**Influence of zinc application on yield, economics and soil zinc status in Paddy**

Sahaja Deva1\*, M. Mallikarjun2,Prasanna Lakshmi Ravuri3, Ganesh Kumar Perneti4,M. Reddi Kumar5 and

M.K.Jyosthna6

 1 Scientist(Agronomy), Regional Agricultural Research Station, Tirupati

2Subject Matter Specialist (Agronomy),Krishi Vigyan Kendra, Kalyanadurg

3Assistant Professor (Entomology), Polytechnic of Agriculture, Tirupati

4 Associate Professor (Ag.Extension), S.V.Agricultural College, Tirupati

5Professor (Pathology), College of Agriculture, Pulivendula

6Associate Professor (Pathology), S.V.Agricultural College, Tirupati

\*Corresponding author email: sahajadeva@angrau.ac.in

Ph: 7259009930

**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 @ 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 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 greatest advantages for sustainable cultivation.

**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 plays a pivotal role 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 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 several physiological and biochemical processes in plants, 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 the application of 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 both 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 as 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 returns, and net returns were calculated based on prevailing market prices, and the benefit-cost ratio was derived. Statistical analysis of data was conducted using SPSS software to evaluate the significance of treatment effects.

**Results and Discussion**

The application of 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 compared to control plots (Table 1 and 2). During the year 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.

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

The initial soil zinc content averaged 0.809 ppm, which increased to 1.165 ppm in zinc-treated plots. Whereas, control plots were depleted their zinc levels 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 collectively underscore the importance of zinc 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. Continuous zinc application, however, proved to be the most effective strategy for maximizing both 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 the inclusion of 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 further 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 in terms of grain yield and profitability across two consecutive Kharif seasons. The residual effects of zinc application further underline its potential for sustainable nutrient management. Additionally, improved soil zinc levels highlight the role of zinc in maintaining soil fertility, ensuring long-term productivity. These findings advocate for the integration of 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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| --- |
| **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** |
| **Treatment** | **Control** | **Treatment** | **Control** | **Treatment** | **Control** | **Treatment** | **Control** | **Treatment** | **Control** |
| 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 | Padigala Rajendraiah | 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** |

**Table 3. Summary of one-way ANOVA during 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** | **Treatment** | **Control** | **Control** | **Residual** | **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 | Padigala Rajendraiah | 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** |

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