Indian Journal of Agricultural Sciences **93** (3): 325–327, March 2023/Short Communication
https://doi.org/10.56093/ijas.v93i3.132909

Effect of polyhalite on growth and yield of wheat (*Triticum aestivum*) in India

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Received: 3 February 2023; Accepted: 13 February 2023

Keywords: Bentonite, Grain yield, Potassium, Polyhalite, Wheat

The rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) system (RWS) is the predominant cropping system in South Asia, covering ~14 million hectares (mha) and feeding more than 400 million people (Singh *et al*. 2010). In Indo-Gangetic Plains (IGP), RWS is cultivated on ~11.3 mha in India (Bhatt *et al*. 2015). The cereal-centric RWS is a highly nutrient-exhaustive production system and often results in soil nutrient imbalance. More than 300 kg of nitrogen (N), 30 kg of phosphorus (P), and 300 kg of potassium (K) per hectare (ha) is removed from the soil by RWS that yields 7 and 4 tonnes/ha rice and wheat, respectively (Singh *et al*. 2004). The diminishing productivity trend of RWS in IGP is primarily due to nutrient imbalance which is dominated by the application of N and P, with very less K application. The subsidized N fertilizers have also encouraged the over-application of N fertilizer. The over-reliance on macronutrient fertilizers and ignorance of other essential secondary and micro-nutrients often results in a disrupted nutrient allocation ratio (Yu *et al*. 2013, Ti *et al*. 2015).

It is generally believed that Indian soils are K-rich and therefore K fertilizers are often ignored, however, not all Indian soils have a plentiful supply of K-bearing minerals, and the requisite quantity of K is imperative for higher productivity at the right time (Majumdar *et al*. 2016). The application of a lesser amount of K than the plant requirements leads to K mining and imbalances between plant nutrients. The application of a single nutrient, such as K (through murate of potash), can have an antagonistic effect on calcium (Ca) and magnesium (Mg) uptake by the plant. The growing negative K balance and mining without appropriate K replenishment in soils can be checked through the application of multi-nutrient compositions like polyhalite in place of conventional fertilizers. Polyhalite is one such commercially available fertilizer with deposits in the North Sea basin, off the coast of the United Kingdom (Kemp *et al*. 2016).

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Polyhalite ($K_2SO_4.MgSO_4.2CaSO_4.2H_2O$) is an evaporative mineral and is a natural source of 14% K_2O, 6% MgO, 17% CaO, and 19% S (Yermiyahu *et al*. 2017). Its granular form has several unique features like water-solubility and higher surface area allowing a season-long controlled release and greater nutrient availability over conventional K sources (Huang *et al*. 2020). Polyhalite is a neutral salt with solubility of 27 g/litre at 25°C and <2% chloride content. Several researchers have demonstrated the benefits of polyhalite over conventional K fertilizers in many crops like potato, sugarcane and barley, but the response in wheat has not been studied widely. Therefore, a field experiment was conducted at Research Farm of Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi during winter (*rabi*) season 2021–22 with the objective to evaluate the response of applied polyhalite on growth and productivity of wheat.

Initially, it was hypothesized that the optimum dose of polyhalite could be able to replace the high doses of K through MOP (murate of potash) along with fetching the benefits of additional nutrients supplied by it. The experimental site was in the western IGP, which receives an average annual rainfall of 714 mm. The treatments on the experimental site were laid out in randomized block design with 3 replications along with a plot size of 8.0 m × 3.5 m (28 m^2). The wheat variety used in the experiment was HD-2967. Initial soil sample analysis revealed that soil was neutral in reaction (*p*H=7.2), medium in organic carbon (0.41%), low in available N (168.9 kg/ha), medium in available soil P (24.4 kg/ha), high in available K (324.6 kg/ha) and medium in available soil S (12.5 kg/ha). All the plots were fertilized with recommended dose (RDF) of N and P through urea and di-ammonium phosphate (DAP) fertilizers, respectively. The treatments having K and S received doses through muriate of potash (MOP) or MOP + polyhalite and bentonite, respectively. The treatments were: No-K, no-S (T_1); Recommended S-bentonite, no-K (T_2); 50% K-MOP (T_3); 75% K-MOP (T_4); 100% K-MOP (T_5); 50% K-Polyhalite (T_6); 75% K-Polyhalite (T_7); 100% K-Polyhalite (T_8); 50% K-MOP + S equal to T_6- bentonite

(T_9); 75% K-MOP + S equal to T_7-bentonite (T_{10}); 100% K-MOP + S equal to T_8- bentonite (T_{11}); and 50% K-MOP + 50% K-polyhalite (T_{12}). Recommended dose of N (150 kg N/ha) and P (60 kg P_2O_5/ha) have been applied to all treatments.

The results indicated that there was a significant improvement in growth parameters of wheat, viz. plant height, number of tillers, leaf area index (LAI), dry matter accumulation, crop growth rate (CGR), and relative growth rate (RGR) at different stages of wheat with polyhalite application. The plant height varied significantly in different treatments at 90 days after sowing (DAS) and at the harvest stage (Table 1). The maximum crop growth rate (CGR) was recorded with T_8, which was statistically significant over other treatments. The maximum relative growth rate (RGR) was recorded with T_5, which was statistically at par with T_{11}, and significantly superior over T_1, and T_2 (Table 2).

At 30 DAS, the tillers (No./m^2) were significantly higher in T_8 (79.2 /m^2). At 60 DAS, a significantly higher tiller count has been recorded over 30 DAS. The leaf area index (LAI) was significantly influenced by the application of polyhalite and MOP levels. At 60 DAS, the maximum value of LAI was observed with T_8, which remained statistically at par with T_{11} (Table 1). Polyhalite ensures the availability of other essential nutrients like calcium (Ca), magnesium (Mg), and sulphur (S) along with K and provides balanced nutrition which resulted in optimum plant growth. The attributes of polyhalite like quick solubility, slow-release pattern, and prolonged nutrient availability that matches the crop's demand over time, resulted in the maximum height of wheat under T_8. The Ca supplied through polyhalite might have also increased plant height because of its role in cell division and elongation (Akhtar *et al*. 2022). The application of T_7 remained statistically at par with T_5, T_{10} and T_{12}. A higher adsorption or fixation of K in soil with MOP as a K source has been reported which reduces the K availability for plants (Bhatt *et al.* 2021). The soil adsorption of K also remains relatively less where polyhalite is being applied due to competition between monovalent ion (K) and divalent ion (Ca, Mg).

The grain yield is the cumulative response of yield attributing characters that depend upon the overall growth and development of the plant. The maximum grain yield was obtained with T_8, which was significantly higher than T_{11}. The application of T_7 resulted in a 11.3% increase in grain yield over T_5 due to a balanced and slow-release prolonged nutrient supply to the plant (Table 1). It also supplies essential secondary nutrients, viz. Ca, Mg, and S through polyhalite contributed to extra yield over a single nutrient supply through MOP (Pavuluri *et al*. 2017, Mello *et al*. 2018). The value of the harvest index remained higher under polyhalite at T_8 (0.43), which was significantly higher than T_1 and T_2, probably due to higher CO_2 assimilation, and greater dry matter partitioning into economic parts of plants with multi-nutrient supply to plant through polyhalite. However in T_1 and T_2, a disruption in the transport system resulted in the accumulation of photosynthates in non-economical parts and not in energy storage organs. It resulted in poor grain yield and energy losses. Multi-nutrient deficiencies and increasing soil nutrient imbalances are serious challenges for agro-ecosystem sustainability in IGP. In these areas, K mining without appropriate K replenishment has resulted in severe deficiencies, leading to poor yield responses in RWS. Polyhalite as a multi-nutrient natural mineral source can potentially enhance the growth and productivity of wheat, especially in Ca-deficit alkaline soils.

Table 1 Effect of polyhalite on growth parameters, grain yield (tonnes/ha) and harvest index of wheat

Treatment	Plant height (cm)	Dry-matter production (g/m^2)	Grain yield (tonnes/ha)	Harvest index	Tillers (No./m^2)		Leaf area index
					30 DAS	60 DAS	60 DAS
T_1	86.7	277.3	2.76	0.39	50.1	214.6	3.39
T_2	87.2	337.4	3.18	0.40	50.2	215.0	3.46
T_3	88.4	397.5	3.60	0.42	57.3	245.1	3.51
T_4	89.9	457.6	4.06	0.42	64.4	275.2	3.84
T_5	91.0	577.7	4.52	0.40	71.6	305.4	4.21
T_6	90.1	457.6	4.11	0.42	64.5	275.3	3.92
T_7	91.6	578.8	5.03	0.41	71.8	305.6	4.35
T_8	92.3	698.9	5.87	0.43	79.2	341.1	4.75
T_9	89.2	457.5	4.01	0.42	64.4	275.2	3.76
T_{10}	90.5	517.7	4.94	0.41	71.7	305.4	4.17
T_{11}	92.0	638.8	5.46	0.43	78.9	335.6	4.57
T_{12}	91.3	578.7	4.96	0.41	71.8	305.5	4.28
SEm ±	0.8	20.2	0.138	0.01	2.4	10.1	0.07
LSD (P=0.05)	2.5	59.7	0.408	0.02	7.0	29.7	0.20

Refer to methodology for treatment details.

Table 2 Effect of the application of various potassium sources on crop growth rate and relative growth rate at different stages of wheat

Treatment	Crop growth rate ($g/m^2/day$)			Relative growth rate (g/g/day)		
	30–60 DAS	60–90 DAS	90 DAS-harvest	30–60 DAS	60–90 DAS	90 DAS-harvest
T_1	1.71	8.99	4.44	0.012	0.007	0.004
T_2	2.05	9.69	4.76	0.013	0.008	0.004
T_3	2.66	10.39	5.04	0.014	0.009	0.004
T_4	3.01	11.12	5.51	0.016	0.009	0.004
T_5	3.36	11.82	6.01	0.017	0.009	0.004
T_6	3.02	11.15	5.59	0.017	0.009	0.004
T_7	3.72	12.58	6.35	0.017	0.009	0.004
T_8	4.40	14.01	6.91	0.019	0.010	0.004
T_9	2.99	11.10	5.41	0.017	0.008	0.004
T_{10}	3.69	12.56	6.32	0.017	0.009	0.004
T_{11}	4.06	13.28	6.63	0.018	0.009	0.004
T_{12}	3.71	12.57	6.33	0.017	0.009	0.004
SEm ±	0.09	0.20	0.08	0.0003	0.0003	0.0001
LSD (P=0.05)	0.25	0.59	0.24	0.001	0.001	NS

Refer to methodology for treatment details.

SUMMARY

A field experiment was conducted at ICAR-Indian Agricultural Research Institute, New Delhi, Research Farm during winter (*rabi*) season 2021–22 to evaluate the effect of multi-nutrient carrier polyhalite and its combinations with variable doses of MOP on growth parameters, yield, and productivity of wheat. The application of 100% K (polyhalite), i.e. T_8 resulted in significantly higher growth and yield parameters of wheat, viz. plant height, dry matter accumulation, tillers numbers, crop growth rate, leaf area index, grain yield (5.87 tonnes/ha). A 7.5% increase in grain yield was observed with the application of T_8 over T_{11}. So, a balanced and prolonged supply of available nutrients with polyhalite to crop in a sustained manner can be maintained.

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