PROM: SUSTAINABLE AGRICULTURE THROUGH ORGANIC PHOSPHATE ENRICHMENT

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The historical trajectory of phosphate fertilizers from the pioneering production of Single Super Phosphate (SSP) at the Rothamsted Experimental Station in 1840 to the contemporary dominance of Di Ammonium Phosphate (DAP) underscores the evolving landscape of agricultural practices. Today, DAP reigns supreme among chemical phosphate fertilizers, with global production and consumption primarily centered around it, along with Mono Ammonium Phosphate (MAP) and SSP. To ensure accessibility to Indian farmers, the Government of India factually subsidized DAP, MAP, and SSP. However, subsidies have skyrocketed, reaching Rs. 28.72 per kg for the 2024 kharif season, compared to Rs. 20.82 per kg in the 2023 rabi season. Despite heavy subsidies, the cost of a 50 kg bag of DAP has risen to around Rs.1350, up from Rs. 956 in 2012. Farmers continue to purchase DAP, MAP, and SSP, influenced by established marketing efforts and the lack of alternative products, even at higher costs and through black market channels.

It has long been recognized that up to 60-70% of the phosphorus (P) applied through chemical phosphatic fertilizers, including DAP, is wasted. This wastage occurs due to various factors such as fixation by soil ions like Al, Fe, Mn in acidic soils, or Ca, Mg in alkaline soils, a phenomenon termed "Phosphate Fixation" (Ranjha et al. 2023). Moreover, DAP's efficacy is compromised in saline soils, and it faces criticism for its imbalanced P:N ratio, leading to the need for urea application to fulfil nitrogen requirements. Additionally, identifying P deficiency in crops is more challenging compared to N and K deficiencies. Typically, phosphorus deficiency appears as stunted growth in plants, during the early stages of development. For annual crops, detecting a visual deficiency may come too late for effective correction. Low phosphorus levels often result in abnormal discoloration, such as a dark bluish-green hue in crops like maize, accompanied by purple leaves and stems (Ranjha et al. 2022).

The excessive and imbalanced use of chemical fertilizers has detrimental effects on soil health, diminishing agricultural output (Ananthakrishnan and Backiyavathy, 2020). Despite government subsidies, the fertilizer industry has not made significant strides in reducing production costs of DAP or developing alternatives of comparable efficiency. However, Phosphate Rich Organic Manure (PROM) emerges as a promising solution, offering comparable efficacy to synthetic fertilizers while mitigating environmental concerns. There are promising reports indicating that combining rock phosphate mineral with farmyard manure could offer comparable effectiveness to DAP.

Additionally, observations show that farmyard manure (FYM) enriched with high-grade rock phosphate (with a P_2O_5 content of +34%) in fine size (d80 at 23 microns) displays superior agronomic performance compared to DAP when applied with equal P_2O_5 amounts basis. By harnessing natural biochemical processes, PROM transforms insoluble phosphates into soluble forms, facilitating optimal nutrient uptake by plants. Integration of organic materials like vermicompost and anaerobic digestor sludge not only enhances soil fertility but also promotes soil health through improved soil structure, nutrient exchange capacity, and water retention. These findings underscore the potential of alternative methods to address agricultural needs effectively.

PHOSPHATE RICH ORGANIC MANURE

PROM's remarkable efficacy lies in its ability to harness the natural processes of biochemical conversion, transforming insoluble phosphates found in rock phosphate into soluble forms that plants can readily assimilate. This innovative approach not only ensures efficient nutrient delivery to crops but also offers comparable residual effects, benefiting subsequent crops. Vermicompost, produced through recycling plant or animal waste with the aid of earthworms, is one of the highly recommended sources of organic material for PROM production. Additionally, anaerobic digestor sludge (ADS), a byproduct of biogas manufacturing from different organic sources like animal wastes (e.g., cow dung, poultry litter) or plant residues (e.g., garden debris, agricultural residues), stands out as another valuable input. Moreover, ADS offers the advantage of being a cost-effective byproduct, further enhancing the economic feasibility of PROM production. Adoption of PROM technology marks a significant milestone in Indian agriculture, underscored by its incorporation into the Fertilizer Control Order (FCO), 1985, as of June 22, 2012. This recognition, endorsed by the Department of fertilizers under the Ministry of Chemicals & Fertilizers, Government of India, signifies a strategic shift towards sustainable fertilization practices aimed at promoting soil health and agricultural productivity.

PRODUCTION OF PROM

PROM is derived through the biochemical conversion of phosphate rock into soluble phosphates. By utilizing raw phosphate rock ore as the starting material, PROM production maintains consistency in its source. Despite its relatively slow process, PROM production does not necessitate high pressures or temperatures. Moreover, there is no requirement for chemical catalysts, and valuable chemicals like sulfuric acid are not consumed during the process. Production of PROM is significantly more economical compared to synthetic phosphatic fertilizers such as SSP, MAP, and DAP. This cost-effectiveness arises from the elimination of the entire manufacturing cost allied with producing phosphoric acid or elemental phosphorus from phosphate rock.

STEPS OF PRODUCTION PROCESS

Various steps involved in the production processes of PROM (Figure 1) are as follows.

Feedstock: Pulverized refined phosphate rock (free from silica), with a uniform size of around 75 microns, is blended with well-ground FYM or vermicompost or Anaerobic Digestor sludge (ADS) in a 1:2 ratio. Average particle size of the blend is >1 mm. Vermicompost undergoes drying, pulverization in a hammer mill, and blending with pulverized rock phosphate ore. Whereas, ADS is collected from a biogas generator employing anaerobic digestion of animal wastes (e.g., cow dung, poultry litter). The discharged slurry is de-watered, dried, finely ground in a ball mill, and mixed with rock phosphate ore as per the specified ratio. Both the ore and organic manure are screened through standard sieves to ensure uniformity of size.

Substrate: The above blend is suspended in water in an aqueous suspension, maintaining a water to solids ratio of 7:3. Small amounts of salt petre and gypsum are added to address nutrient deficiencies and promote bacterial growth.

Bioreactor: The process takes place in a slurry reactor in two stages: First stage includes continuous addition of substrate slurry into bioreactor, agitated, and allowed to ferment for 7 - 10 days (thermophillic stage). The pH remains around 7.0, and the temperature is kept constant, seldom exceeding 60°C. During second stage (optional), an inoculum of nitrogen-fixing microbes, such as *Azotobacter,* is added, and the bioreactor is allowed to ferment for an additional 5 - 10 days.

The optimum conditions maintained in bioreactor are:

- Optimum operating temperature: 30°C - 35°C
- Maximum operating temperature: 60°C
- Optimum pH: 7.0; Operating pressure: 1 atm
- Oxygen level: 10-18%
- Microbial culture: *Bacillus megatherium* var *phosphaticum* (phosphorus solubilizing bacteria)
- Size of inoculum: 3% - 5%

Downstream Processing*:* The product solution is filtered to separate solid biofertilizer, which is then dried, ground, labeled, and packaged. PROM contains 16.5% phosphorus (as soluble P_2O_5) and has a C:N ratio <20:1. It can be directly used in agricultural fields. As the nature of biochemical processes is slow, a large residence time for the bioreactor is required. For a given capacity, it is recommended to use 2-3 bioreactors with parallel feeding of substrate slurry.

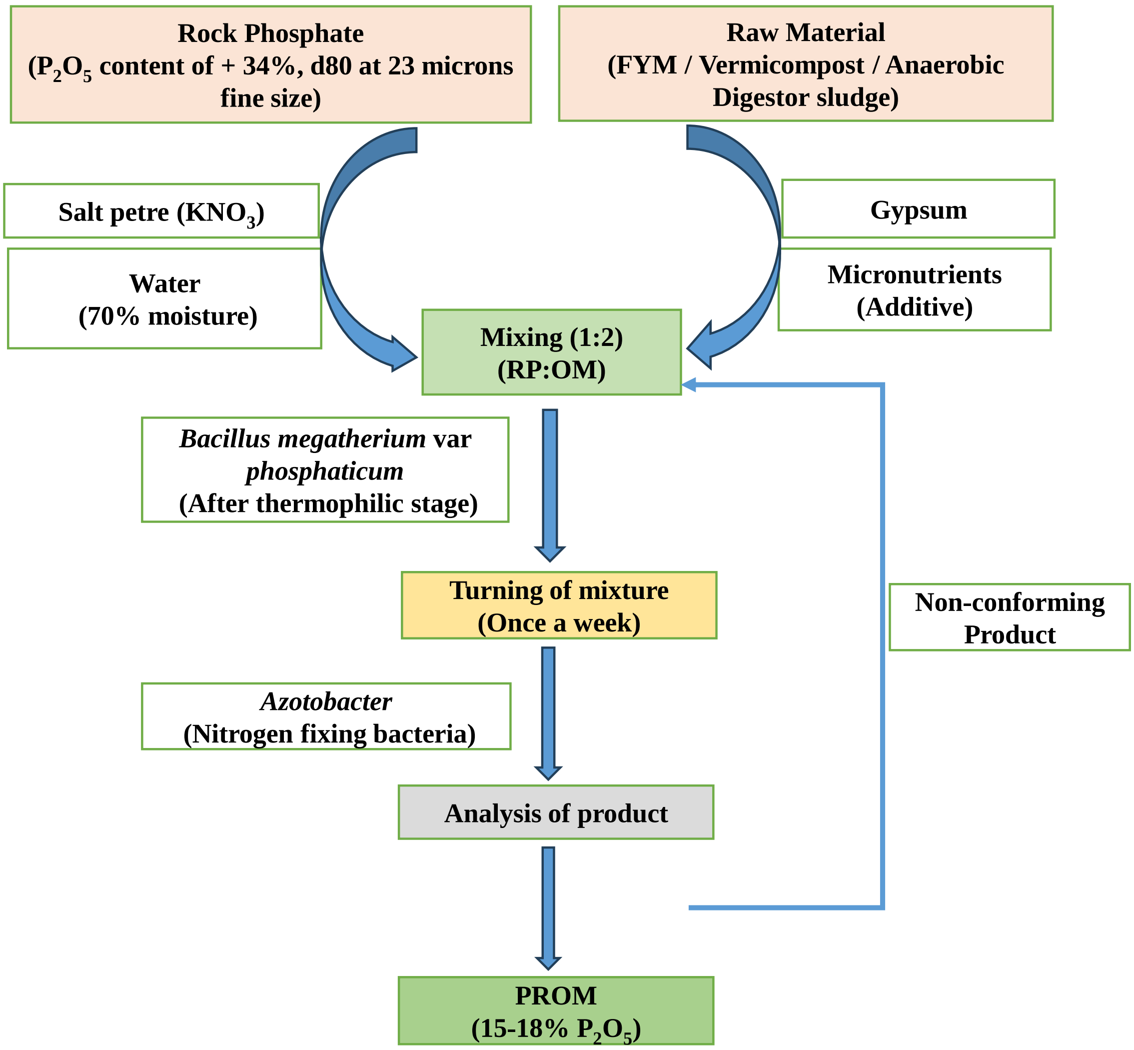

Figure 1. Flow chart of production of PROM

IMPORTANCE OF PROM IN AGRICULTURE

PROM has proven to be readily absorbed by plants and can be directly applied to the field. It exhibits equal effectiveness in both acidic and alkaline soils. Extensive field trials have shown that PROM performs comparably to, and often better than, synthetic fertilizers such as SSP, DAP, or MAP with respect to yield of crops, legumes, and vegetables. Additionally, experiments conducted with flowering plants (such as roses and sunflowers) and orchard products (such as mangoes, apples, and lemons) have yielded equally promising results (Narayanan, 2012). Sekhar et al, 2008 reported that PROM is very effective as phosphatic fertilizer even in saline soils where DAP completely failed. Application of PROM enriches the soil with organic matter, providing a more balanced nutrient supply to plants compared to inorganic fertilizers. This stimulates the soil flora and fauna, leading to an increased soil biological activity. Organic matter contributes to the plant growth in multiple ways, including improving soil structure, promoting soil aggregation, and increasing water retention, enhancing the exchange capacity of nutrients, mobilizing nutrients, acting as a buffer against soil alkalinity, acidity, salinity, heavy metals, and pesticides (Mihir and Jagadeesh, 2016; Noor et al, 2020).

CONCLUSION

The rising costs and environmental concerns related with synthetic fertilizers like DAP underscore the need for their sustainable alternatives. PROM emerges as a promising solution, offering comparable efficacy to synthetic fertilizers while promoting soil health and environmental sustainability. With its cost-effectiveness, reduced environmental impact, and proven efficacy across diverse soil conditions, PROM represents a significant advancement in agricultural sustainability. Embracing PROM signifies a commitment to fostering resilient and environmentally responsible agricultural practices for a sustainable future.

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