

Research Article

Influence of polyhalite on biometric, yield parameters and yield of rice (*Oryza sativa* var. (ADT43)) grown in alluvial soils of Tamil Nadu

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Abstract

Polyhalite is a mineral fertilizer that provides essential nutrients such as K, S, Ca and Mg, which are required by crops in substantial amounts. However, its use as fertilizer for rice has not been extensively studied. Given the high potassium requirement of rice crops for improved growth, the present study was undertaken to assess the impact of polyhalite and muriate of potash (MOP) on biometrics, yield characters, and yield of rice var. ADT43 in sandy clay loam soil, at Department of Soil Science, Annamalai University, Chidambaram, Tamil Nadu during *kharif* of 2023. The experiment was carried out under CRD which included ten treatments *viz.*, T₁- Control, T₂-NP + K (0), T₃-NP + 50% K as MOP, T₄-NP + 50% K as Polyhalite, T₅-NP + 100% K as MOP, T₆-NP + 100% K as Polyhalite, T₇-NP + 150% K as MOP, T₈-NP + 150% K as Polyhalite, T₉-NP + 200% K as MOP, T₁₀-NP + 200% K as Polyhalite. Application of potassium fertilizers at varying levels had a significant effect on biometric and yield parameters of rice. The experimental findings indicated that, application of 200% K as polyhalite + NP (T₁₀) recorded maximum biometric traits *viz.*, plant height, DMP (87.5 g pot⁻¹), yield characters *viz.*, no. of panicle pot⁻¹, no. of grains panicle⁻¹ (81.23). Further, it showed an increase of 67% and 47.6% in grain and straw yield, respectively, over control. Based on the results, this experiment could assist rice-growing farmers in enhancing crop yield by using polyhalite as a source of potassium fertilizer.

Keywords: Alluvial soil, Growth, Polyhalite, Potassium, Rice, Yield**INTRODUCTION**

Rice (*Oryza sativa* L.) stands as a vital staple crop globally, providing sustenance for a significant portion of the world's population. Worldwide rice production in 2023-2024 is 513.54 MMT (Statistics 2024, <https://www.statista.com/statistics/263977/world-grain-production-by-type/>). China ranks first in rice production, followed by India and Bangladesh. India's rice production for the year 2023-2024 was estimated to be 1367 LMT. Tamil Nadu has a total rice production of 7.56 Mha with an area of 2.16Mha and with a yield of 3500 kg ha⁻¹ in the crop year 2021-22 (Directorate of

Economics and Statistics (2021-22).

Maximizing rice yields is imperative for sustainable agriculture and food security. In Tamil Nadu, rice production predominantly relies on alluvial soils, renowned for their fertility. Despite their richness, these soils are vulnerable to nutrient depletion through leaching and erosion, hampering rice growth and yield potential. Proper application of organic manures and inorganic fertilizers, tailored to crop requirements, is crucial for optimizing productivity (Karthikeyan *et al.*, 2019).

Potassium, a vital macronutrient, significantly influences plant yield and quality. Besides activating numerous enzymes, potassium is pivotal in maintaining

electrical potential gradients across cell membranes and generating turgor. Muriate of potash serves as a prevalent potassium fertilizer worldwide. However, the quest for alternative potassium sources led to the discovery of polyhalite, a naturally occurring mineral fertilizer in North Yorkshire, United Kingdom (Karthikeyan *et al.*, 2025). Polyhalite has garnered attention for its potential to enhance crop performance, especially in challenging agricultural environments. Polyhalite provides a holistic solution to rectify nutrient deficiencies and enhance soil health by combining essential nutrients such as potassium, sulfur, magnesium, and calcium. Polyhalite is a single complex crystal. It usually appears as fibrous, massive pieces and rarely appears as tabular crystals. Polyhalite is officially analyzed to contain a minimum of 48% sulfur trioxide, 14% potassium oxide, 6% magnesium oxide and 17% calcium oxide (Gokul *et al.*, 2023).

Therefore, the present study aimed to investigate the influence of polyhalite on rice (var. ADT43) growth and yield in alluvial soils. This research attempts to elucidate polyhalite's efficacy as a soil amendment in rice cultivation by assessing its impact on key growth parameters and yield components.

MATERIALS AND METHODS

Study site

A pot experiment was conducted on rice var. ADT43 during the 2023 *kharif* season at the pot culture yard of the Department of Soil Science, Faculty of Agriculture, Annamalai University, Chidambaram. The experimental site is situated at a latitude of 11°24'N and a longitude of 79°41'E, approximately 6 kilometers from the Bay of Bengal and lies at an elevation of 5.79 meters above mean sea level. The experiment was laid out in a completely randomized design with three replications and ten treatments. The experimental soil was sandy clay loam in texture (Typic Ustifluvent) belonging to the order Entisol.

Methodology

Analysis of soil samples

The initial soil sample was analysed for chemical compositions following standard methods (Alam *et al.*, 2020). The soil was neutral in pH (7.3), non-saline (EC-0.83 dSm⁻¹) was measured in the suspension of (1:2.5 soil: water) using a pH meter and conductivity was measured in the same suspension using a conductivity meter, low in available N (166 kg ha⁻¹) by alkaline permanganate method (Subbiah and Asija, 1956) and medium in available P (16 kg ha⁻¹) was quantified by the Spectrophotometer method (Olsen *et al.*, 1954) and K (176.4 kg ha⁻¹) by using neutral normal ammonium acetate extract was determined by the Flame photometric method (Stanford and English, 1949). The short-duration

rice variety ADT-43 was transplanted into the pots @ 4 hills/pot. The recommended fertilizer dose of 150, 50 and 50 kg ha⁻¹ of N, P₂O₅, and K₂O is the standard (100%) (Crop Production Guide Agriculture 2020). Half of the N dose was applied basally in the form of urea (46% N) and the remaining 50% was split into two equal amounts and top-dressed at tillering and panicle initiation stages. Phosphorus was applied basally in the form of superphosphate (SSP, 16% P₂O₅). Potassium was applied according to the designated treatments in the form of MOP.

The growth parameters like plant height, number of tillers per hill, leaf area index (Francis *et al.*, 1969), leaf chlorophyll content by SPAD (Peng *et al.*, 1993), and dry matter production were recorded at different growth stages of rice. The yield parameters and yield, such as the number of panicles per pot, the number of grains per panicle, the panicle length, the thousand-grain weight, the grain yield, and the straw yield, were recorded at harvest.

Statistical analysis

The experimental data was analyzed statistically using the web-based agricultural software WASP 2.0. A critical difference was calculated for results found to be significant at the 5% probability level. Treatment differences that were not statistically significant were indicated as 'NS'.

RESULTS AND DISCUSSION

Plant height

The results depicted that the plant height had significantly improved with the increasing levels of potassium. Between two different potassium sources, polyhalite was significantly more effective than MOP. The perusal of data presented in Table 1 indicated that the application of polyhalite significantly influenced the plant height. The maximum plant height of 58.8, 81.6 and 103.1 cm at active tillering, panicle initiation and harvest stage, respectively, were recorded with the application of NP + 200% K as polyhalite (T₁₀), which is on par with NP + 150% K as polyhalite (T₈) and lowest plant height was recorded in control. 200% K as polyhalite performed better than the 200% K as MOP. The observed enhancement in plant height associated with polyhalite application can be largely attributed to the increased availability of potassium, a key nutrient. Polyhalite contains potassium, sulphur, calcium and magnesium, where potassium plays a pivotal role in activating numerous enzymatic reactions involved in fundamental physiological processes such as protein synthesis, photosynthesis, starch formation, and the translocation of carbohydrates. These findings corroborate with the results of Reddy *et al.* (2022). The sulfur component of polyhalite also significantly contributes to plant nutrition

Table 1. Effect of polyhalite on plant height and number of tillers per plant of rice

Treatments	Plant height (cm)			No. of tillers hill ⁻¹
	Active tillering	Panicle initiation	Harvest	
T ₁ -Control	25.5	52.9	65.5	7.08
T ₂ - NP + K (0)	28.3	56.6	72.1	8.27
T ₃ - NP + 50% K as MOP	31.5	58.7	75.7	9.43
T ₄ - NP + 50% K as Polyhalite	35.7	61.2	79.7	10.58
T ₅ - NP + 100 % K as MOP	38.0	45.1	83.4	11.65
T ₆ - NP + 100% K as Polyhalite	43.4	69.1	87.7	12.95
T ₇ -NP + 150% K as MOP	49.8	73.2	91.8	14.08
T ₈ - NP + 150% K as Polyhalite	58.1	80.4	100.8	17.21
T ₉ - NP + 200% K as MOP	50.7	74.1	93.1	15.41
T ₁₀ - NP + 200% K as Polyhalite	58.8	81.6	103.1	18.25
SE _d	0.61	0.96	1.86	0.52
CD (p=0.05)	1.3	1.7	3.9	1.08

by participating in redox reactions and acting as a constituent of ferredoxin, thereby facilitating electron transport during photosynthesis. These processes collectively stimulate metabolic efficiency, promoting vigorous vegetative growth and increased plant stature, as supported by the findings of Raghunath *et al.* (2021). Moreover, calcium and magnesium in polyhalite play crucial roles in regulating nitrogen metabolism. Calcium enhances ammonium uptake and supports cellular functions such as cell division and membrane integrity, both of which are essential for sustained shoot elongation and biomass accumulation (Shrestha *et al.*, 2020). Magnesium, a central component of chlorophyll and ribosomes, is indispensable for photosynthesis and protein synthesis. Furthermore, it modulates enzymes responsible for phosphate transfer, improving root development and indirectly contributing to plant height. These effects have been corroborated by Deng *et al.* (2023), who reported significant improvement in rice crop growth with magnesium supplementation.

Number of tillers hill⁻¹

The effect of polyhalite fertilization on the number of tillers hill⁻¹ clearly indicated that a significant response was observed with the application of graded doses of potassium applied through MOP and polyhalite over control. It ranged from 18.25 to 7.08 (Table 1). The highest number of tillers/hill (18.25) was observed in treatment T₁₀ with NP + 200% K as polyhalite, followed by treatment T₈ with NP + 150% K as polyhalite. The minimum tillers were observed in control (T₁). The observed improvement in the number of tillers per hill may be attributed to the multifaceted benefits of potassium released from polyhalite. Potassium enhances water and nutrient use efficiency, acts as a key activator of various enzymatic processes and significantly improves nitrogen uptake and utilization. These functions collectively stimu-

late robust root development, enabling the plant to access water and essential nutrients more efficiently. Additionally, the sulphur component in polyhalite contributes to increased tiller formation by enhancing the synthesis of sulphur-containing amino acids and proteins, which are critical for shoot development and overall plant growth. These findings align with the results of Kumar *et al.* (2023). Moreover, the synergistic interaction between calcium and nitrate supplied by polyhalite plays a pivotal role during early vegetative stages by promoting cell division and elongation, which are essential for effective tillering. This observation is consistent with the findings of Wang *et al.* (2025). Furthermore, the magnesium in polyhalite supplies adequate Mg²⁺ ions, vital for chlorophyll synthesis, photosynthetic activity, enzyme activation, nutrient transport and maintaining cellular membrane integrity. These physiological improvements create favorable conditions for enhanced tiller production, as Ahmed *et al.* (2023) reported.

Dry matter production

Various potassium sources and application rates significantly impacted dry matter production, as demonstrated in Table 2. Notably, the application of 200% potassium in the form of polyhalite, along with the recommended dose of N and P (T₁₀), has significantly improved the DMP of rice compared to the application of 200% K as MOP with recommended dose of N and P (T₉). The highest DMP was recorded as 47.8 and 87.5 g/pot at active tillering and panicle initiation stages, respectively. These values are on par with the treatment T₈ (NP + 150% K as Polyhalite) recorded 46 and 86.9 g/pot at active tillering and panicle initiation stage, respectively. The enhanced dry matter production observed in treatments receiving polyhalite application can be attributed to its ability to supply a balanced suite of essential secondary and micronutrients—particularly calcium, magnesium

and sulphur, in addition to potassium. Calcium is fundamental for maintaining cell wall structure, membrane integrity and intracellular signaling, while magnesium is a central component of the chlorophyll molecule and is indispensable for photosynthesis and energy transfer.

On the other hand, Sulphur plays a critical role in synthesising amino acids, proteins and coenzymes, thereby enhancing vegetative growth and biomass accumulation. In contrast, Muriate of Potash, though widely used as a potassium source, supplies only K in the form of potassium chloride. High chloride levels from MOP may lead to salt stress under certain soil conditions, inhibiting nutrient uptake and negatively impacting plant metabolic processes. Furthermore, MOP lacks the secondary nutrients provided by polyhalite, which comprehensively limits its capacity to support plant growth and dry matter accumulation. This is supported with findings of Johnson *et al.* (2022). Potassium from polyhalite improves osmotic regulation and enzyme activation and enhances photosynthates' translocation from source (leaves) to sink organs (grains), contributing to superior dry matter partitioning and yield formation. These findings are in line with the observations of Sardans *et al.*, (2021). The synergistic availability of Ca, Mg and S in polyhalite supports holistic plant development, which is less attainable through MOP-based fertilization alone. Hence, the multi-nutrient profile of polyhalite makes it a superior alternative to MOP in promoting dry matter production and overall crop productivity.

Leaf area index

The observation in Table 3 indicates that the addition of different potassium sources and levels significantly influenced the leaf area index in different growth stages of rice. The highest values of 3.82 and 9.48 at active tillering and panicle initiation, respectively, were recorded in the treatment with the application of NP + 200% K as polyhalite (T₁₀), which is on par with the treatment

with application of NP + 150% K as polyhalite (T₈), at critical stages, respectively. The unchanged doses of nitrogen and phosphorus and increased potassium doses up to 200% potassium from polyhalite and MOP increased rice's leaf area index. It was on par with a dose of 150% potassium through both sources. The maximum leaf area recorded in treatment T₁₀ may be primarily attributed to the adequate and balanced supply of potassium from polyhalite. Potassium is a highly mobile nutrient within the plant system. It plays a pivotal role in regulating cell expansion, stomatal activity and photosynthetic efficiency, all of which contribute to increased leaf expansion and canopy development. An optimal supply of potassium enhances turgor pressure, which is essential for cell enlargement and leaf surface area expansion. This is in accordance with the findings of Bhatt *et al.* (2021). Moreover, polyhalite also provides sulphur, which, when combined with nitrogen from other sources, creates a synergistic effect that promotes chlorophyll synthesis and protein formation. This biochemical synergy can lead to an increase in photosynthetically active tissues, thereby expanding the leaf area index of rice. Enhanced LAI improves light interception and energy capture, crucial for higher biomass production. Furthermore, sulphur plays an important role in the formation of certain coenzymes and vitamins that contribute to efficient photosynthetic performance and leaf longevity. As a result, the combined influence of these nutrients promotes greater leaf expansion. It sustains functional leaf area for longer, supporting higher photosynthetic output throughout the crop growth cycle (Aslam *et al.*, 2023).

Chlorophyll content (SPAD values)

The appraisal for chlorophyll content (Table 3) of rice leaves revealed that there was a significant difference found among the different treatments experimented.

Table 2. Effect of polyhalite on dry matter production at different growth stages of rice

Treatments	DMP (g pot ⁻¹)	
	Active tillering	Panicle initiation
T ₁ -Control	24.2	59.2
T ₂ - NP + K (0)	26.1	63.0
T ₃ - NP + 50% K as MOP	28.2	66.5
T ₄ - NP + 50% K as Polyhalite	31.4	70.1
T ₅ - NP + 100 % K as MOP	35.0	73.0
T ₆ - NP + 100% K as Polyhalite	38.5	76.8
T ₇ -NP + 150% K as MOP	41.0	80.3
T ₈ - NP + 150% K as Polyhalite	46.0	86.9
T ₉ - NP + 200% K as MOP	42.3	82.0
T ₁₀ - NP + 200% K as Polyhalite	47.8	87.5
SE _d	0.9	1.3
CD (p=0.05)	1.9	2.6

The experiment showed that the maximum chlorophyll content of 35.90 and 44.50 (SPAD values) at active tillering and panicle initiation were recorded with application of NP + 200% K as polyhalite over control. The treatments next in order were T₈, T₉, T₇, T₆, T₅, T₄, T₃, T₂ and T₁. However, the treatments T₁₀ and T₈; T₉ and T₇ were comparable. Polyhalite, as a source of sulphur, plays a crucial role in enhancing chlorophyll content by ensuring the availability of this essential nutrient. sulphur is a key component of amino acids such as cysteine and methionine and is an essential component of proteins and vitamins, including those involved in chlorophyll synthesis, further supporting plant growth and development. These findings align with the observations of Jha *et al.*, (2024). Magnesium from polyhalite supports plant photosynthesis, glucose partitioning and nutrient transport. Magnesium, a central component of the chlorophyll molecule, directly influences chlorophyll synthesis. The maximum chlorophyll content (44.50) was obtained in the treatment (T₁₀), this might be attributed to the magnesium content in polyhalite contributes to increased chlorophyll levels in plant tissues, aligning with the findings of Gowthami *et al.* 2022.

Yield parameters

Various treatment combinations led to a significant enhancement in the yield attributes of rice. The performance of rice under different potassium treatments on yield parameters viz., no. of panicles pot⁻¹, no. of grains panicle⁻¹, panicle length and test weight at harvest stage significantly varied and presented in Table 4. Among the treatments, T₁₀ recorded the highest no. of panicles pot⁻¹ (39.01), no. of grains panicle⁻¹ (81.23), panicle length (28.53 cm) and test weight (15.91 g), which is on par with T₈ and the lowest values were observed in the control plot. Polyhalite has a much more positive effect on rice than MOP. The improvement in the number of

panicles per pot may be attributed to an adequate potassium supply, which is essential for tiller initiation, development, and enhanced root growth, supporting better nutrient and water uptake. Furthermore, polyhalite application can enhance the reproductive efficiency of rice by promoting flower initiation, pollen development, and fertilization. The potassium, sulfur and magnesium provided by polyhalite play critical roles in these processes, leading to an increased number of grains per panicle. Adequate supply of potassium and magnesium is vital for panicle development and elongation and polyhalite ensures their availability, thereby promoting panicle elongation and increasing panicle length. Test weight, an indicator of grain density and quality, is influenced by grain size, shape and filling. Potassium plays a key role in starch synthesis and grain development and its adequate supply significantly enhances grain weight. Polyhalite application improves nutrient uptake and translocation, resulting in robust grain filling and improved grain quality. The balanced nutrient supply from polyhalite also supports optimal plant growth and reproductive development, contributing to higher test weights. Similar findings were reported by Ranjan and Singh (2021), who observed significant improvements in rice yield attributes with the application of potassium levels ranging from 0 to 60 kg ha⁻¹.

Grain and straw yield

Grain and straw yield are the results of the combined influence or intricate interactions among various yield components, which are shaped by both the vegetative and reproductive stages of the plant's growth. The grain and straw yield of rice was significantly affected by different potassium treatments. The data on yield are set out in Table 4. The results revealed that the application of NP + 200% K as polyhalite recorded the highest

Table 3. Effect of polyhalite on leaf area index and chlorophyll content (SPAD) of rice

Treatments	Leaf area index		Chlorophyll content	
	Active tillering	Panicle initiation	Active tillering	Panicle initiation
T ₁ -Control	2.05	6.04	21.13	25.20
T ₂ - NP + K (0)	2.26	6.52	23.30	28.73
T ₃ - NP + 50% K as MOP	2.49	6.91	24.53	31.70
T ₄ - NP + 50% K as Polyhalite	2.66	7.01	25.87	33.73
T ₅ - NP + 100 % K as MOP	2.89	7.35	27.23	35.57
T ₆ - NP + 100% K as Polyhalite	3.02	7.54	30.43	37.33
T ₇ -NP + 150% K as MOP	3.13	8.50	31.53	38.43
T ₈ - NP + 150% K as Polyhalite	3.51	9.20	35.23	43.57
T ₉ - NP + 200% K as MOP	3.20	8.61	32.10	39.07
T ₁₀ - NP + 200% K as Polyhalite	3.82	9.48	35.90	44.50
SE _d	0.2	0.2	0.36	0.49
CD (p=0.05)	0.25	0.66	0.75	1.02

Table 4. Effect of polyhalite on yield parameters and yield of rice

Treatments	No. of panicles pot ⁻¹	No. of grains panicle ⁻¹	Panicle length (cm)	Test weight (g)	Grain yield (g pot ⁻¹)	Straw yield (g pot ⁻¹)
T ₁ -Control	15.11	56.10	19.13	15.15	50.51	70.63
T ₂ - NP + K (0)	18.01	58.17	20.33	15.21	61.28	82.07
T ₃ - NP + 50% K as MOP	21.23	61.27	21.37	15.38	64.10	84.69
T ₄ - NP + 50% K as Polyhalite	23.04	63.47	22.40	15.52	68.64	87.73
T ₅ - NP + 100 % K as MOP	26.02	68.20	24.20	15.73	71.48	90.54
T ₆ - NP + 100% K as Polyhalite	31.82	72.27	25.07	15.74	74.89	94.08
T ₇ -NP + 150% K as MOP	34.03	74.77	26.42	15.80	78.00	98.51
T ₈ - NP + 150% K as Polyhalite	38.59	80.50	27.83	15.92	83.74	103.55
T ₉ - NP + 200% K as MOP	35.21	76.43	26.70	15.82	79.40	99.81
T ₁₀ - NP + 200% K as Polyhalite	39.01	81.23	28.53	15.91	84.33	104.25
SE _d	1.10	0.98	0.23	0.04	0.46	0.55
CD (p=0.05)	2.28	2.04	0.48	NS	2.09	1.60

grain and straw yield of 84.33 and 104.25 g pot⁻¹, respectively. The treatments next in order were T₈, T₉, T₇, T₆, T₅, T₄, T₃, T₂ and T₁. However, the treatments T₁₀ and T₈; T₉ and T₇ were comparable with each other. The lowest yield was observed in control T₁(50.51 g pot⁻¹ of grain and 70.63 g pot⁻¹ of straw). Between the two potassium sources, polyhalite was significantly more effective than MOP. Application of polyhalite as 200% K showed a percentage increase of 67% and 47.6% in grain and straw yield; meanwhile, application of the same dose of K through MOP, T₉ resulted in a yield increase of 57.19% in grain and 41.31% in straw over control.

The increase in yield can be associated with the application of polyhalite, which supplies essential nutrients such as potassium, sulfur, magnesium and calcium, playing pivotal roles in supporting rice growth and development. Although alluvial soils are naturally fertile, nutrient losses through leaching and erosion are common, polyhalite application addresses this by replenishing key nutrients and ensuring a balanced supply throughout the growth cycle. This balanced nutrition promotes optimal vegetative and reproductive development, ultimately enhancing grain and straw yields. Furthermore, polyhalite improves nutrient uptake efficiency and stimulates root proliferation, further supporting plant vigor and yield enhancement. The calcium in polyhalite plays a vital role in improving soil structure, thereby enhancing water retention and drainage. This ensures a steady supply of water during crucial growth phases. Additionally, as a source of calcium and magnesium, polyhalite application boosts the availability of these nutrients in the soil, resulting in greater plant uptake. By promoting better water and nutrient absorption from the soil, potassium supplied through polyhalite ultimately leads to increased rice yields. These results are consistent with the findings reported by Abdelsatar (2021).

Compared to Muriate of Potash (MOP), which supplies only potassium and contains high chloride levels, polyhalite provides a multi-nutrient source with a slow-release effect and no chloride toxicity. While MOP can meet immediate potassium demands, excessive chloride may negatively impact soil health and crop performance. In contrast, polyhalite sustains potassium availability and supplies secondary nutrients crucial for grain filling, test weight, and biomass accumulation. Consequently, polyhalite has demonstrated greater effectiveness than MOP in improving grain and straw yields in rice by promoting comprehensive plant growth and maintaining long-term soil productivity.

Conclusion

Polyhalite proved to be highly effective as a fertilizer for rice as it improved its yield to a greater extent compared to the performance of MOP. Application of 200% and 150% of potassium through polyhalite in addition to the recommended dose of nitrogen and phosphorus (T₁₀ and T₈) showed a significant impact on biometric and yield attributes of rice (var. ADT 43) in Entisols. Polyhalite, as a single fertilizer, is an alternative source of K, Ca, Mg, and S and can meet the nutritional requirements for the healthy growth of crops. Therefore, this study suggests that supplying potassium through polyhalite improves rice productivity.

Conflict of interest

The authors declare that they have no conflict of interest.

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