



Replacing chemical fertilizers with organic alternatives: A comparison of performance of Phosphate Rich Organic Manure and Di Ammonium Phosphate on mustard

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Abstract

Combining rock phosphate with natural organics facilitates the release of phosphorus (P) from the mineral in a form that is easily available to plants. Replacing chemical fertilizers with such organic alternative is expected to improve soil organic matter content and increase agricultural soil sustainability. Phosphorus release rate from rock phosphate in presence of organic matter containing tobacco waste is observed to be better than or at par with that due to activity of P solubilizing bacteria. A field experiment was conducted to study the production and nutrient cluster of Indian mustard influenced by the organic source of P - Phosphate Rich Organic Manure (PROM) and the chemical fertilizer Diammonium Phosphate (DAP). Phosphorous release rate from rock phosphate by bacterial activity is compared with that by organic acids present in tobacco to see higher release of P by the later. Results indicated clear possibility for partially replacing chemical phosphatic fertilizers with organic alternatives. Using rock phosphate composted with organic manure turns out to be an excellent alternative for chemical phosphatic fertilizers. Higher yield parameters are obtained with PROM and DAP in combination as P source for mustard crop. A combination of PROM as source of 66% of P requirement and DAP as source of the rest of the P requirement gave best results in the efficacy studies, indicating possibilities in replacement of chemical fertilizers with organic alternatives and hence reducing consumption of rock phosphate mineral for production of chemical fertilizers.

Keywords: DAP, mustard, organic alternatives, PROM, soil organic matter

Introduction

In the 21st century, intensive farming has boosted agricultural efficiency but caused environmental degradation, as excessive fertilizer and pesticide use harms agro-ecosystem health and its capacity to provide goods and services (Pimental *et al.*, 2009). Runoff and leaching of nutrients and toxic chemicals are increasingly contaminating water sources, causing eutrophication and reducing soil quality (Khan *et al.*, 2018). Damaging farming methods and poor management are hurting soil health and cutting harvests, so more and more farmers are choosing organic fertilizers to keep their land fertile and increase yields (Benabise *et al.*, 2012). Phosphorus is a crucial nutrient for plants, forming part of their DNA and RNA (Elser, 2012) and powering life processes through energy molecules like ATP and ADP, which drive photosynthesis and respiration (Raghothama, 2005). It is also one of the main nutrients that can limit plant growth if not available in enough quantity (Noor *et al.*, 2020). The most commonly used synthetic phosphatic fertilizers are DAP and single super phosphate (SSP). For the past

two decades, an alternative organic fertilizer named Phosphate Rich Organic Manure (PROM) has become a part of organic farming and is presenting an opportunity to replace the synthetic chemical fertilizers. PROM consists primarily of high-grade rock phosphate in a fine form combined with well-matured organic manure (Mihir *et al.*, 2016). It is produced by co-composting high-grade rock phosphate in fine size with organic matter sourced from farmyard manure (FYM), paddy or wheat straw, press mud, oil cakes, and waste from fruit industries and distilleries. Phosphate-solubilizing bacteria (PSB) and nitrogen-fixing bacteria are added to enhance efficiency (Narayanan, 2012). This study shows that using a combination of chemical fertilizer and organic manure can boost Indian mustard yields while keeping soil and the environment healthier.

Materials and Methods

DAP and PROM

DAP is produced by reacting phosphoric and sulphuric acids (from phosphate rock) with ammonia to form a slurry, which is granulated, dried, cooled, screened, and

packaged. Despite its high quality, only about 30% of its water soluble phosphorus is available to plants as losses occur through leaching, runoff, or fixation by metals. Phosphorus availability is highest in soils with a pH of 5.5 to 7 (Sekhar *et al.*, 2008). PROM is an organic fertilizer produced by mixing and granulation. The raw materials used in the production of PROM are organic materials sourced from plants and manure. Green waste from farms, tobacco waste, sugar process waste materials etc. are rich in organic carbon and nitrogen. These materials can prove to be an excellent fertilizer when composted properly. Finley ground rock phosphate having 18-32% P₂O₅ content is mixed with the organic material and allowed to compost for a period of 45-60 days. Phosphorous solubilizing bacteria are optionally added to get the phosphorus from the rock phosphate. The blending of these raw materials was done in a way to get at least 8% P₂O₅, 8% organic carbon and 0.4 % nitrogen in the final product. The production of PROM granules

involves blending raw materials, granulating the mix using a binder, and then drying the granules to reduce moisture below 25%. After drying, the granules are cooled, screened to ensure uniform size, and finally packaged. In this study, Sardar brand DAP and PROM by Gujarat State Fertilizers and Chemicals Limited (GSFC) was used. The process ensures consistent quality suitable for agricultural use.

Climate and soil

The field experiment was conducted at the GSFC, AGRO Research Farm, Fertilizer Nagar, Vadodara, Gujarat (22.377_N latitude and 73.140_E longitude). The field area is located in the subtropical region of Gujarat, India. This region experiences a monsoon season from June to September, with average precipitation ranging from 500 to 800 mm. The subtropical climate in this region is characterized by hot and humid conditions with heavy downpours during the *kharif* season. In contrast, the *rabi* season has lower precipitation and relatively cool

Table 1: The characteristics of the soil before crop

OC %	P ₂ O ₅ (kg /acre)	K ₂ O (kg /acre)	pH(1:2)	EC(1:2)	S (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
1.08	8	19	7.27	0.21	8.44	0.39	3.69	2.16	1.01

temperatures. The characteristics of the soil before crop sowing are given in Table 1.

Crop management

The field experiment has been carried out from the month of October 2022 to March 2023 to ensure the dose optimization of PROM and DAP for growing of mustard crop. The seeds and compound fertilizer (N & P) for mustard crop were purchased from APMC, market of Vadodara. Mustard variety (cv. Sai Prabha) was sown in the experiment. The experiment was laid out in a Randomized Block Design (RBD) consisting of nine treatments with four replications & plot size was 3.0 m × 4.0 m.

The crop was sown on 1st Oct 2022 and harvested on 28th Jan 2023. Phosphorus (25 kg/acre) and nitrogen (7 kg/acre) fertilizers were applied at the time of sowing and remaining nitrogen (7 kg/acre) was applied before first irrigation in the respective plots. During growing period, four irrigations were given to the crop. The plant height, number of primary branches, siliquae per plant, siliqua length (cm), seeds per siliqua, test weight (g), seed yield (kg/ha), harvest index (%), nutrient concentration (%) in seed and stover were recorded during the experiment from the respective plot following standard procedures and expressed in standard units. Statistical analysis of the recorded data was carried out using analysis of variance technique for randomized block design (Gomez *et al.*, 1984).

Table 2: Treatment details of the experiment

Treatments	Symbols used
Absolute control	T ₁
100% P (50% PROM and 50% DAP) + Remaining N through urea	T ₂
100% P (66% PROM and 34% DAP) + Remaining N through urea	T ₃
100% P (66% DAP and 34% PROM) + Remaining N through urea	T ₄
100% RDF (DAP + Urea)	T ₅
100% RDF (PROM + Urea)	T ₆
100% P through PROM only	T ₇
100% P through DAP only	T ₈
161.08 gm PROM only (equivalent to DAP dose)	T ₉

Results and Discussion

The study was focused on the effects of PROM and DAP fertilizer, both applied at the time of sowing as a basal dose in mustard. Treatments as shown in tables 4 and 5, the impacts of using 66% phosphorus-rich organic manure combined with 34% DAP and the remaining nitrogen through urea fertilizer significantly influenced all yield parameters.

Release of P from rock phosphate in PROM

Phosphorus release from PROM is achieved by solubilizing P present in the rock phosphate. It is generally achieved owing to the formation of organic acids like formic acid, malic acid, glutamic acid *etc.* during bacterial digestion of the organic materials. These acids dissolve rock phosphate. A general expectation is by using another organic material with contents of these organic acids could achieve similar results. Tobacco is known to have organic acids in considerable quantity (Leffingwel, 1999). The P dissolution rate using phosphorus solubilizing bacteria and that using tobacco were estimated in the laboratory experiments. In a first experiment, rock phosphate sample containing 30% P_2O_5 was made to

interact with tobacco waste containing ~2 % nicotine (Fig 1). The proportion of 60g tobacco waste in 120g rock phosphate is taken to be representative to the raw material composition used in production of PROM. In the second set, 0.8 ml phosphorus solubilizing bacteria (10^8 CFU) is made to interact with 120g rock phosphate containing 30% P_2O_5 . The P_2O_5 release from the mixture is monitored on a weekly basis (Table 3). The data shows that release rate of P from rock phosphate in contact with nicotine is higher than that from the rock phosphate being interacted by phosphate solubilizing bacteria.

A fundamental mechanism of phosphate solubilization is by reducing the soil pH. The organic acids released by phosphorous solubilizing microorganisms (such as *Bacillus* and *Pseudomonas*; Zaidi *et al.*, 2009) or other organic sources like tobacco act as chelating agents, binding to metal ions in the soil and forming soluble complexes. This process leads to soil acidification, resulting in the development of a more acidic environment. Top of Form

The decline in pH is particularly advantageous because it transforms less soluble phosphate forms into more

Table 3: Phosphorus emission via the utilization of nicotine and bacteria in the presence of rock phosphate

Date	Release of P_2O_5 from Rock Phosphate (%)		
	Blank	with Nicotine	with Bacteria
13/01/2023	0	0.073	0
20/01/2023	0	0.092	0
27/01/2023	0	0.109	0.007
03/02/2023	0	0.079	0.0072
10/02/2023	0	0.063	0.0072
17/02/2023	0	0.071	0.008
24/02/2023	0	0.07	0.0081
03/03/2023	0	0.068	0.0081
10/03/2023	0	0.072	0.0081
17/03/2023	0	0.073	0.0088

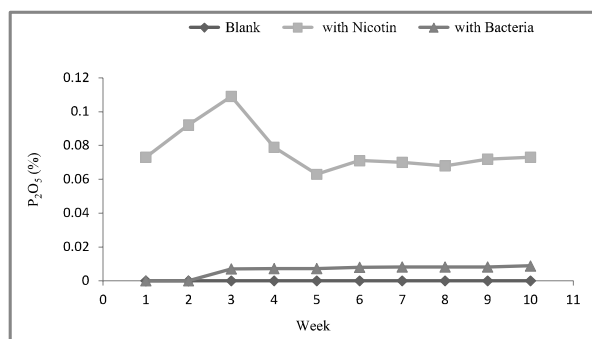


Fig. 1: Phosphorus (P_2O_5) dissolution through the use of nicotine and bacteria from rock phosphate

soluble monovalent phosphate forms, such as $H_2PO_4^-$ and HPO_4^{2-} , which are easily absorbed by plants. The conversion of insoluble phosphate forms into soluble forms renders phosphorus more accessible to plant roots, fostering improved growth, development, and yield.

Growth parameters

The phosphate nutrient sources PROM and DAP were subjected to a field study in the farm and data has been recorded as per international standards (Abdulla Mohammed *et al.*, 2019). Data regarding Growth parameters *viz.*, Plant height (cm) and number of primary branches/ plant are mentioned in Table 4.

Table 4: Influence of different level of PROM and DAP on growth parameters of mustard

Treatment	Plant height (cm)			Primary branch/ plant (no.)
	30 DAS	60 DAS	At Harvest	
T ₁	15.54	125.35	146.35	3.45
T ₂	17.18	145.60	160.15	3.40
T ₃	19.66	150.55	165.40	3.60
T ₄	18.92	139.60	160.05	3.60
T ₅	20.66	144.20	159.70	3.85
T ₆	18.10	142.55	164.75	3.50
T ₇	18.94	138.35	153.25	3.10
T ₈	20.19	147.10	164.15	3.55
T ₉	17.63	140.60	150.25	3.20
Avg	18.54	141.54	158.23	3.47
LSD (p=0.05)	2.56	8.35	8.20	NS
SEm±	0.87	2.84	2.79	0.19
CV	9.42	4.02	3.53	11.00

*DAS – Day after sowing

The highest plant height (165.40 cm) at harvesting stage of mustard was observed from treatment T₃, followed by treatment T₆. The least height (146.45 cm) was observed in T₁. At 30 DAS, T₇ (18.94 cm) shows slightly better plant height than T₆ (18.10 cm) due to PROM's slow-release phosphorus supporting early root growth. At 60 DAS, T₆ (142.55 cm) outperforms T₇ (138.35 cm) as urea supplies nitrogen for vegetative growth. By the harvest stage, T₆ (164.75 cm) significantly exceeds T₇ (153.25 cm). Among the treatments, the maximum numbers of primary branches per plant (3.85) before harvest were recorded in treatment T₅ followed by treatment T₃. The favorable effect on plant height might be due to the greater number of branches,

which is associated with high photosynthetic accumulation. This improvement in growth parameters can be attributed to a better soil environment with an effective nutrient management system. The synergy of PROM and urea balances phosphorus supply with fast-acting nitrogen, ensuring sustained growth. PROM alone supports initial growth but lacks sufficient nitrogen for later stages. The beneficial effects may have arisen from the combined application of essential macronutrients, micronutrients, and organic matter, which satisfied the immediate nutrient requirements and created a favorable soil environment for improved plant growth. The results obtained from this experiment closely align with the

Table 5: Evaluation of the effect of PROM and DAP on yield parameters of mustard

Treatment	SL(cm)	Siliqua/plant (no.)	Seeds/siliqua (no.)	TW (g)	BY(kg/12 m ²)	SY (kg/12 m ²)	HI (%)
T ₁	4.36	193.20	11.05	3.67	2.158	0.315	15.30
T ₂	4.84	243.35	12.60	3.99	3.185	0.847	26.77
T ₃	4.88	245.65	12.85	4.10	3.556	0.873	24.82
T ₄	5.03	220.75	12.45	3.80	3.031	0.602	20.00
T ₅	4.78	244.70	12.40	4.00	3.330	0.720	21.72
T ₆	4.61	241.70	12.65	3.81	3.250	0.659	20.50
T ₇	4.62	199.45	11.65	3.86	2.393	0.560	25.40
T ₈	4.94	203.40	12.65	3.96	2.974	0.642	21.77
T ₉	4.69	213.90	11.40	3.73	2.541	0.567	22.92
Avg	4.75	222.90	12.19	3.88	2.94	0.64	22.13
LSD (p=0.05)	0.32	37.92	1.20	0.25	0.48	0.13	5.43
SEm±	0.11	12.92	0.41	0.09	0.16	0.04	1.85
CV	4.57	11.31	6.69	4.43	11.08	13.22	16.71

SL- siliqua length, TW- test weight, g- gram, BY- biological yield, SY- seed yield, HI- harvest Index, CD- critical difference, CV- coefficient of variation

findings of (Gajjela Indira *et al.*, 2021; Khaswanet *et al.*, 2016, Shehzad *et al.*, 2023).

Data regarding yield parameters *viz.*, siliqua length, number of siliqua/plant, number of seeds/siliqua, test weight Seed yield, biological yield and harvest index is mentioned in Table 5.

Yield and yield attributes

“The siliqua length, siliqua per plant and seeds/siliqua are important yield components of mustard, which are affected by the application of PROM and DAP”. The maximum siliqua length (5.03 cm) was recorded under treatment T₄ and followed by treatment T₃. Among the treatments, number of siliqua/plant (245.65) was recorded under T₃ and followed by treatment T₅. Maximum number of seeds per siliqua (12.85) was recorded under treatment T₃ and followed by treatment T₆ seeds per siliqua (12.65), suggesting that slow-release phosphorus from PROM supports seed development over time, while T₅ (12.40) followed closely, indicating that immediate phosphorus supply also aids seed formation. Treatment T₁, recorded the least number of seeds per siliqua (11.04), likely due to phosphorus deficiency during the critical seed-filling period. The application of phosphorus rich organic manure can have a positive effect on the siliqua length, number of siliqua per plant and number of seeds/siliqua. A higher proportion of PROM ensures a steady supply of phosphorus, which is crucial for seed development, resulting in better productivity. However, it is important to note that the exact effect may depend on several factors such as the type and amount of PROM and DAP’s dose, soil properties, and environmental conditions.

The maximum test weight of mustard seeds (4.10 g) was recorded under treatment T₃ and followed by treatment T₅. Test weight reflects the seed quality, which improves with sustained nutrient supply provided by PROM. This study investigated the effect of PROM on test weight parameters of mustard crops. Here are some references to relevant studies, in a study conducted by (Kumar *et al.*, 2017) in India, the effect of different sources of phosphorus, including organic manure, on the growth and yield of mustard was investigated. The results showed that the application of organic manure significantly increased the test weight of mustard compared to inorganic sources of phosphorus. Overall, these studies suggest that the application of phosphorus-rich organic manure can significantly improve the test weight parameters of mustard crops. However, the specific effect may depend on the type and quality of organic manure, as well as the soil conditions and climate in which the crops are grown. PROM has a positive effect on the

biological yield parameters of the mustard crop. The maximum mustard biological yield (3.556 kg/12 m² plot) was recorded under treatment T₃ and followed by treatment T₂. Biomass yield was significantly higher in T₅ (3.330 kg), reflecting the benefits of rapid nutrient availability on overall plant growth, while T₆ (3.250 kg) followed closely, demonstrating that the combination can also support robust growth, albeit with a slight lag in nutrient release timing. PROM contributes to sustained nutrient release, supporting seed development and higher seed yield and biological yield. Several studies have demonstrated the beneficial effect of organic manure containing high levels of phosphorus on mustard yield. Similar results were also reported by Bairwa *et al.*, 2021, in India, indicating that the application of PROM significantly increased the biological yield of mustard crop compared to chemical fertilizers.

Moreover, the maximum mustard seed yield (0.873 kg/12 m² plot) was recorded under treatment T₃ and followed by treatment T₂. In a study conducted by (Kumar *et al.*, 2018) and (Kumar *et al.*, 2019), was found that the application of PROM along with DAP significantly increased the yield and quality parameters of mustard. The highest seed yield and oil content were recorded in the treatment that received both organic manure and DAP. The application of PROM and DAP had a significant effect on the yield and quality parameters of mustard crop (Purohit *et al.*, 2020). The highest seed yield were obtained in the treatment that received both organic manure and DAP. Similarly, the maximum harvest index (26.77%) was recorded under treatment T₂ and followed by treatment T₇. The harvest index reflects the proportion of economic yield (seed) relative to the total biomass. A higher proportion of PROM indicates a better balance between vegetative and reproductive growth. The application of PROM and DAP fertilizers can increase the availability of essential nutrients, enhance photosynthesis, and can improve reproductive growth in mustard which attributed to an increase in harvest index.

Nutrient concentration

The treatment, T₃ have a non-significant impact on the total nitrogen (% w/w) content both in terms of the seed and stover of mustard but significant effect was present on P₂O₅ (% w/w) and K₂O (% w/w) content as compared to T₄. Treatments that combined DAP with PROM (like T₂, T₃, and T₆) showed better overall nutrient balance in both seed and stover, indicating that a combination of slow-release and immediate release phosphorus sources may improve nutrient efficiency for both vegetative growth and seed development. These treatments performed well in both phosphorus and potassium

Table 6: Nutrient concentration in mustard seed and stover as influenced by different treatments

Treatment	Nutrient concentration in seed (%)			Nutrient concentration in stover (%)		
	N	P	K	N	P	K
T ₁	3.680	0.653	5.517	0.535	0.229	0.934
T ₂	3.550	0.784	5.730	0.607	0.246	1.020
T ₃	3.730	0.831	7.970	0.523	0.250	0.994
T ₄	3.640	0.665	7.463	0.513	0.227	0.917
T ₅	3.730	0.605	5.413	0.613	0.227	0.927
T ₆	3.493	0.686	7.347	0.548	0.224	0.971
T ₇	3.703	0.709	6.350	0.566	0.212	0.903
T ₈	3.253	0.823	5.920	0.558	0.215	0.840
T ₉	3.447	0.649	8.483	0.498	0.218	0.815
T ₁	3.581	0.712	6.688	0.55	0.23	0.92
Total	32.229	6.405	60.193	4.96	2.05	8.32
CD	NS	0.126	0.906	NS	NS	NS
SE(m)	0.169	0.042	0.300	0.03	0.01	0.05
CV	8.169	10.106	7.760	11.52	11.26	10.22

concentrations. PROM consistently enhanced potassium concentrations in seeds and stover, suggesting that it is a valuable component for improving potassium uptake. The slow-release nature of PROM allows for sustained potassium availability, especially under stress conditions. Similarly, in a study conducted by Kumar *et al.*, (2019), the effect of different fertilizers on the nutrient content of mustard stover was evaluated. The study found that the application of PROM significantly increased the levels of nitrogen, phosphorus, and potassium in mustard stover, which can improve its quality as a livestock feed. The study also found that DAP improved the nutrient content of mustard stover, although its impact was more limited compared to PROM (Table 6).

Conclusion

Organic fertilizers containing organic sources of carbon and other nutrients are known to be improving soil properties and usability for agriculture on long term. Microbial activity in the soil increases with increased organic matter. On the other hand, inorganic chemical fertilizers leaving residues in the soil even after crop cycle may lead to soil deterioration for agricultural purposes. Hence, replacing chemical fertilizers with organic fertilizers without compromising yield is a requirement. One such alternative is PROM against chemical phosphatic fertilizers like DAP. The efficacy trials show that using PROM has considerable impact in increasing harvest index. Combined application of phosphate-rich organic manure and DAP as phosphorus source for mustard improves yield and quality. This approach boosts yield and overall crop quality, making it a sustainable and effective agricultural practice. The enhanced yield can

be achieved by a combination of 66% PROM and 34% DAP. The results obtained from application of this combination is higher than that from the application of DAP only as P source. Considering the high consumption of rock phosphate in production of DAP as compared to that required for production of PROM, combined application of PROM and DAP is expected to lead to considerable reduction in consumption of rock phosphate around the world.

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