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Research Article

Effect of polyhalite and muriate of potash on quality attributes of sugarcane (*Saccharum officinarum* L.) in Inceptisols

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Abstract

Polyhalite is a hydrated sulphate evaporate mineral containing potassium, sulphur, calcium and magnesium that crops require in significant quantities but has limited evaluation as a fertilizer for sugarcane.The sugarcane crop has a high demand for potassium for better quality. To keep the above facts in mind, the present experiment was conducted to evaluate the effect of polyhalite and muriate of potash (MOP) on the quality attributes of sugarcane var. Co 11015 (Atulya) in sandy loam soil at Arachalur, Erode district. The experiment was laid out in a randomized block design consisting of ten treatments. The treatment included were T_1 –control, T_2 - 50% K as MOP, T_3 - 100% K as MOP, T_4 - 100% K as Polyhalite, T_5 - 100% K (1:1 ratio of Polyhalite and MOP), T_6 - 100% K (1:3 ratio of Polyhalite and MOP), T_7 - 150% K as MOP, T_8 - 150% K as Polyhalite, T_9 - 150% K (1:1 ratio of Polyhalite and MOP), T_{10} - 150% K (1:3 ratio of Polyhalite and MOP). The application of potassium fertilizers in different levels and ratios significantly (5%) influenced the quality attributes of sugarcane. The results of the experiment revealed that the application of 150% K (169.5 kg K_2O ha^{-1}) as polyhalite (T_8) recorded maximum brix, pol, purity, CCS%, and extraction% and also this treatment was recorded minimum reducing sugar and fibre%. The present experiment would be helpful to sugarcane farmers for quality improvement through the application of polyhalite as a potassium fertilizer.

Keywords: Fertilizer, Muriate of potash, Polyhalite, Quality, Sugarcane

INTRODUCTION

Sugarcane is one of the important sugar and Jaggery-producing crops and also provides a large amount of sucrose, alcohol and organic matter waste used as fertilizer in India. Sugarcane is one of the most important cash crops in tropical areas. It produces around 70% of the world's sugar (Hao Zhang *et al.,* 2021).Compared to other crops, sugarcane requires a greater dose of the primary nutrients N, P and K because it is a long-lasting, nutrient-intensive crop. The availability of these nutrients is fundamentally necessary for the proper nutrient uptake by plants. Nutrients like nitrogen, phosphorus and potassium are critical factors that seriously limit crop growth, quality and yield (Gokul *et al.,* 2023). In India, sugarcane is cultivated in an area of 48.46 lakh ha with a production of 360 million ha and yields of 78.8 tonnes ha^{-1}(Karthikeyan and Gokul, 2023). The average productivity is concerned; Tamil Nadu recorded a maximum (99.70 tonnes ha^{-1}) followed by West Bengal and Karnataka.

For the healthy growth and development of the sugarcane crop, an adequate supply of potassium is considered an essential factor influencing the accumulation and storage of nutrients. (Hemeid *et al.,*2017). Potassium is a major important element in numerous physiological and biochemical processes supporting plant growth. The requirement of potassium in high-yielding varieties of crops frequently exceeds that of nitrogen and phosphorus. In the context of modern intensive agriculture, which strives for higher crop yields per unit area and per unit time, the K gained significance. India has no indigenous source of potash. Although 150 countries worldwide have reported using potash, only a select few have potash reserves (Evgeniya Ushakova *et al.,* 2023). The current idea of agricultural sustainability research on the proper application of fertilizers is necessary for the success of sugarcane production. One alternative is the use of multi-nutrient sources, like polyhalite, which can deliver many macronutrients in a single application (Karthikeyan *et al.,* 2023). Sugarcane requires a lot of minerals, the most important of which is potassium, which has a high absorption and export rate. Mineral fertilizers can provide other necessary nutrients like nitrogen, phosphorus, calcium, magnesium, and sulphur (Herrera *et al.,* 2022).

The natural mineral polyhalite trademark is polysulphate, made at the Boulby mine in Cleveland, United Kingdom. The mineral is a hydrated sulfate of potassium, calcium and magnesium with the formula of $K_2Ca_2Mg(SO_4)_4{\cdot}2H_2O$ (Tiwari *et al.,* 2015). The declared minimum analysis of polyhalite for S, K, Mg and Ca is 48% sulfur trioxide, 14% potassium oxide, 6% magnesium oxide and 17% calcium oxide, respectively. After mining, the material is treated to produce different granule sizes. Polyhalite is mined 1200 m below the Earth's surface, in the North Sea, along the northeastern coast of the UK, and haslower environmental impacts than other fertilizers (Rajan Bhatt *et al.,* 2021). The key benefits of polyhalite are that it is fully soluble in all nutrients, available in granular, mini granular and standard grades, prolonged release of nutrients, is environmentally friendly, has a low carbon footprint and is also ideal for chloride-sensitive crops. Polyhalite releases nutrients moreslowly than traditional fertilizers (Vale, 2016). Another advantage of polyhalite is that it is a fertilizer that may be used in organic farming because it naturally occurs in minerals.

Sugarcane soils become less fertile and cannot provide bigger yields due to the severe depletion of soil nutrients.Nutrient replenishment by adding fertilizers to the soil is essential for producing higher cane yields moving forward. Because of this, the present study was initiated to evaluate polyhalite as a multi-nutrient source for sugarcane in Tamil Nadu and assess the juice quality of sugarcanevar. Co 11015 by changing the potassium source from muriate of potash (MOP) to polyhalite.

MATERIALS AND METHODS

An experiment was conducted to assess the effect of polyhalite and MOP on the juice quality of sugarcane (var. Co 11015) at a farmer's field, Arachalur, Erode district, Tamil Nadu during 2021-22 (Fig.1).The experimental soil texture was sandy loam (Typic Ustropepts) belonging to the order Inceptisol. The experiment was laid out in a randomized block design with three replications and ten treatments.

The treatments in the experiment consisted of T_1 – RDF (N, P alone) - control, T_2 - RDF (N, P alone) + 50% K as MOP, T_3 - RDF (N, P alone) + 100% K as MOP, T_4 - RDF (N, P alone) + 100% K as Polyhalite, T_5 - RDF (N, P alone) + 100% K (1:1 ratio of Polyhalite and MOP), T_6 - RDF (N, P alone) + 100% K (1:3 ratio of Polyhalite and MOP), T_7 - RDF (N, P alone) + 150% K as MOP, T_8 - RDF (N, P alone) + 150% K as Polyhalite, T_9 - RDF (N, P alone) + 150% K (1:1 ratio of Polyhalite and MOP), T_{10} - RDF (N, P alone) + 150% K (1:3ratio of Polyhalite and MOP). The 100% recommended dose of nitrogen (275 kg ha^{-1}), phosphorus (62.5 kg ha^{-1}) and 50, 100 and 150% of potassium (56.5, 113 and 169.5 kg ha^{-1}, respectively) were applied as per the treatment schedule (Table 1).

Ten randomly selected sugarcane stalks were harvested from each experimental plot at harvest. The juice was extracted using a power-driven cane-crusher which was analyzed for quality following standard methods.

Brix (per cent)

Brix was determined using a Schmidt + Haensch Refractometer - ATR SW (Meade and Chen, 1977).

Sucrose or Pol (per cent)

To estimate the sucrose content of cane juice, 100 ml of cane juice was taken in a conical flask, to which one gram of dry lead acetate was added followed by vigorous stirring. The impurities from cane juice were filtered off using Whatman No. 42 filter paper. The clearfiltrate cane juice was taken in a 20 cm polarimeter tube and pol reading was recorded with the help of a Schmidt + Haensch polarimeter as described by Spencer and Meade (1955).

Fig.1. *Experimental farm located at Arachalur, Erode district, Tamil Nadu, India (11^{0}09'46.6" N Latitude, 77^{0}42'19.9" E Longitude)*

Table 1. Detailed description of fertilizer treatments

Treatment details	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})		Total K_2O (kg ha^{-1})
			MOP	Polyhalite	
T_1- K=0	275	62.5	-	-	-
T_2- 50%K (MOP)	275	62.5	56.5	-	56.5
T_3- 100%K (MOP)	275	62.5	113	-	113
T_4- 100%K (Polyhalite)	275	62.5	-	113	113
T_5- 100%K (1:1 ratio of Polyhalite & MOP)	275	62.5	56.5	56.5	113
T_6 -100%K (1:3 ratio of Polyhalite & MOP)	275	62.5	84.75	28.25	113
T_7-150%K (MOP)	275	62.5	169.5	-	169.5
T_8- 150%K (Polyhalite)	275	62.5	-	169.5	169.5
T_9- 150%K (1:1 ratio of Polyhalite & MOP)	275	62.5	84.75	84.75	169.5
T_{10}-150%K (1:3 ratio of Polyhalite & MOP)	275	62.5	127.125	42.375	169.5

Purity co-efficient (per cent)

It is the ratio of pol per cent of cane juice to the corrected degrees brix and the values were computed as per the following formula.

$$\text{Purity coefficient \%} = \frac{\text{Pol per cent of juice}}{\text{Brix per cent of juice}} \text{X } 100 \qquad (1)$$

Commercial cane sugar (per cent)

The percentage of commercial cane sugar (CCS%) content was calculated using the equation:

CCS (%) = [Sucrose % − (Brix % − Sucrose %) × 0.4] × 0.73 ` (2)

Reducing sugar (per cent)

Reducing sugar was estimated using the Lane and Eynon (original) method using Fehling A and Fehling B solutions.

Fibre (%)

Fibre % of the cane was calculated by using the following formula:

Fibre % = Dry weight of the washed shredded cane (g)/ Fresh weight of the shredded cane (g) X 100 (3)

Juice extraction (%)

A power-driven cane-crusher crushed the sample of five canes after recording their fresh weight to estimate juice extraction %. The weight of juice was recorded and the juice extraction % was worked out as:

Juice extraction (%) = Weight of juice (kg)/ Weight of cane (kg) X 100 (4)

Juice pH

Determining sugarcane juice pH was done through the potentiometric method (electrodes are used to measure the H^+ ion concentration of the sugarcane juice).

RESULTS AND DISCUSSION

Brix (%)

The application of different potassium levels (50, 100 and 150%) and sources (muriate of potash and polyhalite) significantly improved the brix per cent or TSS of sugarcane juice (Table 2). Brix per cent varied from 20.50 to 23.55%. The highest brix (23.55%) was recorded in treatment T_8 (150% K through polyhalite), while the lowest brix (20.50%) was found in treatment T_1 (without potassium). Applying 150% potassium increased the brix percentage by 100% and 50%. Concerning two potassium sources, polyhalite positively performed than muriate of potash. Among the two ratios of polyhalite and MOP, the 1:1 ratio enhanced the brix per cent more than 1:3. This improvement is mainly due to the application of polyhalite, which supplies four major nutrients (potassium, sulphur, calcium and magnesium). Gomathi and Thandapani (2005) reported that potassium improved sugar synthesis in sugar-

Table 2. Influence of different levels of polyhalite and muriate of potash on brix, pol, purity and CCS percentage of sugarcane juice (plant crop)

Treatments	Brix (%)	Pol (%)	Purity (%)	CCS (%)
T_1-RDF (N, P alone) + K=0	20.50	15.58	76.00	9.94
T_2- RDF (N, P alone) + 50%K (MOP)	20.94	16.22	77.46	10.46
T_3- RDF (N, P alone) + 100%K (MOP)	21.35	16.81	78.74	10.95
T_4- RDF (N, P alone) + 100%K (Polyhalite)	22.14	18.01	81.35	11.94
T_5- RDF (N, P alone) + 100%K (1:1 ratio of polyhalite & MOP)	21.75	17.43	80.14	11.46
T_6 - RDF (N, P alone) + 100%K (1:3 ratio of polyhalite & MOP)	21.36	16.82	78.75	10.95
T_7- RDF (N, P alone) + 150%K (MOP)	22.56	18.61	82.49	12.43
T_8- RDF (N, P alone) + 150%K (Polyhalite)	23.55	20.03	85.05	13.59
T_9- RDF (N, P alone) + 150%K (1:1 ratio of polyhalite & MOP)	23.06	19.32	83.78	13.01
T_{10}- RDF (N, P alone) + 150%K (1:3 ratio of polyhalite & MOP)	22.57	18.63	82.54	12.45
Sed	0.18	0.26	0.54	0.21
C.D. (P=0.05)	0. 38	0.55	1.13	0.44

cane by regulating the activities of various enzymes and by efficiently transporting sugars to sink organs. The sulphur from polyhalite also plays a significant role in improving juice quality. The sulphur is mainly involved in the plant's metabolism and is also required for amino acids, proteins and photosynthesis (Asha and Bose, 2021).

Pol (%)

Data from Table 2 shows that the polyhalite and MOP application significantly responded to sugarcane juice's pol per cent or sucrose. Pol cent varied from 15.58 to 20.03%. The application of 150% potassium as polyhalite recorded the maximum pol per cent (20.03%), followed by 150% potassium as a 1:1 ratio of polyhalite and MOP. The increased potassium level through polyhalite improved the pol per cent of sugarcane juice. The increased levels of potassium (150%) through polyhalite significantly responded. Potassium plays an important role in the moisture economy of the plant and the translocation and storage of sucrose. Ruth Rhodesa*et al.*(2018) stated that the application of potassium, in addition to sulphur, calcium and magnesium, plays an important role in the stimulation of phloem transport of sugars, which enhances the pol per cent of cane juice. Pereira *et al.* (2017) stated that the higher value of pol% indicated more mature sugarcane.

Purity co-efficient(%)

Different potassium sources and levels significantly influenced the purity per cent of cane juice (Table 2). Among all the treatments, the highest value of purity per cent in juice (85.05%) was found in the T_8 treatment (150% K as polyhalite).The treatments next in order were T_9 (150% K as 1:1 ratio of polyhalite and MOP), T_{10}(150% K as 1:3 ratio of polyhalite and MOP), T_7(150% K as MOP), T_4(100% K as polyhalite), T_5 (100% K as 1:1 ratio of polyhalite and MOP), T_6(100% K as 1:3 ratio of polyhalite and MOP), T_3(100% K asMOP), T_2(50% K asMOP) and T_1(without potassium-control). The lowest value (76.00%) was recorded in the control treatment, which received the recommended dose of nitrogen and phosphorus alone. The higher results were obtained in the T_8treatments that received polyhalite alone, which supplied 150% potassium. The increased purity per cent maybe because the polyhalite as a source of potassium fertilizer improved the efficiency of water and nitrogen use of the sugarcane roots, thus improving stomatal opening (Quampah *et al.,* 2011).

Commercial cane sugar (CCS) (%)

Commercial cane sugar percentage differed considerably due to various potassium application levels and sources (Table 2). Among the treatments experimented with, the highest CCS% (13.59) was recorded in the treatment T_8 (RDF (NP alone) + 150% K as polyhalite), which was followed by treatments $T_9$and T_{10}. The treatment T_{10} did not significantly differ from T_7. This was followed by treatments T_4, T_5, T_6, T_3, andT_2 in order.The treatment T_6 did not significantly differ from T_3. The least CCS% (9.94)was recorded in cane juice at harvest under the treatment T_1 (Control). From the results, 150% potassium increased the CCS% more than 100% and 50% of potassium, and polyhalite significantly improved the quality than muriate of potash. Concerning the ratio of polyhalite and MOP, 1:1 ratio increased the CCS% by 1:3. The results indicated that CCS% is governed by brix and pol percentage.According to Ashraf *et al.* (2009),applying K fertilizers through polyhalite to potassium-deficient soil may improve sucrose recovery by increasing the pol per cent and brix per cent.

Reducing sugar (%)

The various treatment combinations applied to sugarcane cropssignificantly influenced the reduction of sugars in sugarcane juice (Table 3). Reducing sugars in cane juice ranged from 0.47 to 0.59%. In plant crops,

Table 3. Influence of different levels of polyhalite and muriate of potash on reducing sugar, fibre, extraction percentage and pH of sugarcane (plant crop)

Treatments	Reducing sugar (%)	Fibre (%)	Extraction (%)	pH
T_1-RDF (N, P alone) + K=0	0.59	16.80	42.55	5.72
T_2- RDF (N, P alone) + 50% K (MOP)	0.57	16.18	44.23	5.70
T_3- RDF (N, P alone) + 100% K (MOP)	0.54	15.81	45.94	5.72
T_4- RDF (N, P alone) + 100% K (Polyhalite)	0.52	14.90	49.41	5.75
T_5- RDF (N, P alone) + 100% K (1:1 ratio of Polyhalite & MOP)	0.53	15.27	47.65	5.74
T_6 - RDF (N, P alone) + 100% K (1:3 ratio of Polyhalite & MOP)	0.54	15.66	45.99	5.71
T_7- RDF (N, P alone) + 150% K (MOP)	0.49	14.46	51.15	5.78
T_8- RDF (N, P alone) + 150% K (Polyhalite)	0.47	13.63	54.88	5.77
T_9- RDF (N, P alone) + 150% K (1:1 ratio of polyhalite & MOP)	0.48	14.01	53.07	5.79
T_{10}- RDF (N, P alone) + 150% K (1:3 ratio of polyhalite & MOP)	0.49	14.42	51.18	5.76
Sed	0.01	0.16	0.76	0.08
C.D. (P=0.05)	0.02	0.35	1.61	NS

the treatment T_8 produced the lowest reducing sugar concentration (0.47%), followed by T_9. The highest significant reducing sugars concentration (0.59%) was recorded in T_1 treatment. Among the two potassium sources (MOP and polyhalite), polyhalite performed well than MOP. The data concerning 1:1 and 1:3 ratios of polyhalite and MOP, the 1:1 ratio recorded minimum reducing sugar concentration. The lowest percentage of reducing sugar might be due to potassium and other secondary nutrients from polyhalite. The application of potassium aids in photosynthesis, the mechanism by which the carbohydrates and energy required for plant growth are generated and transformed. According to Rajan Bhatt (2022), potassium is the third macronutrient that plays important roles*, viz.,* transport glucose from leaves to the whole plant. The highest value of reducing sugar in the treatment T_1 might be due to a deficiency of potassium, sulphur, calcium and magnesium, which cause immature sugarcane and negatively influence reducing sugars in cane juice (Pereira *et al.,* 2017).

Fibre (%)

The fibre per cent was significantly influenced by the application of potassium through MOP and polyhalite in different levels and ratios is presented in Table 3. Among the two different potassium fertilizer (polyhalite and MOP) treatments, T_1 (control) gave the highest concentration of fibre per cent (16.80) Furthermore, the lowest fibre per cent (13.63) was recorded on the treatment T_8 (150% K as Polyhalite). This might be attributed to the application of polyhalite acting as a multi-nutrient source, which reduces the fibre per cent of sugarcane. The decreasing levels of potassium and sulphur, but in the presence of nitrogen and phosphorus, enhanced the fibre per cent of sugarcane. These were in agreement with the findings of Bokhtiar *et al.* (2008).

Extraction (%)

The juice extraction percentage from sugarcane is presented in Table 3. A significant influence on extraction percentage was noticed due to polyhalite as a source of potassium. Among the treatments tested, the treatment T_8 (150% K as Polyhalite) significantly excelled over other treatments with the highest extraction percentage (54.88%). This was followed by T_9(150%K (1:1 ratio of polyhalite and MOP)) and T_{10}(150%K (1:3 ratio of polyhalite and MOP)) with a value of 53.07% and 51.18%, respectively. The lowest extraction percentage of 42.55% was recorded in the treatment T_1 (Control). Among the different levels, 150% of potassium application through polyhalite responded better than 100 and 50%. Adding K increased extraction percentage and improved juice quality and extraction percentage in sugarcane, which could berelated to their effects on enzyme activities. Ashraf *et al.* (2009) stated that potassium regulated the activities of invertase, peroxidase, polyphenol oxidase, phosphatase and adenosine triphosphatase in sugarcane. Reducing phosphatase activity provided a greater supply of essential high-energy precursors needed for optimum cane growth and sugar production.

Juice pH

The pH of cane juice did not differ significantly among the different treatments at harvest in plant crops (Table 3). However, the pH of cane juice ranged from 5.70 to 5.79.

Conclusion

Polyhalite significantly performed well as a fertilizer for sugarcane var. Co 11015 (Atulya) as it enhanced the juice quality parameters more than the performance of MOP. Application of 150% potassium (169.5 kg K_2O ha^{-1}) through polyhalite in addition to the recommended dose of nitrogen (275 kg ha^{-1}) and phosphorus (62.5 kg ha^{-1}) (T_8) recorded a significant result on quality attributes of sugarcane var. Co 11015 in Inceptisols. Thus, the application of potassium as a polyhalite fertilizer was beneficial in enhancing the quality of sugarcane juice.

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Conflict of interest

The authors declare that they have no conflict of interest.

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