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Zn distribution in soils of Odisha and its management in a cereal based cropping system through graded dose of $ZnSO_4$ application

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Abstract
Zinc deficiency is one among many constraints limiting rice yield. Reports of All India Coordinated Research Project on Micro-Secondary Nutrients envisages that the soils of all districts of Odisha are deficient in Zn with an overall state mean deficiency of 33% of samples collected (GPS based). To sustain production and productivity of rice Zn application is inevitable. Since there exist a narrow gap between deficiency and sufficiency value of Zn in soil continuous use may lead other soil related nutrient problems or imbalance.
Keeping in view the above facts to find out the optimum dose and frequency of Zn application through $ZnSO_4$, a field experiment was conducted by taking 4 graded doses of Zn (2.5, 5.0, 7.5, 10.0 kg/ha) applied through 3 different frequencies (F1-Once, F2-Alternate year (1st, 3rd, 5th year), F3-Every year upto 6 year) with one no Zn control constituting 13 treatments replicated thrice in a randomized block design. In a rice - rice cropping system grown in an Zn deficient Inceptisols of central farm, OUAT, Bhubaneswar.
Results of the 6 cropping cycles revealed that, Rice crop responded to Zn application with respect to increasing dose and frequency with a highest mean grain yield of 4.3 t/ha as well as cumulative yield of 21.3 t/ha in the treatment of residual effect of once Zn application @ 7.5 kg/ha with highest B:C ratio of 1.47 per rupee investment followed by every year Zn application @ 2.5 kg/ha (1.45). Also yields were sustainable at 2, 5 kg Zn/ha every year, 7.5 kg alternate year and 10 kg/ha once Zn application condition within 6 year. Hence from the above study it may be concluded that Zn application is required in light texture sandyloam soils @ 2.5 kg every year or 7.5 kg in alternate year that is 1st,3rd,5th year or 10 kg once which can sustain yield upto 6 year in a rice-rice cropping system.

Keywords: Triclosan, TCS, determination, detection, sensor

Introduction
Zinc (Zn) is an essential micronutrient and has particular physiological functions in all living systems,such as the maintenance of structural and functional integrity of biological membranes Brown *et al*. 1993 [1]; Marschner 1995 [2]; Sadeghzadeh and Rengel 2011 [11] and facilitation of protein synthesis and gene expression. Compared with legumes, cereals are generally more prone to Zn deficiency leading to a substantial reduction in grain yield and nutritional quality (Cakmak *et al*.1999) [2]. But since there exists a narrow gap between Zn deficiency and toxicity. Not only Zn deficiency affects growth and yield of crops but also Zn toxicity affects crop yield. In Odisha from survey of Soil micronutrients status it was found that 33% surface soils were deficient in Zn that is <0.6 mg/kg soil. The cause of such deficiency may be attributed to Hence Zn fertilization needs to be managed in a careful way to get optimum yield and return without affecting soil nutrient balance. Hence an experiment was designed to find out suitable sustainable dose of Zn and frequency of application for a rice-rice cropping system which comprises of 3.31 lakh ha land of the state Odisha. The efficiency of applied Zn fertilizer is reduced under continuous flooding due to formation of insoluble ZnS and zinc franklinite ($ZnFe_2O_4$) (Ponnamperuma1972; Sajwan1985). Most common method of Zn fertilization is through soil application.

Materials and methods
For the study of Zn distribution GPS based soil samples were collected from different districts of Odisha @ 25 samples/block. A total of 6991 no of surface soil samples were collected from 22 districts of Odisha. Samples after processing were analysed for micronutrients Zn by DTPA extraction method of Lindsay and Novell (1978) [6].

District wise percent Zn deficiency was calculated by taking the critical limit of Zn as 0.6 mg/kg. pH and EC were determined in 1:2.5 soil : solution ratio as per Jackson, 1973. Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [10]. Soil texture by Bouyoucos hydrometer method (Piper, 1966).

To find out a suitable sustainable dose for cereal based cropping system, a field experiment was conducted from 2012-13 to 2017-18 for 6 years in a Zn deficient acidic laterite soil of centralfarm, Bhubaneswar. The treatments were 4 graded doses of $ZnSO_4$ (12.5, 25.0, 37.5, 50.0 kg $ZnSO_4$/ha) applied over 3 frequencies (F_1- once, F_2-alternate year, F_3-every year) with one no Zn control constituting 13 treatments replicated thrice in RBD in a rice –rice cropping system. Rice crop received recommended doses of NPK. Zn was applied through $ZnSO_4.7\ H_2O$ to the *kharif* rice only in respective treatments, *rabi* rice being grown on residual Zn treatment. Out of 13 treatments, T_1-T_4 received Zn application only in first year, rest years crop was grown on residual effect of Zn. In treatment no T_5-T_8 rice crop received Zn application on 1sy year, 3rd year and 5th year as alternate year Zn application. In treatment no T_9-T_{12} Rice crop received Zn application every year during *kharif*. After harvest Zn concentration in grain and straw samples were estimated by AAS. Yield for each season was recorded. After harvest of the crop post-harvest soil was analysed to find out possible changes in physic-chemical properties.

Results and Discussion

Zinc distribution in surface soils of Odisha

From the analysis of 6993 no of GPS based surface soils covering 22 districts of Odisha so far. Zinc content of surface soils ranged from 0.08 to 32.0mg/kg with mean value of 1.1mg/kg and overall deficiency of 32.9% of the samples collected. Among the 8 micronutrients Zn deficiency is widespread and found to present in almost all districts of the state. Digitized soil fertility map of Zn prepared with the help of Arc GIS software and presented in Figure -.1.

Table 1: District wise Zn Distribution in Soils of Odisha

	District	Sample Size	Range	Mean	PSD (%)
1	Kendrapara	148	0.80-7.54	2.63	-
2	Nuapada	82	0.23-5.57	1.85	09.0
3	Kalahandi	204	0.31-11.52	2.86	09.0
4	Jagatsingpur	83	0.10-9.18	2.27	08.0
5	Nayagarh	184	0.31-4.35	1.43	05.0
6	Sambalpur	282	0.15-16.5	1.85	04.0
7	Puri	424	0.11-7.06	1.25	06.2
8	Boudh	84	0.16-2.51	0.69	47.0
9	Dhenkanal	301	0.15-4.06	1.19	15.0
10	Sonepur	140	0.09-3.88	0.94	31.4
11	Angul	225	0.06-3.29	0.63	64.9
12	Bhadrak	358	0.1-2.61	0.64	51.9
13	Kandhamal	595	0.02-32.77	1.09	33.5
14	Khorda	377	0.08-6.5	0.66	54.4
15	Mayurbhanj	650	0.01-15.16	0.99	35.5
16	Deogarh	208	0.06-3.20	0.95	30.8
17	Jajpur	660	0.13-4.08	0.99	26.7
18	Nawarangpur	361	0.06-13.89	0.68	64.0
19	Balasore	360	0.01-10.24	0.69	55.8
20	Malkangiri	350	0.04-3.19	0.56	68.0
21	Ganjam	565	0.02-19.21	1.32	31.4
22	Koraput	350	0.01-7.28	1.08	39.4
	GPS	6991	0.01-32.77	1.17	32.9 (33%)
	Odisha	Non GPS			19

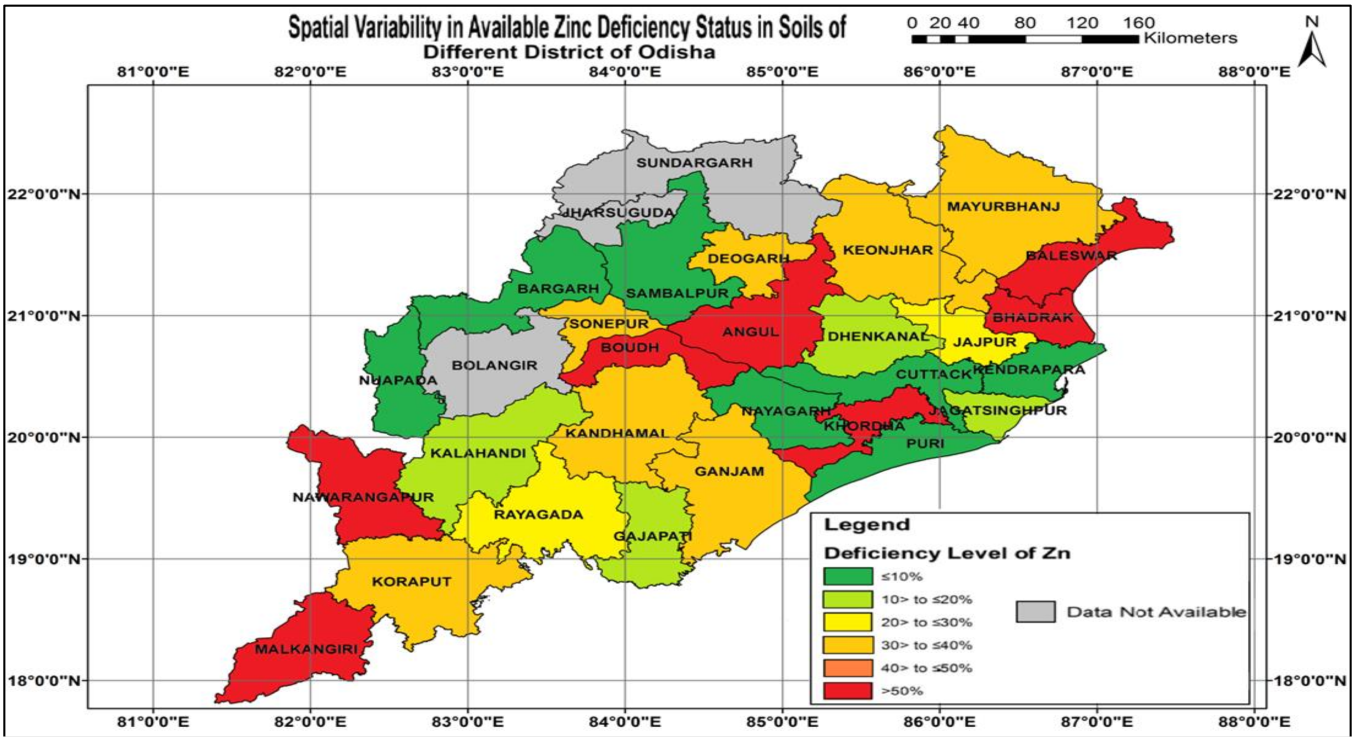

Fig 1: Spatial variability of Zn deficiency in soils of Odisha

Agro climatic Zone wise Zn distribution (PSD) of Odisha

The state of Odisha is divided into 10 agro climatic Zone which supports important crops and cropping systems. Hence to have a knowledge on agro climatic zone wise Zn status, it was computed from the district wise Zn status and is presented in Figure no.2.

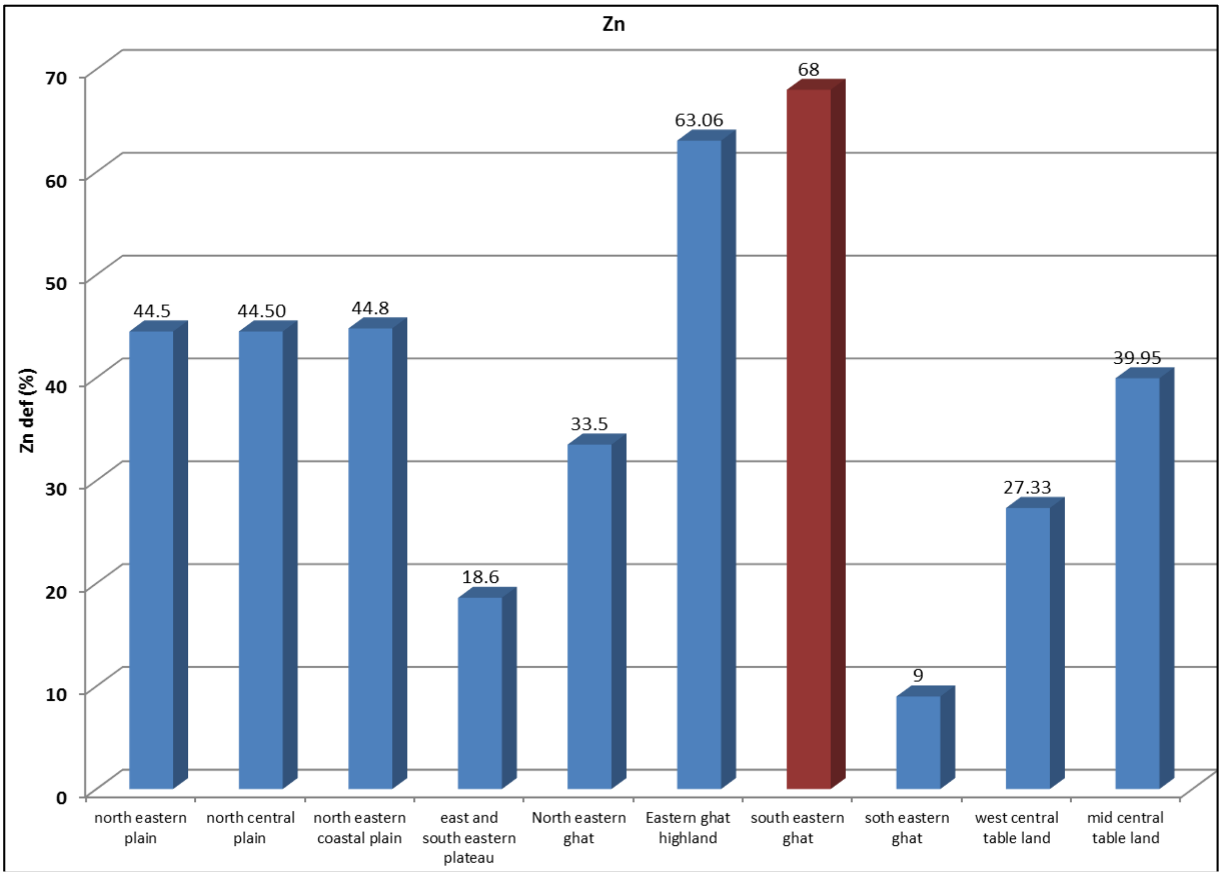

Fig 2: Agroclimatic Zone wise Zn deficiency distribution of Odisha

Highest Zn deficiency was found in South eastern ghat zone comprising of the districts like Koraput, Malkangiri which supports the cropping systems like Rice, millets, Maize, pulses, oilseeds etc. Under this agro climatic zone 68% of soils analyzed showing Zn deficiency. To prevent crop yield loss due to Zn deficiency these zones need Zn management by either soil application or foliar spray. Next highest Zn deficient zone was Eastern ghat high land zone. Hence from this study it was concluded that Zn application is inevitable. Similar findings were also reported by Shukla *et al* (2017) for soils of Odisha

But with regards to how much quality of Zn needs to be applied with what frequency and for how long it is to be applied is a question for farmers for which field experiment was conducted

Field experiment

To find out the optimum and sustainable dose of Zn application to a rice based cropping system a field experiment was conducted by taking 4 graded doses of Zn applied to first rice of a rice-rice cropping system the details of which given in below table 2.

Table 2: Details of yearwise Zn fertilization application for different treatments

	Frequency	Dose	2012-13 1st year	2013-14 1st year	2014-15 2nd year	2015-16 3rd year	2016-17 4th year	2017-18 5th year	Total Zn applied (kg/ha)
1	Once (F1)	D1=Zn @ 2.5 kg/ha	2.5	1st Residual	2ndResidual	3rd Residual	4thResidual	5th Residua	2.5
2		D2=Zn @ 5 kg/ha	5.0						5.0
3		D3=Zn @ 7.5 kg/ha	7.5						7.5
4		D4=Zn @ 10 kg/ha	10.0						10.0
5	Alt year (F2)	D1=Zn @ 2.5 kg/ha	2.5		2.5		2.5		7.5
6		D2=Zn @ 5 kg/ha	5.0		5.0		5.0		15.0
7		D3=Zn @ 7.5 kg/ha	7.5		7.5		7.5		22.5
8		D4=Zn @ 10 kg/ha	10.0		10.0		10.0		30.0
9	Every year (F3)	D1=Zn @ 2.5 kg/ha	2.5	2.5	2.5	2.5	2.5	2.5	15.0
10		D2=Zn @ 5 kg/ha	5.0	5.0	5.0	5.0	5.0	5.0	30.0
11		D3=Zn @ 7.5 kg/ha	7.5	7.5	7.5	7.5	7.5	7.5	45.0
12		D4=Zn @ 10 kg/ha	10.0	10.0	10.0	10.0	10.0	10.0	60.0
13	Control	Control (No Zn)	0	0	0	0	0	0	0.0

The experiment was started in the year 2012—13 in an light textured soils of central farm belonging to Inceptisols order due to peneplaination pyogenic process affecting horizon development. The soil was sandy loam in texture, acidic in reaction and non-saline, low in organic carbon status. Soil was also low with respect to available N, P, K status. DTPA extractable Zn content was medium in status. The soil was sufficient with respect to other cationic micronutrients like Mn, Cu, Fe. Total Zn content of the experimental site was 5.36 mg/kg and Total Fe 0f 2200 mg/kg.

Rice grain yield as affected by direct and residual effect of Zn dose and frequency from 2012-2018 is presented in Table 3.

Table 3: Effect of Dose and frequency of $ZnSO_4$ application on grain yield of Rice-rice cropping system over 6 years

treat	Rice grain yield (tha^{-1})												
	2012-13		2013-14		2014-15		2015-16		2016-17		2017-18		Mean
	Kh	Rb	Kh	Rb	Kh	Rb	Kh	Rb	Kh	Rb	Kh	Rb	
F1D1	4.13	3.40	2.53	3.53	3.42	3.58	3.41	3.62	3.08	3.87	3.26	3.18	3.42
F1D2	4.38	3.77	2.77	3.70	3.58	4.35	3.87	4.00	3.21	4.43	3.40	3.45	3.74
F1D3	4.92	4.33	3.43	3.73	3.70	4.43	3.98	4.12	3.45	5.52	3.48	3.13	4.02
F1D4	4.25	4.63	3.33	3.40	3.77	4.19	3.74	4.27	3.46	6.03	3.36	2.77	3.93
F2D1	4.17	3.23	3.67	3.17	3.73	3.35	3.81	3.58	3.38	3.38	3.70	3.12	3.52
F2D2	4.79	3.60	3.73	3.67	4.22	4.43	3.87	4.06	3.43	3.85	3.13	3.37	3.85
F2D3	4.80	3.87	3.90	3.83	3.36	3.79	3.54	3.63	3.64	4.33	2.74	2.92	3.70
F2D4	4.13	3.50	4.03	3.93	4.03	4.94	3.61	4.36	3.06	4.50	2.73	2.92	3.81
F3D1	4.25	3.78	3.87	5.27	3.84	4.69	4.57	3.87	3.02	4.50	3.55	2.93	4.01
F3D2	4.33	4.03	4.10	4.33	3.67	5.01	4.66	3.84	3.47	5.05	3.53	3.17	4.10
F3D3	4.42	4.08	3.00	4.33	3.69	4.80	3.62	3.55	3.26	5.20	3.19	3.08	3.85
F3D4	4.35	3.68	3.50	4.23	3.74	3.74	3.32	3.77	3.20	4.92	2.42	2.72	3.63
Control	3.45	2.97	2.23	3.03	3.08	3.26	3.28	3.53	2.70	3.40	2.83	3.13	36.89

From the table it was found that significant variation in Rice grain yield was observed with respect to Zn dose as well as frequency of application. For better interpretation of the effect of Zn application mean rice grain yield of 12 crops is presented in Table 4.

Table 4: Mean rice grain yield as affected by ZnSO4 application

	F1 (Once)	F2 (Alt Year)	F3 (every year)	Mean
D1=Zn@2.5 kg ha^{-1}	3.42	3.52	4.01	3.65
D2=Zn@ 5.0 kg ha^{-1}	3.74	3.85	4.10	3.90
D3=Zn@ 7.5 kg ha^{-1}	4.02	3.70	3.85	3.86
D4=Zn@ 10.0 kg ha^{-1}	3.93	3.81	3.63	3.79
Mean	3.78	3.72	3.90	
C.D.(0.05)	D=0.15	F =0.12	DxF =0.26	

Mean rice grain yield as affected by Zn Dose and frequency of Zn application is presented in Table 5. Significant effect of Dose, frequency and interaction was observed on mean rice grain yield. Mean rice grain yield in D_1(2.5 kg Zn ha $^{-1}$) was 3.7 t ha^{-1} which increased significantly at D_2(5 kg Zn ha^{-1}) to 3.9 t ha^{-1}.Similarly rice grain yield was found to increase with increase in frequency of Zn application highest being at F_3(3.9 t ha $^{-1}$) significant increase over F_1 or F_2.Interaction effect of Zn dose with frequency produced highest significant rice grain yield of 4.1 t/ha (D_2F_3).Yield increase was observed under residual Zn doses of 2.5-10 kg ha^{-1} up to 7.5 kg/ha but yield declined at 10 kg residual Zn after 6 cropping cycles.

Increase in yield due to Zn application might be due to increased growth due to balanced fertilization, efficient utilization of major nutrients, protein synthesis, activation of enzymes detoxification of ROS in plant cells etc. Increase yield with increasing Zn dose may be due to enhanced synthesis of carbohydrate and there transport to the site of grain production. Zinc deficiency results in abnormalities in plants which becomes visible as stunted growth, cholorosis and small leaves, spikelet sterility Zinc application to zinc deficient plant has been found to boost the growth of plants and yield of crop to a great extant. Zinc is the essential mineral element for Protein synthesis (Dixit *et al*., 2012).

Keram *et al*. (2012) [5] also observed highest grain and straw yield in treatment consisting NPK+20 kg Zn ha^{-1} compared to NPK alone. Muthukumararaja *et al*. (2012) [8] reported that highest grain yield and straw yield was noticed at 5 mg Zn kg^{-1} which was about 10% and 86% greater than control (no Zn) respectively.

Table 5: Effect of Zn treatments on use efficiency and SYI of rice-rice cropping system

Frequency	Treatments	Cumulative ZnSO4 applied (kg/ha)	Cumulative Yield (t/ha)	Mean Yield (t/ha)	SYI	ZnUE	B:C ratio
F1 ONCE	Zn @ 2.5 kg/ha	12.5	40.99	3.42	0.52	18.0	1.26
	Zn @ 5 kg/ha	25.0	44.90	3.74	0.58	16.0	1.37
	Zn @ 7.5 kg/ha	37.5	48.21 (+8.0)	4.02	0.64	15.5	1.47
	Zn @ 10 kg/ha	50.0	47.20	3.93	0.63	11.1	1.43
F2 ALTERNATE YEAR	Zn @ 2.5 kg/ha	37.5	42.30	3.52	0.53	22.0	1.29
	Zn @ 5 kg/ha	75.0	46.15	3.85	0.60	19.2	1.39
	Zn @ 7.5 kg/ha	112.5	44.35	3.70	0.59	11.6	1.32
	Zn @ 10 kg/ha	150.0	45.73	3.81	0.61	10.1	1.34
F3 Every Year	Zn @ 2.5 kg/ha	75.0	48.13	4.01	0.64	46.8	1.45
	Zn @ 5 kg/ha	150.0	49.19 (+18.0)	4.10	0.65	25.0	1.44
	Zn @ 7.5 kg/ha	225.0	46.23	3.85	0.61	13.3	1.33
	Zn @ 10 kg/ha	300.0	40.99	3.42	0.58	8.5	1.22
Control	Control (0)	0.0	44.90	3.74	0.46	-	1.13

In second frequency (F_2) of alternate year the rice crop received Zn application during 2013, 2015, 2017 *kharif* with cumulative Zn dose of 7.5 to 30.0 $kgha^{-1}$ and a cumulative yield range of 42.3 - 46.2 t ha^{-1} and mean yield of 3.5 -3.8 t ha^{-1}. Under this frequency grain yield was higher than once applied doses and yield was also found to increase with increase in Zn dose.

Treatments receiving Zn application every year from initial year 2012-2017, *kharif* have a cumulative Zn application of 15.0 - 60.0 kg ha^{-1} which produced a cumulative grain yield of 40.9 -49.0 t ha^{-1} from 12 crops over a period of 6 year. Yield was found to increase up to second highest dose of 5.0 kg ha^{-1} after which it deceased. Decrease in yield in every year Zn application might be due to toxic effect of Zn on rice crop.

Singh and Abrol (1985) also found similar result for a rice-wheat system where application of Zn @ 4.5 kg annually was found optimum for the system. Higher Zn application increased the availability of Zn in the soil and its content in the plants but did not increase crop yield.

Increase yield with increasing Zn dose may be due to enhanced synthesis of carbohydrate and there transport to the site of grain production. Zinc deficiency results in abnormalities in plants which becomes visible as stunted growth, cholorosis and small leaves, spikelet sterility.

Since every year Zn application may lead to Zn toxicity and other nutrient interactions leading to decrease in yield. Also Zn application is a costly affair hence use efficiency of Zn was computed by taking average yield and SYI was computed by taking yield of all the years and presented in Table 6. It was found that in once Zn applied treatments 2.5 to 10 kg Zn were applied once at the time of planting of first kharif rice crop. Subsequent crops being raised on residual Zn status with RDF only. This once applied frequency produced a cumulative rice yield of 40.91 -48.21 t/ha over a 6 year period. Which indicated cumulative yield over years increased with increase in Zn dose upto 7.5 kg/ha but decreased.

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Sustainable yield Index

Sustainable yield index varied from 0.52 – 0.65 in Zn treatments and in control it was 0.46. Sustainable Yield Index value of 0.3 and above is considered sustainable. Hence yield at all levels of Zn dose and frequency was found to be sustainable. However lowest index value was observed in control getting NPK only without any Zn application. Among Zn treatments lowest index value was F_1D_1 (0.52) and highest was in 0.65 (F_3D_2).

Zinc use efficiency

Zinc use efficiency indicated kg of grain produced from kg of Zn applied. Zn UE was lowest 8.5 in F_3D_4 and highest 46.8 in F_3D_1. In once applied treatments Zn UE varied from 11.1 - 18.0 and it decreased as dose increased. Both highest and lowest efficiency was observed in every year Zn applied treatments.

Post-harvest Soil status

Table 6: Change in Av. Zn (mgkg^{-1}) status of surface soil over two year

Frequency (Dose)	pH (1:2.5)	Initial Zn Status 2013-14	DTPA-Zn (mgkg^{-1}) After 6 year
Once(2.5-10 kg Zn ha^{-1})	4.8-5.4	0.6-1.8	0.51-1.6
Alternate Year(2.5-10 kg Zn ha^{-1})	5.0-5.4	0.68-2.3	1.72-2.53
Every Year(2.5-10 kg Zn ha^{-1})	5.0-5.2	1.7-3.9	1.8-4.6
Control	5.0	0.42	0.40
Initial	5.4	0.48	0.48

Considerable increase and decrease in soil available Zn was observed from first year of 2013-14 to last year of experiment. Zn depletion in once applied Zn doses was observed where as in Alternate year and every year Zn build up was observed after meeting crop requirement.

Most of the Zn applied to surface soil remained in soil or Zn buildup of was noticed after meeting crop requirement though toxic symptoms are not observed in rice plants and converted to different less labile and non-labile forms and stored for future use.

Conclusion

Micronutrient Zn is deficient in Odisha soils. Micronutrient Zn application has a positive impact on growth, yield of rice with higher economic return. But its application every year at a higher dose can have negative impact on soil enzymes and microbial biodiversity. It may be concluded from the above experiment that once or one time application of Zn@ 7.5 kgha^{-1} through $ZnSO_4$ along with RDF during initial year for a light textured sandyloam soil can increase production, productivity of a rice –rice cropping system upto six year by 8% over no application of Zn. This dose of Zn is also sustainable with highest economic return. For marginal farmers instead of applying single bulk application if Zn application can be done in alternate year frequency @ 10 Kgha^{-1} to the first rice crop of a rice-rice cropping system can also sustain production and productivity. For progressive farmers small dose Zn application every year at a dose of 5.0 kgha^{-1} can produce highest mean, cumulative yield with highest sustainable yield index and B: C ratio of 1.44 without hampering the nutrient balance.

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