept in shade for dry and weighed. After harvesting and threshing the weight of grain was recorded. Straw yield was calculated by subtracting grain yield from biological yield. Plant samples (grain and leaf) drawn at harvesting were dried in shade and then kept in oven at 70^0C for 12 hours to make free from moisture. After there, samples were ground in grinder and the total P, K and S content in plant samples were determined by digesting the samples with di–acid (HNO_3:$HClO_4$ in 10:4) mixture [12] while N was determined by chromic acid [15]. The DTPA extractable Zn was separately determined fallowing the procedure of [16].

Plant uptake of NPK S and Zn were computed by multiplying the yield with the respective nutrient content. The data collected from field and laboratory were analyzed statistically using standard procedure of randomized block design [17]. Critical difference (C.D.) and standard error of mean (SEM) were calculated to determine the significance among treatment means.

Organic Carbon: In respect to organic carbon, various treatments of Zn and FYM could be arrange in the order T_6> T_4> T_7> T_5> T_3> T_2> T_1>. The values of organic carbon content of soil varied from 0.57 to 0.64, 0.54 to 0.61, 0.52 to 0.57, 0.49 to 0.55, 0.47 to 0.53, 0.45 to 0.52, and 0.43 to 0.49 percent under respective treatment (table-1). Incorporation of FYM with Zn slightly increased the organic carbon content over Zn alone at all level of Zn. Significantly higher organic carbon content was recorded under T_6 over rest of the treatment at all growth stages. Application of FYM might have created environment conducive for formation of humic acid, stimulated the activity of soil micro-organism resulting in an increase in organic carbon content in the soil [18,19]. The increase in organic carbon content in the manurial treatment combination is attributed to direct addition of organic manure in the soil which stimulated the growth and activity of micro-organism and also due to better root growth resulting in the higher production of biomass, crop stubbles and residues [20,21]. The increase in soil organic carbon content with the use of FYM has also been reported previously [22]. The results revealed that due to Zn application there was significant increase in organic carbon content of soil might be attributed to higher biomass addition through crop residue and stubbles. The beneficial effect of Zn on organic carbon content have been reported [23].

Table1. Effect of Integrated use of Zinc and FYM on organic carbon, available N.P.K. and S of Soil Fertility, Production Potential and Nutrient Uptake Efficiency under Rice (*Oryza sativa* L.)

Treatme-nts	Organic carbon (%)		Available nutrients (kg ha^{-1})							
			N		P		K		S	
	30 DAT	At harvesting	30 DAT	At harves-ting	30 DAT	At harves-ting	30 DAT	At harves-ting	30 DAT	At harvesting
T_1	0.49	0.43	235.00	206.00	17.00	11.00	236.00	201.00	10.10	7.20
T_2	0.52	0.45	239.00	212.00	20.10	13.30	241.00	207.00	12.00	9.10
T_3	0.53	0.47	242.00	217.00	21.50	15.00	235.00	211.00	13.40	11.50
T_4	0.61	0.54	257.00	232.00	27.40	20.60	251.00	223.00	18.50	15.00
T_5	0.55	0.49	248.00	223.00	23.00	16.50	240.00	217.00	15.00	13.00
T_6	0.64	0.57	260.00	235.00	30.60	21.50	255.00	228.00	20.60	16.30
T_7	0.57	0.52	250.00	225.00	25.60	18.30	243.00	220.00	16.20	14.20
SEm(±)	0.01666	0.01303	3.509	2.260	0.6846	1.139	1.485	1.825	1.072	1.219
CD (P=0.05)	0.03631	0.02839	7.647	4.926	1.4917	2.481	3.236	3.978	2.337	2.658

DAT=Days after transplanting

Available Nitrogen: The effect of different treatment of Zn and FYM on available nitrogen content could be arranged in the order T_6>T_4> T_7> T_5> T_3> T_2 > T_1 and value varied from 235 to 260, 232 to 257, 225 to 250, 223 to 248, 217 to 242, 212 to 239 and 206 to 235 kg ha^{-1} under respective treatment (table-1).

Significantly higher nitrogen content was recorded in 20 kg Zn ha^{-1} through $ZnSO_4$ and FYM (10 t ha^{-1}) treated plots over rest of treatment. Increasing levels of Zn significantly increased available N content however; there was a significant build up of available N in soil receiving Zn along with 10 t FYM ha^{-1} as compared to Zn alone. The increased in available N might be attributed to the enhanced multiplication of microbes by the incorporation of FYM for the conversion of organically bound N to inorganic form. The favorable soil condition under organic manure application might have facilitated the mineralization of soil N leading to build-up of higher available N [21]. The application of zinc considerably increased the nitrogen content of soil and maximum amount obtained at 20 kg Zn ha^{-1} at all growth stages. The beneficial effect of Zn in improving soil properties and enhancing the N availability has been reported [24] and the similar result has been also suggested [25, 26].

Available Phosphorus: Continuous omission of P in crop nutrition has caused mining of its native pools which has resulted in the decreased caused in crop yield (table-1). Incorporation of FYM along with Zn recorded significantly higher available P as compared to Zn alone. The increased availability of P with FYM could ascribed to their solubilizing effect on the native soil P and consequent contribution of the P as solubilized to labile pool. Incorporation of FYM along with zinc increased availability of P to crop and mineralization of organic P due to microbial action [23]. FYM (humus) may also reduce the fixation of phosphate by providing protective cover on sesquioxides and thus reduce the phosphate fixing capacity and increase the available P. The increase in available P found to be significantly higher with FYM ten tons plus Zn 20 kg ha^{-1} as compared to rest treatments. The increase in available P with use of FYM plus Zn in rice-wheat system has also been reported previously [24 & 26]. It was also found that increasing levels of Zn significantly increased available P content of soil. This may be attributed to higher biomass production at higher level of Zn [24, 27, 28]. In respect of available P content of soil, the Zn treatment could be arranged in the order $T_6 > T_7 > T_4 > T_5 > T_3 > T_2 > T_1$ and values varied between 11.0 to 30.60 kg ha^{-1}.

Available Potassium: In respect of available potassium, different could be arranged in the order $T_6 > T_7 > T_4 > T_5 > T_2 > T_3$ and T_1 and values varied from 228 to 255, 220 to 243, 223 to 251, 217 to 240, 207 to 241, 211 to 235 and 201 to 236 kg ha^{-1} under respective treatment significantly higher available K content was recorded with 20 kg Zn ha^{1} plus 10 t FYM ha^{-1} application over rest of treatment (table-1). Addition of FYM with Zn at any levels recorded significantly higher available K as compared to Zn by $ZnSO_4$ alone. Similar, findings have also been reported [24]. Application of Zn increased the available K over control. The maximum value was recorded at 20 kg Zn ha^{-1} treatment followed by 10, 5 kg Zn ha^{-1} and control. The results corroborated the findings [29 & 26].

Available Sulphur: The available sulphur content differed significantly due to various levels of Zn in combination with FYM (table-1). Like available NPK, highest available S content was recorded in use of the treatment consisting of 10 t FYM ha^{-1} plus 20 kg Zn ha^{-1}. The beneficial effect of FYM on available S status may be as cribbed to the direct sulphur addition in sulphur pool of the soil**.** Similar improvement in available S status due to integrated use of FYM and $ZnSO_4$ has been noted [29, 26 & 30]. It was also found that increasing levels of Zn significantly increased the sulphure content may be attributed to large amount sulphur added through $ZnSO_4$ at large amount of Zn since the amount of unabsorbed sulphur also increased with added quantity of sulphur. The results corroborated the findings. The effect of Zn and FYM treatments on available S content was found in the order $T_6 > T_4 > T_7 > T_5 > T_3 > T_2 > T_1$ and the values varied from 7.20 to 20.60 under respective treatments.

DTPA Extractable Zn (mg kg^{-1}) in Post Harvest Soil: It is evident from result that application of increasing levels of Zn significantly increased the DTPA extractable Zn in soil after harvesting of rice (table-2). The effect of various levels of Zn on DTPA Zn in post harvest soil could be arranged in order of $T_6 > T_4 > T_7 > T_5 > T_3 > T_2 > T_1$ and the values were 2.53, 1.98, 2.25, 1.86, 1.45, 1.00, 0.65 mg kg^{-1}. Significantly increase in DTPA – Zn with Zn application was also confirmed [4 & 31]. Response of zinc in transplanted rice under integrated nutrient management in new alluvial Zone of west Bengal [32].

Table 2. Effect of Zn and FYM application on DTPA extractable Zn in post harvest soil of rice crop.

Treatment	DTPA extractable Zn (mg kg^{-1})
T1	0.66
T2	1.00
T3	1.45
T4	1.98
T5	1.86
T6	2.53
T7	2.25
SEm+	0.0589
CD (0.05%)	0.1284

Soil pH and EC: As evident from results, the soil pH of rice plots under different treatments varied from 7.40 to 7.25, and 7.49 to 7.30 at 30, DAT and at harvesting, respectively (table-3). Soil pH under different treatment was found in the order $T_1 > T_2 > T_3 > T_5 > T_7 > T_4 > T_6$ and values varied from 7.40 to 7.49, 7.34 to 7.42, 7.30 to 7.37, 7.20 to 7.24, 7.27 to 7.32, 7.16 to 7.20 and 7.25 to 7.32 under respective treatments. Application of FYM with $ZnSO_4$ decreased the soil pH over control and Zn alone but the differences amongs treatments were not significant. Soil pH decreased with increasing levels of Zn though $ZnSO_4$ might be attributed to the sulphur in $ZnSO_4$ on biological oxidation yield sulphuric acid which responsible for decreased pH at increased levels of sulphur [33].

The electrical conductivity of soil under different combination of Zn and FYM varied from 0.38 to 0.58, dS m^{-1}. At any level of Zn, addition of FYM along with Zn decreased the soil EC might be attributed to release of organic acid during decomposition of FYM which replace the salt from exchange site as well as soil solution. EC of soil decreased with rise in doses of Zn thought $ZnSO_4$ and recorded lower value under 20 kg $ZnSO_4$ applied plots. The results are also in accordance with those of Prasad (2010) who reported that increased level of S reduce EC of soil. The effect of different treatment on soil EC could be arranged in order $T_1 > T_2 > T_3 > T_5 > T_7 > T_4 > T_6$.

Table3: Effect of Integrated use of Zinc and FYM on physico-chemical properties of soil under rice crop (*Oryza sativa* L.)

Treatments	Soil pH		EC (dS m^{-1})		Bulk density (Mg m^{-3})	
	30 DAT	At harvesting	30 DAT	At harvesting	30 DAT	At harvesting
T_1	7.40	7.49	0.55	0.58	1.36	1.46
T_2	7.34	7.42	0.52	0.55	1.35	1.45
T_3	7.30	7.37	0.49	0.51	1.32	1.42
T_4	7.20	7.24	0.41	0.45	1.31	1.41
T_5	7.27	7.32	0.45	0.48	1.30	1.40
T_6	7.16	7.20	0.38	0.41	1.28	1.39
T_7	7.25	7.32	0.46	0.49	1.27	1.36
SEm(±)	0.648	0.362	0.0141	0.0097	0.0403	0.0585
CD (P=0.05)	1.412	0.789	0.0308	0.0212	0.0878	0.1276

Bulk Density: The bulk density increased gradually with time on account of natural consolidation of soil particle in all treatment up to harvesting of crop (table-3). Significantly lower bulk density was recorded under Zn through $ZnSO_4$ and FYM (10 t ha^{-1}). Zn (T_7 to T_2) applied plots as compared to other treatment T_1 on bulk density was found in the order $T_1 > T_2 > T_3 > T_4 > T_5 > T_6 > T_7$ and the values varied from 1.36 to 1.46, 1.35 to 1.45, 1.32 to 1.42, 1.31 to 1.41, 1.30 to 1.40, 1.28 to 1.39 and 1.27 to 1.36 Mg m^{-3} under respective treatment. Decreased the bulk density in nitrogen through FYM+ recommended dose of NPK and Zn applied plots may be due to higher organic matter more pore spaces and better soil aggregation. Also reported that more crop residue, higher organic matter content and better root growth, might be possible reasons for decrease in bulk density [34].

Growth Parameters

Plant Height: The plant height of rice crop increased continuously with advancement in growth stages up to the harvest under all treatments (table-4). In respect of plant height, various treatment could be arranged in order of $T_6 > T_4 > T_7 > T_5 > T_3 > T_2 > T_1 >$ and value were 116.80, 115.00, 113.64, 112.70, 111.05, 110.00 and 108.10 cm at harvesting, respectively. Application of FYM along with $ZnSO_4$ significantly increased plant height as compared to $ZnSO_4$ alone. Increasing levels of Zn from 0 to 20 kg ha^{-1} significantly increased plant height and maximum value obtained at 20 kg followed by 15, 10, 5 and 0 kg Zn ha^{-1}. Similar finding were reported [35, 36]. Application of 10 t FYM along with 20 kg Zn ha^{-1} recorded significantly higher plant height might be attributed to better supply of nutrient through incorporation of FYM [37]. The similar result has been also suggested by Ram U. S. [38].

Treatments	plant height (cm)		No of tillers(m^{-2})		Grain yield (Q ha^{-1})	Straw yield (Q ha^{-1})	Test weight (gram/1000 grain)
	30 DAS	At harvesting	30 DAS	At harvesting			
T_1	73.10	108.10	35.00	44.95	30.10	46.10	21.81
T_2	75.00	110.00	43.10	47.00	34.10	51.00	21.90
T_3	77.45	111.05	49.60	50.12	37.25	53.10	22.60
T_4	82.60	115.00	58.10	59.65	45.12	62.12	23.90
T_5	79.15	112.70	53.25	53.45	40.00	57.00	24.0
T_6	84.00	116.80	60.62	61.70	47.38	64.53	24.10
T_7	80.75	113.64	54.75	54.75	41.25	59.35	24.22
SEm(±)	1.263	2.6452	2.6582	2.4949	1.5313	1.4420	3.157
CD (P=0.05)	2.753	5.7639	5.7923	5.4365	3.3367	3.1422	6.879

Table4: Effect of Integrated use of Zinc and FYM on growth and yield on rice crop (*Oryza sativa* L.)

Number of Tillers: The number of plant tillers per meter row length of rice under different treatments increased with time and reached maximum at harvesting (table-4). Effective tillers was significantly influenced due to application of FYM plus $ZnSO_4$ in comparison to control and $ZnSO_4$ alone. This may be due to fact that slowly released nutrients through FYM helped to produce more number of effective tillers m^{-1} row length [39]. Effective tiller increased significantly with increasing levels Zn and maximum value was recorded at 20 kg Zn ha1 treatment similar results were also obtained by Ali *et al*. 2013. The effect of various treatments on number of tillers were found in the order T_6> T_4> T_7> T_5> T_3> T_2> T_1> and value varied between 35.00 to 61.70 m^{-1} row length. The similar result has been also suggested by Ram U. S. [38].

Yield Attributes

Test Weight, Grain and Straw Yield: Data depicted in table- revealed that effect of different treatments consisted of Zn and FYM on test weight of rice found in the order T_6> T_4> T_7> T_5> T_3> T_2> T_1 and the value were 24.22, 24.10, 24.00, 23.90 22.60, 21.90 and 21.81 g per 1000 grain under respective treatment. T_6 treatment was recorded significantly higher test weight over other treatments. The similar result has been also suggested by Ram U. S. [38].

The effect of various treatment on grain yield of rice could be arranged in the order T_6> T_4> T_7> T_5> T_3> T_2> T_1 and the value were 47.38, 45.12, 41.25, 40.00, 37.25, 34.10 and 30.10 q ha^{-1} under respective treatment. Application of Zn increased the grain and straw yield over control. It's was increased significantly with increasing levels of Zn and maximum with values recorded at 20 kg Zn ha^{-1} plus 10 t FYM applications. The increase in grain yield due to Zn application from control to 20 kg Zn ha^{-1} varied from 30.10 to 47.38 q ha^{-1}. Whereas straw yield increased from 46.10 to 64.53 q ha^{-1}. The increase in grain and straw yield might be due to role of Zn in biosynthesis of IAA (Indole Acetic acid) and specially due to its role in initiation of primordial for reproductive part and partitioning of photosynthesis towards them which resulted in better flowering and fruiting [40]. Similar findings were also reported [36]. Application of 10 FYM along with 20 kg Zn ha^{-1} recorded significantly highest yield response followed by 10 FYM plus 10 kg Zn ha^{-1}. Benefits accruing from the integrated use of FYM with Zn might be attributed to better supply of nutrient thought incorporation of FYM along with conductive physical environment leading to better root activity and higher nutrient absorption, which resulted in better result plant growth and superior yield attributed responsible for higher yield [37 & 41]. The similar result has been also suggested by Ram U. S. [38].

Effect of Zn and FYM Application on Nutrient Uptake by Rice Crop: Application of Zn with FYM significantly improved the total uptake of NPK and S by rice as compared to control and Zn along (Fig.1).The increase in uptake of nutrients in FYM treated plots may be due to extra amount of nutrients supplied by FYM and it provide conductive physical environment better root growth and adsorption facilitating of nutrient from the native as well as applied sources which ultimately favored the highest nutrient uptake [21]. Nutrient (N, P, K, S and Zn) uptake was significantly increased with increasing level of Zn as compared to control as observed [42]. The increase in nutrients uptake may be due to increase in nutrient content and dry matter production. Zn plays structural and regulatory role in large number of enzymes and protein synthesis, which directly affects the nutrients absorption from the soil [43]. The effect of various treatment on nutrient uptake by grain and straw was found in order T_6> T_4> T_7> T_5> T_3> T_2> T_1. The similar result has been also suggested by Ram U. S. [38 & 40]

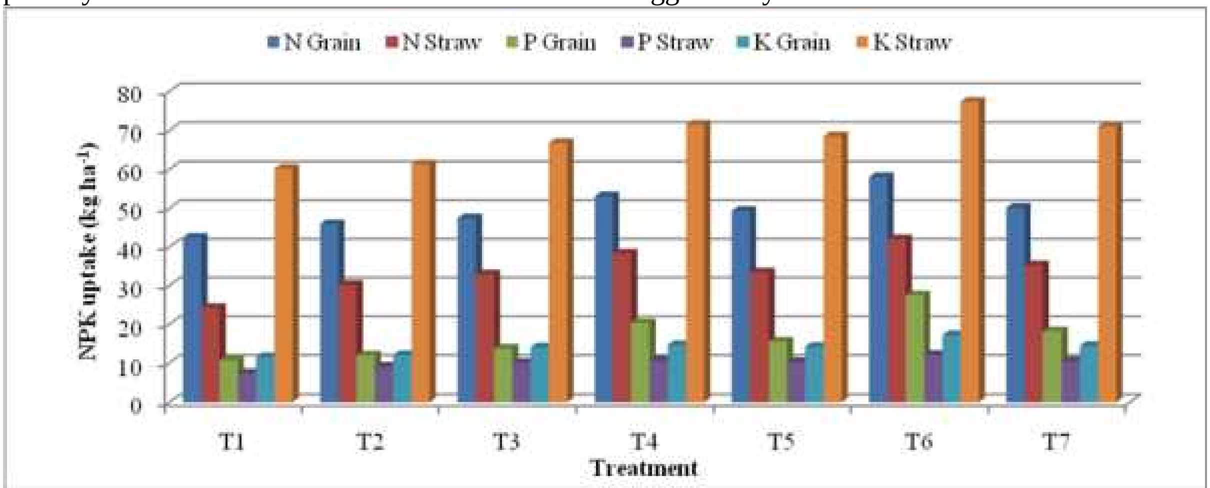

Fig. 1. Effect of Zn and FYM application on nutrients (N P K Zn and S) uptake (kg ha^{-1}) by rice crop.

Conclusion: Overall results of the study reveal that Zn and FYM combination was found superior over Zn application as $ZnSO_4\ 2H_2O$ to improve soil fertility and increase crop yield.

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