

RESEARCH ARTICLE

Influence of Zinc Application on Yield, Economics, and Soil Zinc Status in Paddy

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ABSTRACT:

This study assessed the impact of zinc sulphate application on paddy yield, economic returns, and soil zinc status in 12 farmer fields across four villages during the Kharif seasons of 2019–20 and 2020–21. Treatments included basal zinc sulphate application at 25 kg/ha, control (no zinc), residual effect plots, and continuous zinc-treated plots, with the RNR 15048 variety grown on clay soils with neutral pH and varying nutrient levels. Results revealed that zinc application significantly enhanced grain yield, with treated plots averaging 6,339 kg/ha compared to 5,790 kg/ha in control plots in 2019–20. During 2020–21, continuous zinc-treated plots produced the highest yield of 6,511 kg/ha, followed by residual plots (6,352 kg/ha) and control plots (5,922 kg/ha). Economic analysis showed higher net returns and benefit-cost ratios for zinc-treated plots, with treated plots recording ₹94,577/ha and a B:C ratio of 2.64 in 2019–20, compared to ₹85,948/ha and 2.62 for control plots. In 2020–21, continuous zinc-treated plots yielded ₹98,691/ha with a B:C ratio of 2.71, outperforming residual and control plots. Soil analysis indicated improved zinc content, increasing from an initial average of 0.992 ppm to 1.325 ppm in treated plots by 2020–21, while control plots averaged 0.848 ppm. These findings underscore the benefits of zinc application for enhancing paddy yield, profitability, and soil health, with continuous zinc application offering the most significant advantages for sustainable cultivation.

Received: 15 Sep 2025

Revised: 27 Nov 2025

Accepted: 14 Dec 2025

Keywords: Zinc sulphate, Paddy yield, Economic analysis, Soil zinc status, Residual effect

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food crop for more than half of the world's population and is pivotal in global food security. To achieve sustainable

productivity, the availability of essential nutrients, particularly micronutrients like zinc, is critical. Zinc deficiency in soils is a widespread problem, particularly

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in regions with high pH, low organic matter, or intensive agricultural practices. It adversely affects plant growth, grain yield, and quality, ultimately threatening food security (Alloway, 2008).

Zinc is vital for plants' physiological and biochemical processes, including enzyme activation, protein synthesis, and membrane integrity. Its deficiency is known to impair growth, reduce chlorophyll content, and limit carbohydrate metabolism, leading to reduced grain production (Cakmak, 2008). Studies have indicated that applying zinc fertilizers, such as zinc sulphate, significantly improves the availability of zinc in the soil and enhances crop productivity. Prasad *et al.*, (2012) observed a positive correlation between zinc application and rice yield, noting improvements in grain weight and number per panicle.

While the benefits of zinc application on crop yield and soil health have been established, there is a growing need to evaluate its residual effects and economic viability under varied field conditions. This study examines the influence of zinc sulphate application on paddy yield, economics, and soil zinc status over two consecutive Kharif seasons. It aims to provide insights into the sustainability of zinc application practices for maximizing productivity and profitability while maintaining soil health.

MATERIALS AND METHODS

The study was conducted during the Kharif seasons of 2019–20 and 2020–21 across 12 farms in four villages: Palem, Yellampalli, Dasireddygaripalli, and Gayamvaripalli. The experimental fields comprised clay soils with neutral pH, low electrical conductivity, high organic carbon content, low available nitrogen, and medium phosphorus and potassium levels. The paddy variety RNR 15048 was chosen for its adaptability and yield potential. Treatments in 2019–20 included the application of zinc sulphate at 25 kg/ha (T1) and a control plot without zinc (T2). In 2020–21, three treatments were established: control plots with no zinc application (T1), residual plots to assess the carryover effect of previous zinc application (T2), and continuous zinc-treated plots where zinc sulphate was applied at 25 kg/ha (T3). The experiment involved land preparation followed by the basal application of zinc sulphate in treatment plots. Seeds were soaked in gunny bags for 12 hours, sprouted over three days, and sown in a nursery in July. Transplantation of one-month-old seedlings into the main field was carried

out with standard agronomic practices, including irrigation, weed management, and pest control. NPK fertilizers were applied per local recommendations, and a foliar spray of zinc sulphate was performed one month after the basal application. Harvesting occurred in November, and grain yield was measured after threshing and sun-drying.

Initial and final soil samples were collected from five random spots within each treatment plot and analyzed for zinc content through Atomic Absorption Spectrometry in the laboratory. The cost of cultivation, gross, and net returns were calculated based on prevailing market prices, and the benefit-cost ratio was derived. Statistical data analysis was conducted using SPSS software to evaluate the significance of treatment effects.

RESULTS AND DISCUSSION

Applying zinc sulphate significantly improved grain yield, economic returns, and soil zinc status across two consecutive Kharif seasons. Grain yields were notably higher in zinc-treated plots than control plots (Tables 1 and 2). During 2019–20, zinc-treated plots achieved an average yield of 6,339 kg/ha, an 8.7% increase over the control plots (5,790 kg/ha). During 2020–21, continuous zinc-treated plots recorded the highest average yield of 6,511 kg/ha, followed by residual plots (6,352 kg/ha) and control plots (5,922 kg/ha). These findings highlight the sustained benefits of zinc fertilization, both directly and through residual effects. The results align with studies by Prasad *et al.*, (2012) and Cakmak (2008), which documented improved grain yield and panicle weight due to enhanced zinc availability.

Economic analysis showed a clear advantage for zinc-treated plots. In 2019–20, these plots recorded an average net return of ₹94,577/ha and a benefit-cost (B:C) ratio of 2.64, compared to ₹85,948/ha and a ratio of 2.62 for control plots. In 2020–21, continuous zinc-treated plots yielded the highest net return (₹98,691/ha) and a B:C ratio of 2.71, followed by residual plots (₹99,440/ha and 2.88) and control plots (₹88,888/ha and 2.68). These results emphasize the economic viability of zinc fertilization, corroborating Alloway's (2008) observations that micronutrient application enhances economic returns by boosting crop productivity and quality.

Soil analysis revealed substantial improvements in zinc levels due to zinc application.

Table 1. Effect of zinc sulphate application on yield and economics of rice during 2019-20:

S.No.	Village	Farmer	Grain Yield (kg/ha)		Cost of cultivation (Rs/ha)		Gross Returns (Rs./ha)		Net Returns (Rs./ha)		B:C ratio	
			Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	Dasireddygaripalli	K Reddappa Reddy	6268	5642	57565	53000	150432	135408	92867	82408	2.61	2.55
2	Dasireddygaripalli	K Anna Reddy	6648	6034	57565	53000	159552	144816	101987	91816	2.77	2.73
3	Dasireddygaripalli	P Shankar Reddy	6725	6134	57565	53000	161400	147216	103835	94216	2.80	2.78
4	Palem	B Chinnappa	6344	5500	57565	53000	152256	132000	94691	79000	2.64	2.49
5	Palem	M Ramana	6846	6000	57565	53000	164304	144000	106739	91000	2.85	2.72
6	Palem	B Krishnaiah	6450	6126	57565	53000	154800	147024	97235	94024	2.69	2.77
7	Gayamvaripalli	G Sreenivasulu Reddy	5820	5432	57565	53000	139680	130368	82115	77368	2.43	2.46
8	Gayamvaripalli	Kodatham Bhaskar	6235	5986	57565	53000	149640	143664	92075	90664	2.60	2.71
9	Gayamvaripalli	PadigalaRajendraiah	6145	5762	57565	53000	147480	138288	89915	85288	2.56	2.61
10	Yellampalli	Y Raghunath Reddy	6600	6000	57565	53000	158400	144000	100835	91000	2.75	2.72
11	Yellampalli	L Mahindra Reddy	5790	5618	57565	53000	138960	134832	81395	81832	2.41	2.54
12	Yellampalli	L Malleswari	6200	5240	57565	53000	148800	125760	91235	72760	2.58	2.37
Average			6339	5790	57565	53000	152142	138948	94577	85948	2.64	2.62

Table 2. Effect of zinc sulphate application on yield and economics of rice during 2020-21

S.No.	Grain Yield (kg/ha)			Cost of cultivation (Rs/ha)			Gross Returns (Rs./ha)			Net Returns (Rs./ha)			B:C ratio		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	6040	6000	6160	53000	53000	57565	144960	144000	147840	91960	91000	90275	2.74	2.72	2.57
2	5373	5300	5613	53000	53000	57565	128952	127200	134712	75952	74200	77147	2.43	2.40	2.34
3	5820	6220	6268	53000	53000	57565	139680	149280	150432	86680	96280	92867	2.64	2.82	2.61
4	6373	6733	6868	53000	53000	57565	152952	161592	164832	99952	108592	107267	2.89	3.05	2.86
5	5750	7193	7140	53000	53000	57565	138000	172632	171360	85000	119632	113795	2.60	3.26	2.98
6	6453	6800	6960	53000	53000	57565	151720	163200	167040	98720	110200	109475	2.86	3.08	2.90
7	6268	6680	6713	53000	53000	57565	150432	160320	161112	97432	107320	103547	2.84	3.02	2.80
8	6000	7220	7373	53000	53000	57565	144000	173280	176952	91000	120280	119387	2.72	3.27	3.07
9	5620	5953	5840	53000	53000	57565	134880	142872	140160	81880	89872	82595	2.54	2.70	2.43
10	6060	6473	6500	53000	53000	57565	145440	155352	156000	92440	102352	98435	2.74	2.93	2.71
11	5468	5520	6560	53000	53000	57565	131232	132480	157440	78232	79480	99875	2.48	2.50	2.73
12	5840	6128	6133	53000	53000	57565	140160	147072	147192	87160	94072	89627	2.64	2.77	2.56
Average	5922	6352	6511	53000	53000	57565	141867	152440	156256	88888	99440	98691	2.68	2.88	2.71

Statistical analysis reveals that application of zinc sulphate in rice shows a significant difference in yield and net returns (Table 3). During 2019-20, yield was significantly higher in zinc-treated plots, at a 1% level of significance. Whereas, net returns showed a significant difference at the 5% level of significance. During 2020-21, both yield and net returns were significantly higher in zinc-treated plots at the 5% level of significance.

The initial soil zinc content averaged 0.809 ppm, which increased to 1.165 ppm in zinc-treated plots. Meanwhile, control plots were depleted, and their zinc levels were depleted to 0.610 during 2019-20. During 2020-21, control plots recorded an average of 0.848 ppm, while residual plots-maintained zinc levels of 0.928 ppm, demonstrating the carryover effect of zinc fertilization, and zinc-treated plots recorded higher zinc levels of 1.333 ppm. These findings support the work of Shivay *et al.*, (2010), who emphasized the role of zinc fertilizers in replenishing soil reserves and maintaining fertility over time.

The results underscore zinc's importance as an essential micronutrient in paddy cultivation. Zinc's physiological role in enzyme activation, protein synthesis, and photosynthesis underpins the observed

yield improvements (Cakmak, 2008). The residual effects of zinc application further suggest that periodic supplementation can sustainably enhance productivity while minimizing input costs. However, Continuous zinc application proved to be the most effective strategy for maximizing yield and profitability. The improved soil zinc status observed in treated plots also addresses long-term concerns about soil fertility, ensuring sustainable agricultural practices.

These findings advocate for including zinc sulphate in nutrient management strategies for paddy cultivation, particularly in zinc-deficient soils. Future research could investigate optimal application rates, methods, and long-term implications on soil health and crop rotations to refine recommendations for farmers.

CONCLUSION

The study demonstrates that zinc sulphate application significantly enhances paddy yield, economic returns, and soil zinc status, with continuous application offering the highest benefits. Zinc-treated plots consistently outperformed control plots regarding grain yield and profitability across two consecutive Kharif seasons. The residual effects of zinc application further underline its potential for sustainable nutrient

Table 3. Summary of one-way ANOVA during the two years of study

2019-20

Treatments	N	Mean	Std. Deviation	F-value	P-value
Yield					
T1	12	6339	333.79	4.3009**	0.0003
T2	12	5790	299.15		
Net returns					
T1	12	94577	8010.9	4.3009*	0.0109
T2	12	85948	7179.7		

**Significant at 1% level of significance

* Significant at 5% level of significance

2020-21

Treatments	N	Mean	Std. Deviation	F-value	P-value
Yield					
T1	12	5922	342.4	3.2849*	0.0212
T2	12	6352	608.9		
T3	12	6511	530.2		
Net returns					
T1	12	88888	7813.6	3.2594*	0.0452
T2	12	99440	14613.7		
T3	12	98691	12726.1		

Table 4. Effect of zinc sulphate application on soil zinc status:

S.No.	Village	Farmer	Zinc (ppm)					
			2019-20			2020-21		
			Initial		Control	Control		Zinc
1	Gayamvaripalli	G Sreenivasulu Reddy	0.488	0.563	0.408	0.723	0.898	1.531
2	Gayamvaripalli	Kodatham Bhaskar	0.932	0.968	0.530	0.718	0.845	0.88
3	Gayamvaripalli	PadigalaRajendraiah	0.461	1.179	0.393	1.861	0.793	2.593
4	Yellampalli	Y Raghunath Reddy	0.756	1.991	0.689	1.082	1.674	2.037
5	Yellampalli	L Mahindra Reddy	0.569	0.928	0.492	0.839	0.848	1.257
6	Yellampalli	L Malleswari	0.707	0.813	0.561	0.541	0.982	1.252
7	Palem	B Chinnappa	1.197	1.729	0.902	0.839	0.922	1.171
8	Palem	M Ramana	0.683	0.687	0.675	0.709	0.655	0.722
9	Palem	B Krishnaiah	1.280	1.909	0.718	0.709	0.938	0.962
10	Dasireddygaripalli	K Reddappa Reddy	0.962	1.097	0.513	0.632	0.736	1.265
11	Dasireddygaripalli	K Anna Reddy	0.903	0.981	0.767	0.812	0.914	0.918
12	Dasireddygaripalli	P Shankar Reddy	0.766	1.132	0.675	0.707	0.931	1.409
Average			0.809	1.165	0.610	0.848	0.928	1.333

management. Additionally, improved soil zinc levels highlight the role of zinc in maintaining soil fertility, ensuring long-term productivity. These findings advocate for integrating zinc fertilization into paddy cultivation practices, particularly in zinc-deficient soils, to optimize yield, improve farmer incomes, and support sustainable agriculture. Future studies could explore the optimization of zinc application rates and methods to enhance its efficiency and minimize environmental impacts.

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