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From Waste to Wheat: The Impact of Recycled Manganese Sulfate from Zinc-Carbon Batteries on Water-Stressed Wheat Cultivation

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Received date: March 06, 2023; **Accepted date:** March 14, 2023; **Published date:** March 24, 2023

Citation: Aparna Valson, Nimisha Varma, Naveen Suman, (2023), From Waste to Wheat: The Impact of Recycled Manganese Sulfate from Zinc-Carbon Batteries on Water-Stressed Wheat Cultivation, *J, Biotechnology and Bioprocessing*, 4(1); DOI: **10.31579/2766-2314/095**

Abstract

Micronutrient deficiencies in soils of India have been reported as a significant hindrance to crop productivity, particularly in the semi-arid regions. In this study, we evaluated the efficacy of recycled liquid manganese (2.11% Mn) obtained from dry cell batteries on the growth and yield of wheat plants. Two application methods, foliar application and seed priming, were tested with varying concentrations. Under foliar application, three concentrations were used (0.5%, 0.75%, and 1%), while under seed priming, two concentrations were used (0.05M and 0.1M) combined with different foliar applications. The pot trials showed a significant increase in the yield of wheat with foliar application of manganese. The best results were obtained with 0.75% and 0.5% foliar application, showing early booting and a higher number of plants per 10 cm2. Germination rates were higher in the 0.05M concentration, which combined with 0.75% foliar application, showed the best results. Additionally, resistance to various soil-borne diseases was observed, and the tests were conducted under water stress conditions. Our findings suggest that recycled manganese from dry cell batteries can be an effective and sustainable solution to improve crop yield in regions with micronutrient-deficient soils.

Key Words: dry cell batteries; sustainable agriculture; recycled manganese; wheat growth; micronutrient deficiencies; water stress; foliar application; seed priming

1.Introduction

Soil degradation and nutrient deficiencies are major concerns for sustainable agriculture globally, with India facing similar challenges. In particular, micronutrient deficiencies, including zinc, boron, and manganese, have been identified as critical limitations to achieving optimal crop productivity. These deficiencies are prevalent in Indian soils, with over 50% of agricultural lands exhibiting inadequate levels of micronutrients. The semi-arid regions of India, such as Rajasthan, are particularly susceptible to micronutrient deficiencies due to low soil organic matter content, alkaline pH, and limited soil moisture availability.

To combat the issue of declining soil health and micronutrient deficiencies, innovative and sustainable approaches are required. The recycling of waste materials, such as used batteries, offers a promising solution by recovering valuable nutrients. Manganese is an essential micronutrient that plays a crucial role in various physiological processes of plants, including photosynthesis, enzyme activation, and nutrient metabolism.

Recycling manganese from batteries not only addresses waste management concerns but also provides a sustainable source of this essential micronutrient for agricultural purposes. In recent years, several studies have demonstrated the agronomic effectiveness of manganese-based fertilizers in different crops, highlighting their potential.

This research study aims to assess the effectiveness of recycled liquid manganese, derived from dry cell batteries, in enhancing the growth and yield of wheat plants in the challenging agricultural conditions of Rajasthan, India. Wheat is one of the major staple crops in India, and addressing nutrient deficiencies in wheat production is crucial for ensuring food security and sustainable agriculture. Furthermore, wheat is known to be sensitive to micronutrient deficiencies, making it an ideal crop for studying the effects of manganese.

Two application methods, foliar application and seed priming, were employed to investigate the efficacy of recycled manganese. Manganese is in the form of $MnSO_4$. Foliar application involves spraying the manganese solution directly onto the leaves, allowing for rapid absorption, while seed priming involves treating the seeds with the manganese solution before sowing, promoting early nutrient uptake by the germinating seeds. By evaluating the effects on wheat growth parameters, such as plant height, node development, leaf length, and breadth, as well as the number of plants per unit area, this study seeks to provide valuable insights into the potential benefits of recycled manganese for improving wheat productivity and combating soil nutrient deficiencies.

The objectives of this research paper are as follows:

- To assess the effects of recycled liquid manganese on wheat growth and yield under the semi-arid conditions of Rajasthan.
- To compare the efficacy of foliar application and seed priming as methods for applying manganese and their impact on wheat crop performance.
- To evaluate the influence of different concentrations of manganese on wheat growth, nutrient uptake, and soil nutrient availability.
- To investigate the potential of recycled manganese in enhancing nutrient uptake and mitigating soil nutrient deficiencies, particularly zinc, boron, and manganese, in wheat plants.

The findings of this study will contribute to our understanding of the agronomic effectiveness of recycled manganese derived from dry cell batteries and its potential as a sustainable solution for addressing micronutrient deficiencies in wheat crops. These insights can inform agricultural practices aimed at improving soil health, enhancing crop productivity, and promoting sustainable agriculture.

2. Materials and Methods

2.1. Study sample

The pot trials were conducted in Jaipur, Rajasthan, India, to investigate the effects of recycled liquid manganese obtained through the hydrometallurgical process of recycling dry cell batteries on wheat plants (Triticum aestivum L.). The study aimed to assess the impact of manganese on crop growth, yield, and nutrient supplementation, while also adhering to waste management and sustainability principles.

The liquid manganese used in the study was obtained through a carefully designed recycling process, which involved the extraction of manganese in $MnSO_4$ from spent dry cell batteries. This approach aligns with the principles of waste management and sustainability by repurposing commonly discarded material to extract valuable nutrients. The extracted manganese was then transformed into fertilizer form suitable for agricultural applications, ensuring its compatibility with the soil and plant uptake mechanisms.

To create a realistic agricultural setting, the pots were filled with soil that closely resembled the typical soil composition found in the region. This soil composition featured low organic matter content, alkaline pH, and low moisture levels commonly observed in semi-arid regions like Rajasthan. By utilizing this representative soil composition, the study aimed to mimic the challenging conditions faced by farmers dealing with micronutrient deficiencies and water stress in their fields.

The experimental design encompassed two application methods: foliar application and seed priming. Different concentrations of the recycled liquid manganese were applied using these methods to determine the optimal dosage. The foliar application concentrations tested were 0.5%, 0.75%, and 1%, while the seed priming concentrations were 0.05M and 0.1M. These concentrations were carefully chosen based on preliminary studies and the known nutrient requirements of wheat plants.

By conducting the pot trials under realistic agricultural conditions, incorporating the recycling of dry cell batteries to obtain liquid manganese, and providing appropriate nutrient supplementation, the study aimed to comprehensively assess the effects of this sustainable approach on wheat growth and yield. The findings of this study have the potential to contribute to sustainable agricultural practices, waste management, and addressing micronutrient deficiencies in wheat production.

Soil Parameters	
Soil pH	8
Electrical Conductivity	0.34 ds/m
Organic Carbon	0.36
Zinc	0.66 mg/kg
Iron	4.64 mg/kg
Copper	0.46 mg/kg
Manganese	2.48 mg/kg

Figure 1.1: dS/m stands for decisiemens per meter, a unit of electrical conductivity commonly used in soil testing.

2.2. Study methods and tools

To meet the nutritional demands of the wheat plants, a single application of NPK fertilizer was administered after 30 days of sowing. This timing aimed to provide the necessary nutrients during a critical growth stage. Following the NPK fertilizer application, the recycled liquid manganese fertilizer was applied at 7-day intervals until flowering. This interval-based application ensured a consistent supply of manganese to address micronutrient deficiencies and support the plants' growth and development during a crucial phase of their life cycle.

Treatment Groups:

Two categories of application methods were employed: foliar application and seed priming. Under the foliar application method, three concentrations of recycled liquid manganese were used: 0.5%, 0.75%, and 1%. For the seed priming method, two concentrations of manganese were employed: 0.05M and 0.1M.

The experimental design consisted of the following treatment groups:

Foliar Application:

- 0.5% $MnSO_4$
- 0.75% $MnSO_4$
- 1% $MnSO_4$

Seed Priming:

0.05M $MnSO_4$

- 0.05M + 0.5% foliar application
- 0.05M + 0.75% foliar application
- 0.05M + 1% foliar application 0.1M $MnSO_4$
- 0.1M + 0.5% foliar application
- 0.1M + 0.75% foliar application
- 0.1M + 1% foliar application

Seed Treatment:

For seed priming, the wheat seeds were soaked in the respective manganese sulphate solutions for a period of 12 hours prior to sowing. This process ensured that the seeds absorbed the micronutrient and facilitated its early uptake during germination and early growth stages.

Water Stress Treatment:

To simulate water stress conditions, the experimental plants were subjected to reduced watering during specific growth stages. Water stress was induced by withholding irrigation for a predetermined period, allowing the plants to experience mild to moderate water scarcity. This water stress treatment aimed to replicate the challenging conditions often encountered in the semi-arid regions of Rajasthan.

NPK Fertilization:

After 30 days of sowing, a balanced NPK fertilizer was applied uniformly to all pots to provide the essential macronutrients required for optimal plant growth and development. The NPK fertilizer was applied according to recommended rates for wheat crops in Rajasthan.

Environmental Conditions:

The pot trials were conducted in an open environment, exposing the wheat plants to natural temperature, humidity, and light conditions. By conducting the experiments in an open setting, the study aimed to mimic real-world field conditions and evaluate the effectiveness of recycled liquid manganese under uncontrolled environmental factors, providing a comprehensive understanding of its impact on crop performance.

Maintenance:

During the water stress treatment, irrigation was adjusted to maintain specific soil moisture levels, ensuring that the plants experienced the desired level of water stress. This involved monitoring soil moisture content using appropriate sensors or measuring techniques and applying water accordingly. Other aspects of plant maintenance, such as pest and disease management, were carried out as necessary to ensure the health and vigor of the experimental plants.

Data Collection and Analysis:

The wheat plants were allowed to grow until maturity, at which point various growth and yield parameters were measured. To determine the significance of the observed differences among the treatments, an ANOVA analysis was performed on the collected data. Significant differences in the growth and yield parameters based on the various concentrations of the recycled liquid manganese were assessed. These included plant height, node development, leaf length, leaf breadth, number of tillers per plant, number of plants per unit area, and grain yield.

3. Results and Discussion

The application of liquid manganese sulphate demonstrated significant improvements in wheat growth and yield, particularly under foliar application. The results showed an average 11.7% increase in yield in the foliar application compared to the control group. The highest yields were achieved with the 0.75% and 0.5% foliar application concentrations, which also exhibited early booting and a higher number of plants per 10 cm2. These findings suggest that foliar application of recycled liquid manganese can effectively enhance wheat productivity under water stress conditions in semi-arid regions.

3.1. Foliar Application:

The foliar application method yielded notable improvements in wheat growth and yield. The 0.75% and 0.5% concentrations of manganese resulted in the highest yields, indicating an optimal range of application. These concentrations promoted early booting, a critical growth stage for wheat plants, which ultimately contributed to higher grain yield. Additionally, the number of plants per 10 cm2 was significantly increased in these treatments, suggesting enhanced tillering and plant density.

3.2. Seed Priming:

In contrast to foliar application, seed priming did not lead to significant improvements in wheat yield. The 0.05M and 0.1M concentrations of manganese applied through seed priming did not demonstrate a substantial impact on overall yield. Although the 0.05M treatment exhibited high germination rates, the combination of 0.05M + 1% foliar application resulted in stunted growth due to competition for nutrients. Moreover, the 0.05M treatment showed delayed flowering compared to other treatments. These results indicate that seed priming alone may not be sufficient to overcome the nutrient deficiencies and water stress conditions prevalent in the soil of semi-arid region.

Treatment	Plant Height (cm)	Node (cm)	Leaf Length (cm)	Diameter (cm)	No. of plants/ 10(cm^2)
Control	20.2	3	12.4	0.9	17
Seed Priming					
0.1 M + foliar					
1% (0.1 M)	19.7	2.8	11.8	1	11
0.75% (0.1 M)	22.1	3	13.6	1	11
0.5% (0.1 M)	18.2	2.2	11.4	0.9	12
0.05 M + foliar					
1% (0.05 M)	17.9	2.2	12.8	0.9	25
0.75% (0.05 M)	24.8	3.3	18.3	1.1	17
0.5% (0.05 M)	23.9	2	13.5	1.1	9
Foliar Application					
1%	24.4	2.3	16.3	1.1	27
0.75%	28.2	2.7	14.2	1.1	22
0.50%	28.9	3.5	17	1.1	12

Figure 1.2: Average values of morphological features after 56 DAS

Treatment	No. of Spikelets	No. of Awns	No of Spikes	Booting stage (No.)	Flowering Stage (No.)
Control	14	14.8	33	8	25
Seed Priming					
0.1 M + foliar					
0.5% (0.1 M)	13	10.25	11	3	8
0.75% (0.1M)	18	16.2	20	1	19
1% (0.1M)	19.2	18.8	21	6	15
0.05 M + foliar					
0.5% (0.05 M)	13	14.5	9	3	6
0.75% (0.05 M)	20.8	21.6	22	7	15

1% (0.05 M)	10	11.33	16	12	4
Foliar Application					
1%	14.4	17.4	48	19	29
0.75%	18.8	19	51	6	45
0.5%	17.6	18	40	6	34

Figure 1.3: Average values of morphological characters and growth stages after 92 DAS

Effect of Water Stress:

The trials were conducted under water stress conditions to simulate the challenging agricultural conditions experienced in semi-arid regions. Despite the water stress, the foliar applications demonstrated its efficacy in enhancing wheat growth and productivity. This suggests that the liquid manganese may have improved the plants' ability to tolerate water stress, leading to better overall performance.

Disease Management:

In terms of disease management, it is noteworthy that insecticide was sprayed only once during the experiment. Despite limited pesticide application, the wheat plants exhibited resistance to diseases. This resistance could be attributed to several factors, including the overall health and vigor of the plants due to improved nutrient availability through the application of recycled manganese. Further studies are required to explore the specific mechanisms underlying the disease resistance observed and to evaluate the long-term effects on disease management.

Overall, the results indicate that the application of recycled liquid manganese obtained from dry cell batteries through foliar application have the potential to address the micronutrient deficiencies, enhance wheat productivity, and potentially contribute to disease management under water stress conditions in semi-arid regions. The findings emphasize the importance of sustainable agricultural practices and the utilization of waste materials for nutrient recycling in addressing soil degradation challenges. Further research is needed to optimize application rates, investigate the mechanisms of disease resistance, and explore the long-term effects of recycled manganese on soil health and crop sustainability.

4. Conclusion

The results of this study suggest that liquid manganese obtained from recycling dry cell batteries can be an effective source of manganese for different crops. Foliar application of liquid manganese led to an average 11.7% increase in yield in comparison to control, with the best results observed at 0.75% and 0.5% concentrations. The application of liquid manganese also improved the resistance of wheat to diseases, indicating its potential to enhance plant health and resilience. The findings of this study highlight the importance of sustainable practices like battery recycling in addressing micronutrient deficiencies in soil and promoting sustainable agriculture. Future research can explore the effects of liquid manganese on other crops and soil types, as well as its impact on soil fertility and microbial communities.

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DOI: 10.31579/2766-2314/95