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Effect of polyhalite on yield, nutrient uptake by wheat and soil properties

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ABSTRACT

This experiment was conducted at the crop research farm of the ICAR, Indian Agricultural Research Institute, New Delhi during the rabi season of 2021–22. The research experiment was laid out in a randomized block design with three replications of twelve treatments. The nutrient uptake by grain and straw was significantly higher with the application of 100% K dose through polyhalite. The application of a 75% K dose through polyhalite results in significantly higher values of total K and S uptake over 50% K through MOP + 50% K through polyhalite, and 50% K through MOP + S (equivalent to T_6). The treatment comprising 100% K dose through polyhalite depicted higher availability of soil available NPKS and organic carbon. The value of soil microbial parameters e.g. MBC and FDA were shown highest with the application of polyhalite treatments than with conventional fertilizer. Potassium and sulphur are two highly important elements for the production of high-quality, oil, crop, and protein, but most Indian farmers are unfamiliar with the advantages, which is why there aren't applying; in this circumstance, crops are taking soil nutrients, causing K and S deficiencies in Indian soils. Therefore use and awareness of polyhalite may be a beneficial option for improving soil health, addressing nutrient imbalances, and raising crop quality and productivity.

Keywords: Polyhalite, nutrient uptake, microbial biomass carbon, fluorescein diacetate

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most widely grown cereal crop, spanning ~218.3 million hectares (Mha) and producing 761 million tonnes (Mt) of grain (FAOSTAT, 2020). The two most important food grains produced and consumed in India are rice and wheat. Wheat is grown on ~35 Mha area, yielding 107.59 Mt, with an average yield of 3.06 t ha^{-1} (MoA & FW, GOI 2021–22). For a large section of the population in India, wheat serves as a key source of nourishment and food. It is largely grown in India's North–Western plains, which include the states of Punjab, Haryana, Rajasthan, Delhi, and Uttar Pradesh. A favourable agro-climate and access to irrigation are important factors for wheat production in these states. The majority of India's wheat production, with the exception of the North Western regions, is rainfed, making it susceptible to the effects of climate change. Despite its importance, wheat production in India faces numerous challenges. The diminished ability of soil to supply plants with nutrients is one of the primary causes of declining production. Wheat productivity is further impacted by the fact that both climate change and water shortage are spreading. Widespread usage of single-nutrient or straight fertilizer, which contains high concentrations of one or two nutrients like nitrogen, phosphorus, or potassium, causes nutritional imbalances in the soil. As a result, the soil may have an excess of these nutrients while being deprived of other crucial elements like potassium, sulphur, and micronutrients (Zhu *et al.*, 2005; Yu *et al.*, 2013; Ti *et al.,* 2015). Moreover, this could encourage soil acidity, loss of organic matter, soil compaction, and eventually a decline in soil biodiversity. On the other hand, straight fertilizers can also have negative effects on nutrient uptake. When straight or conventional fertilisers are added to the soil, it may result in an abundance of one or more nutrients. This can result in an accumulation of these nutrients in the soil, which might be bad for the plants. This could be avoided by using a multi-nutrient fertilizer like polyhalite, which contains four macronutrients — potassium, calcium, magnesium, and sulphur— as well as micronutrients (Yermiyahu *et al.*, 2017; Yermiyahu *et al.*, 2019; Huang *et al.,* 2020). Polyhalite is a hydrated natural mineral, that has evaporative qualities and provides critical essential nutrients to plants in a slow-release pattern. It contains rated nutrient content

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of 14% K_2O, 6% MgO, 17% CaO, and 19% S and well suggested as a nutrient supplier to the plant by several researchers (Fraps, 1932; Zheng *et al.,* 2015; Sirius Minerals, 2016).

MATERIALS AND METHODS

The experiment was conducted in the crop research farm, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, during the *rabi* season of 2021–2022. Geographically, the experimental site becomes under the category of semi-arid, sub-tropical climate with hot dry summers and chilling winters and is located at latitude 28°38'23" N, Longitude: 77°09'27"E, Altitude: 228.61 meters above MSL. The soil was sandy–loam, neutral in reactivity, medium in organic matter, low in readily available nitrogen, medium in readily available phosphorus, and high in readily available soil potassium. Three replications of each of the twelve treatments were used in the field trial, which was set up using a randomized block design. The experiment was laid out in a randomized block design (RBD) of twelve treatments with three replications. The treatments description; T_1 (No-K, no-S), T_2 (Recommended through bentonite, no-K), T_3 (50% K through MOP), T_4 (75% K through MOP), T_5 (100% K through MOP), T_6 (50% K through polyhalite), T_7 (75% K through polyhalite), T_8 (100% K through polyhalite), T_9 (50% K through MOP+S–equal toT_6; bentonite), T_{10} (75% K through MOP+S–equal to T_7; bentonite), T_{11} (100% K through MOP + S–equal toT_8; bentonite), and T_{12} (50% K through MOP+50% through polyhalite). The mega–variety HD 2967 was sown in a plot size of 8.0 x 3.5m (*i.e.*, 28 m^2). The nitrogen and phosphorus were fertilized in each plot as per recommended dose (150 kg N ha^{-1} and 26.2 kg P ha^{-1}). The application of K was supplied through polyhalite and Muriate of Potash (MOP) at various levels (50, 75, and 100% dose). The different blends of MOP plus a source of S–bentonite was taken as treatments in order to evaluate the efficiency of polyhalite. The P, K, and S content in grain and straw were multiplied by their respective yield on a hectare basis to estimate the total amount of P, K, and S taken up by plants. The P, S, and K contents in grain and straw were estimated using the analysis consisted (Jackson, 1973), with the help of the spectrophotometer and flame emission photometry. The Walkley and Black organic carbon, available S, K, and N (Jackson, 1973and available P (Olsen *et al.,* 1954) were determined. The microbial biomass carbon (MBC) was determined by using the chloroform fumigation process (Nunan *et al.*, 1998) and fluorescein diacetate activity (FDA) was represented as µg of fluorescein released g^{-1} soil h^{-1} (Green *et al.,* 2006). Net plot plants were harvested after the border rows were removed and allowed to dry in the sun for four to five days. Following this, samples were weighed for biological yield, followed by the grain yield after threshing, and the final grain yield was adjusted to account for the grain's 14% moisture content.

RESULTS AND DISCUSSION

Soil properties

The soil samples were taken prior to the experiment and after harvesting the crop for organic carbon, available N, P, K, and S. It was discovered that the application of polyhalite significantly affects the aforementioned nutrients. Increased available N (210.2 kg ha^{-1}) was obtained in the treatment using polyhalite as a K source with 100% K recommended dosage, which was significantly higher than other treatments but statistically at par with 100% K through MOP + S (equivalent to T_8) and 50% K through MOP + 50% K through polyhalite (Figure1). The results of the P analysis of the same samples showed the same pattern in the values as in N. The highest soil available K was observed with a 100% K dose through polyhalite (373.0 kg ha^{-1}), which was statistically at par with treatment applied 100% K MOP + S (equivalent to T_8). Polyhalite is a multi-nutrient fertilizer that also contains a sizable amount of S, so samples were analyzed for S content. It was discovered that, compared to other conventional materials, polyhalite offered a significantly higher amount of available sulphur (16.3 kg ha^{-1}), where nutrient management was carried out through the polyhalite, but at par with 100% K MOP + S-bentonite (equivalent to T_8). Organic carbon was higher under treatments with 100% K dose through polyhalite and lowest under treatment no-K, no-S. These outcomes might be attributed due to the polyhalite is a naturally occurring fertilizer that contains oxides of Ca, Mg, K, and S, these salts are very essential for the flocculation of soil aggregate. Polyhalite enhances the properties of the soil, supplies multiple nutrients in a slow-release pattern, reduces leaching, and also fosters synergy between the soil, microbes, and plants. It has also been reported by (Yermiyahu *et al.,* 2017) that using polyhalite as a fertilizer material has improved the soil's qualities.

Soil biological properties

It is essential to evaluate the biological properties of the soil in order to determine the impact of any fertilizer on the health of the soil's flora. As a consequence, soil samples for fluorescein diacetate activity (FDA) and microbial biomass carbon (MBC) were collected at the flowering stage, when the field's moisture level was nearly at its field capacity. MBC and FDA were recorded highest under 100% K through polyhalite followed by 100% K MOP + S-T_8, 50% K through MOP+50% K through polyhalite (Figure 2). Polyhalite is a naturally occurring fertilizer, that delivers a number of nutrients all at once over a long period of time. This increased nutrient availability resulted in greater plant growth, and studies have shown that when plants grow well, they release more photosynthates in the form of root exudates in the rhizosphere (Olanrewaju *et al.,* 2019). Polyhalite also supplies Ca, Mg, K, and S, which are additional necessary nutrients for microbes. Improvements in soil biological properties brought on by the application of polyhalite have also been reported by (Wang *et al.,* 2019).

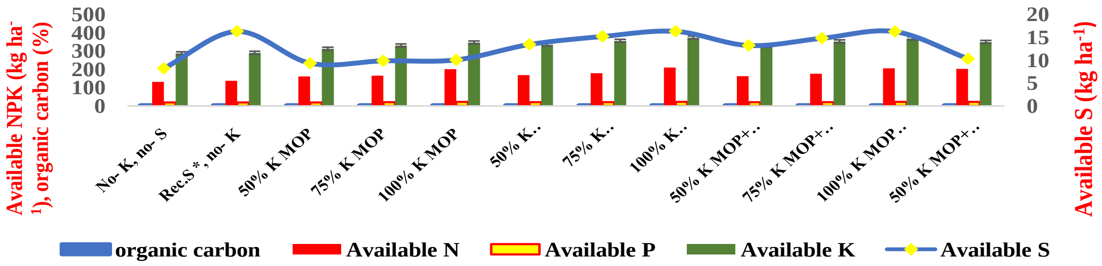

Fig.1: Effect of polyhalite on soil organic carbon, available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) (kg ha^{-1}) in soil

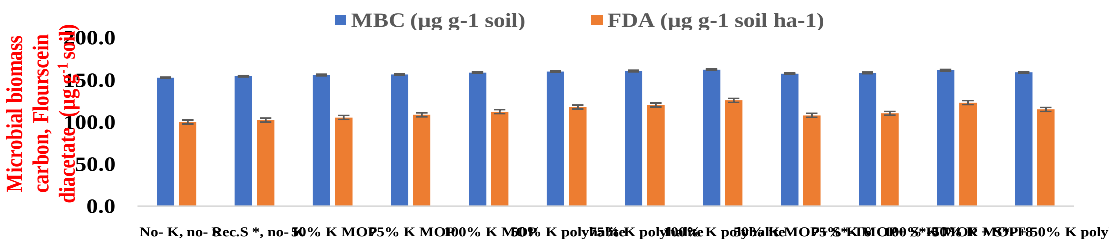

Fig. 2: Effect of polyhalite on soil biological properties at flowering in wheat

Uptake of P, K, and S

The P, K, and S uptake by grain and straw of wheat varied significantly with polyhalite application. Under 100% K dosage through polyhalite, the uptake of nitrogen and phosphorus in grain and straw was higher and significantly higher compared to other treatments, but statistically at par with 100% K through MOP+S (Table 1). Under 100% K dosage administered using polyhalite, the total uptake of K and S was reported at its maximum level, which was notably higher than 100% K MOP + S (equivalent to T_8). The application of a 75% K dose through polyhalite results in significantly higher values of total sulphur uptake over 50% K through MOP+ 50% K through polyhalite, and 50% K through MOP+ S (equivalent to T_6), while statistically at par with 75% K through MOP+ S (equivalent to T_7) through bentonite. The reason for this was polyhalite's ability to provide nutrients like Ca, Mg, S, and K to plants, which are very essential for cell membrane permeability, the formation of chlorophyll, and the translocation, absorption, and assimilation of photosynthates. Additionally, polyhalite supports nutrient synergism in plants by providing nutrients in a slow-release manner throughout the course of the crop-growing season. Increment in the uptake of nutrients by the application of polyhalite has also been reported by (Li *et al.*, 2020).

Grain Yield

The grain yield of wheat varied significantly with the influence of polyhalite and polyhalite + MOP treatment levels (Table 1). The highest grain yield was recorded with a 100% K dose through polyhalite (5.87 t ha^{-1}), which was significantly higher than 100% K MOP + S (equivalent to T8) and other treatments. The application of 75% K through polyhalite results in statistically higher results over 100% K through MOP, T_1, T_2, T_3, T_4, T_6, and T_9, but at par with T_{10}, and T_{12}. A 29.9 % increase in yield was recorded with the application of 100% K dose through polyhalite over 100% K dose through MOP. The application of polyhalite @100% K through polyhalite resulted in a 112.3, 84.8% increase in grain yield over no-K, no-S, and Rec. S*, no-K. The increment in soil organic carbon, N, P, K, S, availability, and microbial properties, as well as the provision of multiple nutrients such as Ca, Mg, K, and S by polyhalite, may be the cause of the increase in grain yield brought on by the application of 100% K through polyhalite. Additionally, polyhalite supplies multiple nutrients such as K, S, and Ca, which encourages the plant's synergism for other nutrients to absorb, translocate, and assimilate. Increment in the grain yield of wheat by the application of polyhalite has also been reported by (Li *et al.*, 2020).

Table 1. Effect of polyhalite on nutrient uptake (kg ha^{-1}) by grain and straw of wheat

Treatments	Grain Yield (t ha^{-1})	P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})		
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 No- K, no- S	2.76	5.5	7.8	13.3	4.1	77.3	81.4	5.8	8.2	14.0
T_2 Rec.S *, no- K	3.18	6.7	9.5	16.2	6.0	91.1	97.2	8.6	11.9	20.5
T_3 50% K MOP	3.60	9.0	10.9	19.9	8.3	101.4	109.7	7.9	9.9	17.9
T_4 75% K MOP	4.06	11.0	13.5	24.4	11.0	122.2	133.2	9.3	12.3	21.7
T_5 100% K MOP	4.52	14.9	14.2	29.2	14.9	156.7	171.6	9.5	13.6	23.1
T_6 50% K polyhalite	4.11	11.1	15.9	27.0	11.9	124.8	136.7	9.9	13.0	22.9
T_7 75% K polyhalite	5.03	14.6	21.7	36.3	19.1	175.9	195.1	13.1	17.4	30.5
T_8 100% K polyhalite	5.87	20.5	17.1	37.7	25.2	198.4	223.7	16.4	19.5	35.9
T_9 50% K MOP+S*-T_6	4.01	10.4	12.7	23.2	10.8	120.7	131.5	9.6	12.7	22.4
T_{10} 75% K MOP+S*-T_7	4.94	13.8	20.6	34.4	18.3	172.8	191.1	12.4	17.1	29.4
T_{11} 100% K MOP+S*-T_8	5.46	18.6	20.3	38.8	22.9	183.9	206.9	14.7	18.0	32.8
T_{12} 50% K MOP+50% K polyhalite	4.96	16.9	16.4	33.3	18.8	172.4	191.3	11.4	15.7	27.1
SEm ±	0.138	0.6	0.6	1.0	0.5	4.2	5.4	0.5	0.5	0.7
LSD (*P*=0.05)	0.408	1.8	1.7	3.1	1.5	12.2	15.9	1.6	1.4	2.0

From the results it may be concluded that the use of polyhalite can eliminate nutrient imbalances in the soil, promote nutrient uptake by plants without endangering their safety, and also stop the indiscriminate use of chemical fertilizers. Overall, the research indicates that polyhalite may benefit soil biological characteristics and plant nutrient uptake. To completely comprehend the mechanisms by which polyhalite enhances soil health and crop yield, more study is required. The recent findings, however, suggested that polyhalite might be a useful soil amendment for enhancing soil health, eliminating nutrient imbalances, and increasing crop productivity.

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