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Corresponding Author
R. Gobinath
e-mail: gnathatr@gmail.com

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Potassium Derived from Molasses (PDM)–A Potassium-Rich Nutrient Gold for Agriculture

R. Gobinath[1*], S. Vijayakumar[1], V. Manasa[1], K. Basavaraj[1], G. Jesudas[1], S. Suvana[2] and P. Kumaresan[3]

Abstract

Molasses, a byproduct of sugar extraction from sugarcane, contains various minerals, including potassium. When molasses is processed, it can be used to produce potassium fertilizers. The extraction process involves dissolving molasses, isolating potassium through chemical reactions, and purifying it to meet agricultural standards. This potassium can then be formulated into fertilizers suitable for various crops. Potassium derived from molasses (PDM) is used as an alternate supplement to synthetic chemical fertilizer for potassium nutrients and the use of PDM will not degrade the environment and enrich the soil with organic inputs. Because of it's organic origin, PDM could be inducted into a package of practices in organic farming to sustain soil health in the long run. This approach improves soil health, increases crop yields, and supports environmentally conscious farming practices.

1. Introduction

Plant growth depends on the nutrient supply from soil and the external application through organic and inorganic fertilizers. Plants receive essential nutrients like NPKS and other micronutrients through nutrient supplements in stipulated intervals. Globally, potassium (K) fertilizer demand is increasing daily to support food production for the mushrooming population. This demand is compensated by potassic fertilizer, which is an import-bound supply and would be sustained for a few more decades. Potassium (K) is an essential nutrient element for plant growth and plays a vital role in various metabolic activities such as the synthesis of starch, cellulose, proteins, and vitamins, as well as the activation of cellular enzymes. Additionally, K enhances other nutrients like nitrogen (N) and phosphorus (P) use efficiency and contributes to resistance against biotic and abiotic stresses. Moreover, it improves the quality of agricultural produce (Brady and Weil, 2013). Despite

Author's Address

[1]ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana (500 030), India
[2]ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, Telangana (500 059), India
[3]Department of Agronomy, Tamilnadu Agricultural University, Coimbatore, Tamil Nadu (641 003), India

its critical importance, K fertilization through synthetic fertilizer remains insufficient in Indian agriculture.

2. Fertilizer Deposits and Consumption in India

Potash, an impure combination of potassium carbonate and potassium (K) salts, serves as an important fertilizer in Indian Agriculture. It is one of the three primary agricultural nutrients (N-P-K). The principal ore for potash is sylvinite, which consists of sylvite (KCl) and halite (NaCl). In India, potash mineral deposits are found in Sidhi district (Madhya Pradesh), Sonbhadra district (Uttar Pradesh), Kaimur district (Bihar), and Sawai Madhopur & Karauli districts (Rajasthan). These deposits typically occur in the form of glauconitic sandstone—a potassium-bearing green mica due to their toposequence, differentiation in soil development and water movement (Srinivasan *et al* 2022). Despite domestic deposits, the majority of India's potash requirement is met through imports. Glauconitic sandstones and greensands deposits serve as an indigenous alternative resource for potash. Glauconite, a complex hydrous silicate of iron and potassium, contains approximately 4–7% K_2O.

Balancing the ongoing food demand while maintaining soil health is a challenging task in agriculture, especially nutrient inputs eg. K. Implementing the right K management strategy is crucial to sustain K availability and enhance crop production. Adhering to the 4R Nutrient Stewardship Principles—selecting the Right Sources of K, applying it at the Right Rate, at the Right Time, and in the Right Place—is essential for effective K utilization in Indian agriculture (Manasa et al, 2020). Furthermore, inadequate K availability in soils directly impacts human nutrition and health (Surekha et al, 2023). To address the issues of shortage of K sources, volatility in the K fertilizer market forcing us to spend more on K fertilizer import and supply to agriculture can be reduced by using unexplored K sources like PDM (Potassium derived molasses) from wastes of sugar industry may support the K fertilizer demand internally for a longer period to attain the self-sufficiency in K fertilizer industry (Gobinath et al, 2021; Vijayakumar et al, 2021). This PDM product is generally a by-product of sugar industries and considered as waste; if we could utilize this product effectively, dependence on K import may be reduced.

The adoption of high-yielding crop varieties during the 1960s played a pivotal role in boosting fertilizer usage. The production of nitrogen and phosphate nutrients rose from 1.8 MT in 1975/76 to 14.2 MT (in terms of K_2O) by 2003/04. Notably, India heavily relies on imported potash fertilizers due to the absence of domestic natural resources. In 2003/04, imports reached 2.6 MT K_2O, a significant increase compared to the 0.4 MT observed in the mid-1970s. Numerous studies have shown that the annual uptake of potassium (K) is comparable to or even surpasses that of nitrogen (N). However, the replenishment of K in the soil does not match that of N. In the years 1970–71, the usage of N and K fertilizers was recorded at 14.87 lakh tonnes and 2.28 lakh tonnes, respectively, which increased significantly to 176.28 lakh tonnes for N and 27.79 lakh tonnes for K by 2018–19. The hectare^{-1} application of K also rose from 7.2 kg ha^{-1} in 1990–91 to 14.1 kg ha^{-1} in 2018–19, although it was higher at 18 kg ha^{-1} in 2010–11 (Figure 1). When comparing the use of N and K in agriculture from 1970–71 to 2018–19, it's evident that the total consumption of these fertilizers escalated by 11.85 times for N and 12.18 times for K.

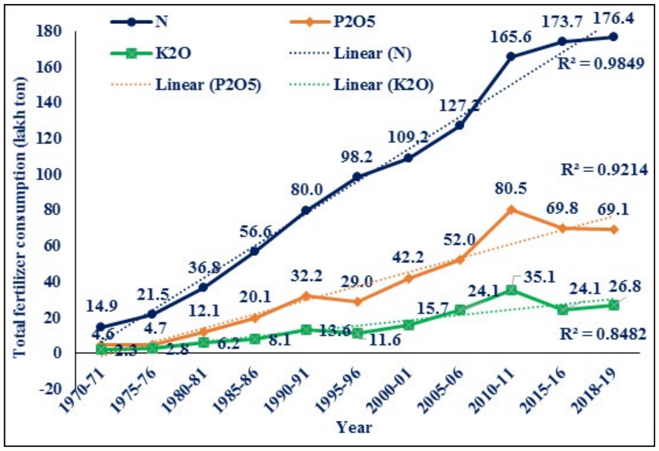

Figure 1: Total fertilizer consumption in India from 1970–71 to 2018–19 (Vijayakumar et al., 2024)

Challenges related to K management include the removal of K by crops, losses due to leaching in coarse-textured soils, and soil erosion. Unfortunately, less than 10% of the K removed from the soil is adequately replaced by fertilizer K and other inputs. Applying less than the required amount of fertilizer K can lead to unbalanced fertilization and significant depletion of soil K reserves, ultimately affecting soil fertility and crop production. While one application of fertilizer K to crops is generally sufficient to meet their requirements, coarse-textured soils with low cation exchange capacity (CEC) may necessitate two or three split doses. However, it's essential to base fertilizer K application rates on the actual K requirements of the crop, rather than relying solely on optimal rates of fertilizer N

The inherent capacity of the K-supplying power of soil depends on the presence of K-bearing minerals. The K-bearing minerals, supplying the power of K vary between 2.4–21.4% in soil (Table 1). Similarly, chemical-origin K fertilizers also majorly supply potassium to the plants (Table 2).

Table 1: K-bearing silicate minerals present in soils and their K_2O%

K bearing minerals	Chemical composition	K_2O (%)
Leucite	$KAl(SiO_3)_2$	21.4
Orthoclase	$KAlSi_3O_8$	16.8
Anorthoclase	NA K $AlSi_3O_8$	2.4–12.1
Microcline	$KAlSi_3O$	16.8
Muscovite	$(H,K)Al_3SiO_4)_3$	11.8
Biotite	$H1KAl_3SiO_4)_3$	6.2–10.1
Phlogopite	$(HKMGF)_3$ $(Mg_3Al\ (SiO_4)_2)$	7.8–10.4

Table 2: Major K fertilizers in the market

Fertilizers	Chemical formula	K_2O
Potassium chloride	KCl	60%
Potassium sulfate	K_2SO_4	50%
Potassium magnesium sulfate	$K_2SO_4.2MgSO_4$	20%
Potassium thiosulfate	$K_2S_2O_3$	17%
Potassium nitrate	KNO_3	44%

3. Waste to Wealth

PDM, a potassium-rich fertilizer derived from ash in molasses-based distilleries is a by-product of sugar sugar-based ethanol industry (Table 3). These distilleries

Table 3: Chemical composition of molasses in comparison with FYM

Properties	FYM	Spent Wash/Molasses
pH	7.5	3.8–4.5
OM (%)	21.7	31.5 (solid basis)
Total N (%)	1.44	2.0
Total P (%)	0.83	0.28
Total K (%)	0.79	9.96
C: N ratio	15.1	15.7

produce a waste chemical called spent wash during the production of ethanol which is burnt in an Incineration Boiler (IB) generating Ash to achieve Zero Liquid Discharge (ZLD). The potash-rich ash can be processed to produce PDM having 14.5% potash content and can be used by farmers in the field as an alternative to MOP (Muriate of Potash with 60% potash content). Regular utilization of PDM could reduce the dependency on foreign countries for potash fertilizers and decrease expenditure on foreign exchange for fertilizer imports. Potash, typically imported in the form of MoP, could thus be significantly substituted by domestically sourced sugar cane molasses. The production of molasses has been steadily increasing each year, reaching an impressive 13,280 thousand tons during the 2018–19 period (Table 4).

Potash derived from molasses (PDM) fertilizer is gaining recognition as a sustainable and environmentally friendly alternative to traditional potash fertilizers. It has key benefits such as,

• **Environmental sustainability:** PDM fertilizer utilizes molasses, a byproduct of the sugar industry, as a source of potassium. This reduces reliance on mined potassium chloride or potassium sulfate, which can have significant environmental impacts due to mining practices.

• **Renewable source:** Molasses, being a byproduct of sugar production, is renewable and typically abundant in regions where sugar crops are grown. This makes PDM a more sustainable choice compared to finite mineral sources of potash.

• **Improved crop yields and quality:** Potassium is essential for plant growth and development, playing a crucial role in various physiological processes such as enzyme activation, osmoregulation, and nutrient transport. PDM provides plants with readily available potassium, thereby enhancing crop yields and improving the quality of agricultural produce.

• **Reduced environmental footprint:** By utilizing molasses to produce potash, PDM contributes to reducing the environmental footprint associated with traditional potash fertilizers. This includes minimizing energy-intensive mining activities, transportation emissions, and the disturbance of natural landscapes.

• **Promotes circular economy:** PDM exemplifies a circular economy approach by repurposing a waste product (molasses) into a valuable resource (potash fertilizer). This closed-loop system reduces waste and enhances resource efficiency in agricultural practices.

Table 4: Molasses production in India (State-wise) (in million tonnes)

States	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23
Andhra Pradesh	480	323	282	288	202	237	269	146	111	117	114
Bihar	291	335	273	249	285	381	400	319	243	262	372
Gujarat	494	482	524	542	408	510	498	402	479	573	443
Haryana	261	282	282	248	320	403	347	339	361	401	413
Karnataka	1501	1686	2056	1779	1001	1633	1894	1567	2056	2967	2880
Kerala & Goa	5	6	6	5	3	4	3	-	-	-	-
MP	115	192	219	187	193	277	285	222	290	319	292
MH	2926	2730	3855	3197	1585	4128	4125	2341	4897	6566	5039
Punjab	221	223	254	292	306	385	335	223	275	311	328
Rajasthan	3	3	4	6	7	4	6	5	6	4	8
TN	1059	782	722	761	589	406	551	454	474	665	722
Telangana	-	149	141	121	53	112	120	65	57	107	103
UP	8344	6988	7348	6078	7776	10750	9536	10506	10938	11254	11782
Uttarakhand	179	153	164	131	164	189	167	173	173	200	232
Others	37	42	26	28	22	19	20	17	15	17	15
Total	11744	10882	12482	10873	9026	14063	13788	11526	14906	18136	16852

The extraction of PDM from Molasses is given in detail here:

✓ **Heating the molasses:** The first step is to heat the molasses to a high temperature, typically between 150 and 200 degrees Celsius. This evaporates the water in the molasses and leaves behind a concentrated solution of potassium salts.

✓ **Cooling and filtering the solution:** The concentrated solution is then cooled to a lower temperature, which causes the potassium salts to crystallize. The solution is then filtered to remove any impurities that may be present.

✓ **Crystallizing the potassium salts:** The crystallized potassium salts are then separated from the liquid solution. This can be done by centrifugation or by allowing the solution to cool and settle.

✓ **Drying and grinding the crystals:** The crystallized potassium salts are then dried and ground into a powder. This is the finished fertilizer product.

The use of PDM significantly enhanced the soil's levels of available potassium (K), multiplying them by two to three times compared to the original soil test values. This boost occurred despite the nutrients taken up by the crops, likely due to the effluent's rich P and K content (Kayalvizhi et al., 2001). The application of molasses and organic fertilizer increases Soil Organic Carbon, nitrogen, potassium and yield of leafy vegetables and also reduces the soil pH Moreover, it not only increased the K content in the topsoil but also ensured that these elevated levels persisted beyond the harvest of the first ratoon in the sugarcane crop. Consequently, it provides essential nutrients for the current crop and simultaneously enhances and preserves soil fertility for the next crop.

3.1. Benefits

• **Inclusion of PDM in the Nutrient Based Subsidy (NBS) Scheme** – may make an effective way to use this waste as fertilizer inputs to promote crop production in India and generate monetary benefit to the farmers. The Indian Government is offering a fair amount of facilitated mutually agreed price of Potassium Derived from Molasses (PDM) @Rs. 4263 mt^{-1} for sale by sugar mills to fertilizer companies for the current year. In addition, PDM Manufacturers can also claim a subsidy at Rs. 345 ton^{-1} at present rates under the Nutrients Based Subsidy Scheme (NBS) of the Department of Fertilizers. Now, both, sugar mills and fertilizer companies are discussing modalities to enter into long-term sale/purchase agreements on PDM.

• Presently about 5 lakh tonnes of Potash ash generated from ethanol distilleries is being sold domestically, whereas the potential to produce this ash could reach up to 10–12 lakh tonnes (Anonymous, 2023).

• Manufacturing and sale of PDM is going to be another revenue stream for sugar mills to add to their cash flows and also to make payments to farmers on time. It is another initiative of the central government to reduce import dependence in the fertilizer sector.

• Production of PDM domestically will reduce import dependency and will make India Atmanirbhar (Self-reliant) in production of PDM. Presently about 5 LMT of Potash Ash generated from ethanol distilleries is being sold domestically whereas the potential to produce this Ash could reach up to 10–12 LMT.

4. Conclusion

The use of eco-friendly PDM and conversion of sugar industry waste into nutrient-rich material plays an important role in reducing the K fertilizer import. It is Necessary to raise awareness and scientific outputs to support the use of PDM in agriculture for self-sufficient agriculture. Manufacturers and research institutes should make a plan for wide demonstrations and promote the use of PDM across the tier of agricultural production and include it in the organic cultivation practices.

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