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Nutrient release pattern of organo-mineral fertilizers in Southern laterites of Kerala

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Abstract
The study was conducted at the Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, during Rabi 2023-2024. It focused on formulating two organo-mineral fertilizers (OMF 1 and OMF 2) suited for Sesamum and evaluating its nutrient release patterns. The experiment utilized a completely randomized block design with four treatments and four replications for each treatment. The treatments were:- T_1 (100% recommended dose of nutrients (RDN) as OMF 1), T_2 (100% RDN as OMF 2), T_3 (100% RDN as per Kerala Agricultural University Package of Practices, and T_4 (Control). At 15 days after incubation (DAI), T_3 (conventional fertilizer) demonstrated significantly higher nutrient release, with 89.99% of applied nitrogen, 80% of phosphorus, and 89.85% of potassium released. In contrast, OMF 1 and OMF 2 exhibited a slower nutrient release, with nitrogen release ranging from 53.18% to 53.22%, phosphorus from 45.65% to 50%, and potassium from 40.40% to 43.23%. At 30 days after incubation, nutrient release remained higher for T_3. However, at 45, 60, 75, and 90 days after incubation, OMF 1 and OMF 2 outperformed T_3, showing a more sustained and gradual release of nutrients over time. This study underscores the potential of organo-mineral fertilizers to provide a controlled and prolonged nutrient supply, enhancing nutrient use efficiency and supporting long-term soil fertility in sesamum cultivation.

Keywords: Organo-mineral fertilizers, Sesamum, incubation studies, nutrient release pattern

Introduction

Efficient nutrient management is essential for optimizing crop yield and productivity. While organic manures improve soil health through slow nutrient release, their low nutrient density and dependence on microbial activity pose challenges for large-scale farming and immediate crop needs. In contrast, chemical fertilizers offer concentrated, readily available nutrients for rapid uptake but can harm soil health and the environment if overused. Sustainable nutrient management, integrating these approaches, is crucial for nutrient-sensitive crops to ensure balanced nutrition, high yield, and long-term soil fertility. Integrating organic manures (OM) with chemical fertilizers (CF) is an effective strategy to improve agronomic efficiency and crop productivity while maintaining soil health (Sahu *et al*., 2017) [7]. This approach has led to the creation of organo-mineral fertilizers (OMFs), which combine the long-term benefits of OM with the quick nutrient availability of CF. OMFs offer a concentrated nutrient composition, enabling reduced application volumes compared to traditional OM, and ensure balanced, controlled nutrient release, minimizing leaching and environmental impact. By incorporating macro- and micronutrients with organic matter, OMFs enhance soil structure, water retention, and microbial activity, addressing the limitations of OM and CF. As a sustainable alternative, OMFs lower reliance on synthetic inputs, promote soil vitality, and support environmentally sustainable farming practices (Sakurada *et al*., 2016; Smith *et al*., 2020) [8, 10]. Although OMF has been proven as a promising technology for sustainable crop production, limited research work has been conducted in Sesamum, which is a highly nutrient responsive, short duration oilseed crop grown in Kerala. Keeping the above in view, the present study was undertaken to formulate organo-mineral fertilizers (OMFs) specifically suited for sesame cultivation and to evaluate their nutrient release patterns.

Materials and Methods

The study was conducted at College of Agriculture, Vellayani during *Rabi* 2023-2024. Organo-mineral fertilizers (OMFs) suited for Sesamum were prepared by mixing organic manures with chemical fertilizers and bio stimulants. The nutrient recommendation of Sesamum is 30:15:30 kg NPK ha-^{1}(ie. recommended NPK ratio of sesamum is 2:1:2). The raw materials were mixed in a proportion such that the final product have a NPK ratio of 2:1:2. Cow dung based organo-mineral fertilizer (OMF 1) was prepared by mixing cow dung powder (30 per cent), neem cake (3 per cent), groundnut cake (3 per cent), urea (16 per cent), rock phosphate (23 per cent), MOP (11 per cent), polyhalite (10 per cent), zinc sulphate (1 per cent), borax (1 per cent), humic acid (1 per cent) and seaweed powder (1 per cent). Rice husk biochar based organo-mineral fertilizer (OMF 2) was prepared by mixing rice husk biochar (15 per cent)), neem cake (6 per cent), groundnut cake (6 per cent), urea (16 per cent), rock phosphate (23 per cent), MOP (11 per cent), polyhalite (15 per cent), zinc sulphate (2 per cent), borax (2 per cent), humic acid (2 per cent) and seaweed powder (2 per cent) on per cent weight basis. After thorough mixing of the components, the two combinations were incubated for 48 hours at room temperature to prepare OMF. OMF 1 had a final NPK content of 6.58 per cent, 3.31 per cent and 6.55 per cent. For OMF 2 it was 6.60 per cent, 3.27 per cent and 6.62 per cent.

The experiment was laid out in completely randomized design (CRD) and the study comprised 4 treatments with four replications for each treatment. Treatment details were as follows; T_1: 100 per cent RD as OMF 1, T_2: 100 per cent RD as OMF 2, T_3: Kerala Agricultural University Package of Practices (KAU POP), T_8: control (no fertilizer application)). For the incubation study, plastic cups of uniform size (10 cm in height, 7 cm in diameter) without drainage holes were filled with 100 g of soil. Initial soil analysis was conducted before the experiment, and the OMF treatments were applied on nitrogen equivalent basis. To prevent direct mixing of materials with the soil, treatments were enclosed in cloth bags. These bags containing treatment combinations were placed at the center of pots filled with soil, followed by adding soil around them. Soil moisture was adjusted to field capacity by adding measured quantity of water, and moisture levels were maintained gravimetrically every day throughout the experiment. Separate pots were designated for destructive sampling at intervals of 15, 30, 45, 60, 75, and 90 days after incubation. The cloth bags were removed from the plastic containers at 15, 30, 45, 60, 75, and 90 days after incubation to investigate the nutrient release pattern. The soil was thoroughly mixed, air-dried in the shade, and analysed for available N, P and K content by following standard analytical procedures. The initial available N, available P and available K content of the soil were 0.097 g kg^{-1} soil, 0.018 g kg^{-1} soil and 0.042 g kg^{-1} soil respectively.

Results and Discussion

Available nitrogen

The available nitrogen showed significant difference during the entire period of incubation study and the data are presented in Table 1. The conventional fertilizer treatment, T_3 (KAU POP) showed significantly higher available nitrogen content (0.582 g kg^{-1} soil) at 15 days after incubation (DAI). The available nitrogen content in OMF 2 (T_2) was 0.411 g kg^{-1} soil which was statistically similar with OMF 1(T_1) (0.392 g kg^{-1} soil). The lowest available nitrogen content was observed in T_4 (control) (0.119 g kg^{-1} soil). At 30 DAI, the treatment T_3 recorded significantly higher available nitrogen content (0.613 g kg^{-1} soil). The available nitrogen content in OMF 2 (T_2) was 0.553 g kg^{-1} soil which was comparable with OMF 1(T_1) (0.522 g kg^{-1} soil). The lowest available nitrogen content was observed in T_4 (control) (0.122 g kg^{-1} soil). At 45 DAI, T_3 recorded higher available nitrogen content (0.639 g kg^{-1} soil) which was comparable with OMF 2 (T_2) (0.611 g kg^{-1} soil). The available nitrogen content in OMF 1 (T_1) was 0.592 g kg^{-1} soil which was on par with T_2. The lowest available nitrogen content was observed in T_4 (control) (0.122 g kg^{-1} soil). At 60 DAI, OMF 2 (T_2) resulted in higher available nitrogen content (0.698 g kg^{-1} soil) which was comparable with OMF 1 (T_1) (0.666 g kg^{-1} soil). Application of recommended dose of nutrients as per KAU POP (T_3) showed available nitrogen content of 0.651 g kg^{-1} soil which was on par with T_1. The lowest available nitrogen content was observed in T_4 (control) (0.126 g kg^{-1} soil). At 75 DAI, OMF 2 (T_2) recorded significantly higher available nitrogen content (0.745 g kg^{-1} soil) followed by T_1 (0.721 g kg^{-1} soil). The lowest available nitrogen content was observed in T_4 (control) (0.131 g kg^{-1} soil). At 90 DAI, OMF 2 (T_2) recorded significantly higher available nitrogen content (0.774 g kg^{-1} soil) followed by T_1 (0.737 g kg^{-1} soil). The lowest available nitrogen content was observed in T_4 (control) (0.135 g kg^{-1} soil).

The absolute nitrogen release over time is shown in Table 2. For the conventional fertilizer treatment (T_3), 86.99 per cent of the total applied nitrogen was released at 15 days after incubation (DAI), whereas OMF 1 (T_1) and OMF 2 (T_2) released only 53.18 per cent and 53.22 per cent of applied nitrogen, respectively, indicating a slower nitrogen release for OMFs compared to conventional fertilizer. At subsequent intervals, nitrogen release from OMF 1 was recorded and it was observed to be 17.63 per cent, 9.49 per cent, 7.46 per cent, and 2.03 per cent at 30, 45, 60, 75, and 90 DAI, respectively. For OMF 2, nitrogen release was 18.21 per cent, 7.49 per cent, 11.36 per cent, 5.94 per cent, and 3.74 per cent at the same intervals. In contrast, the conventional fertilizer treatment showed nitrogen release rates of 4.78 per cent, 3.73 per cent, 1.79 per cent, 2.09 per cent, and 0.59 per cent at 30, 45, 60, 75, and 90 DAI, respectively. This data highlights the sustained, slower nitrogen release profile of OMFs compared to conventional fertilizers. The graphical representation of absolute release of nitrogen is shown in Fig 1.

When organo-mineral fertilizers are applied to soil, they interact with soil particles and organic matter leading to adsorption of nitrogen. This interaction can limit immediate nitrogen availability and promote a gradual release over time (Qudus *et al*., 2021) [6]. The presence of biostimulants in OMFs further modifies the chemical environment, slowing the hydrolysis of urea into ammonia and carbon dioxide. This stabilization helps maintain nitrogen availability over extended periods, reducing the risk of rapid nitrogen loss through volatilization or leaching (Wang *et al*., 2022) [12]. Additionally, organic components like neem cake and groundnut cake contain nitrogen compounds that require microbial decomposition before plants can utilize them. Their slower decomposition rate, compared to inorganic fertilizers, contributes to a more controlled nitrogen release (Hamed *et al*., 2023) [2].

Biochar, a key component of OMF 2, is also reported to significantly enhance nitrogen retention in soils. Studies show that biochar applications reduce nitrogen concentrations in leachate, due to its high cation and anion exchange capacities and its ability to immobilize nitrogen through microbial utilization of labile carbon (Peng *et al*., 2021) [5]. Biochar's high surface area and porous structure facilitate adsorption of nitrogen slowing their release into the soil. These properties allow biochar to hold onto ammonium and nitrate ions, minimizing its leaching. Research has also shown that biochar can notably decrease total dissolved nitrogen in leachate, indicating improved nitrogen retention in soil (Schofield *et al*., 2019) [9]. These factors might have likely contributed to the slower nitrogen release observed in OMF 2 compared to conventional mineral fertilizers.

Table 1. Effect of organo-mineral fertilizers on available nitrogen on incubation, g kg^{-1} soil

Treatment	Available Nitrogen					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T_1 (OMF 1)	0.392	0.522	0.592	0.667	0.722	0.737
T_2 (OMF 2)	0.412	0.553	0.611	0.699	0.745	0.774
T_3 (KAU POP)	0.582	0.614	0.639	0.651	0.665	0.669
T_4 (Control)	0.120	0.122	0.122	0.127	0.132	0.135
SEm (±)	0.014	0.015	0.01	0.012	0.005	0.006
CD (0.05)	0.042	0.047	0.032	0.037	0.016	0.017

DAI- Days after incubation, OMF- organo-mineral fertilizers

Table 2: Absolute release of nitrogen during incubation period, g kg^{-1} soil

Treatment	Absolute Release Rate Of Nitrogen					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T_1 (OMF 1)	0.392	0.13	0.07	0.075	0.055	0.015
T_2 (OMF 2)	0.412	0.141	0.078	0.088	0.046	0.029
T_3 (KAU POP)	0.582	0.032	0.025	0.012	0.014	0.004
T_4 (Control)	0.12	0.002	0	0.005	0.005	0.005

DAI- Days after incubation, OMF- organo-mineral fertilizers

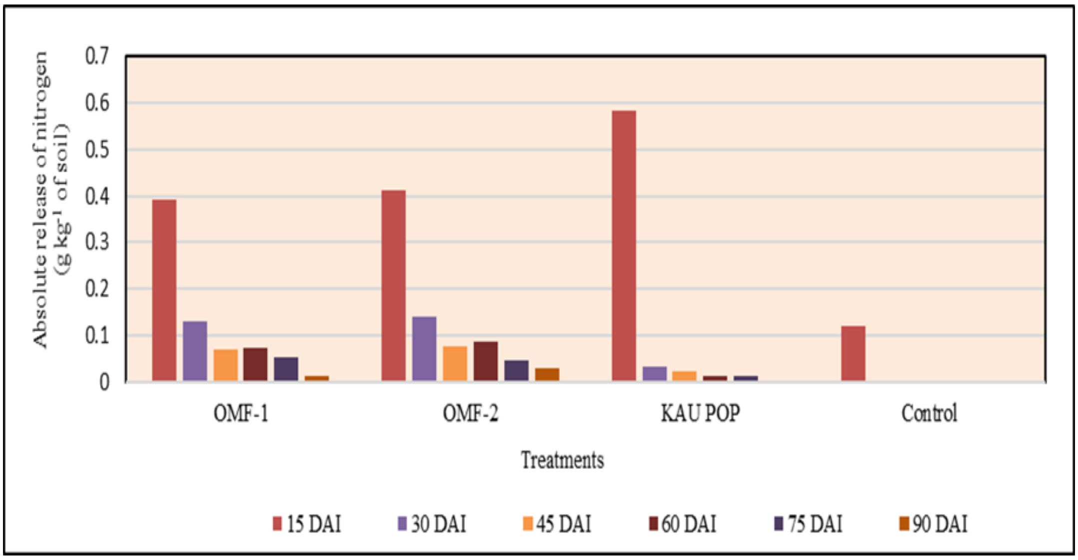

Fig 1: Absolute release of nitrogen during incubation

Available phosphorus

Significant difference was observed in available phosphorus among treatments and the data are presented in Table 3. The conventional fertilizer treatment T_3 (KAU POP) showed significantly higher available phosphorus content (0.032 g kg^{-1} soil) at 15 days after incubation (DAI). The available phosphorus content in OMF 2 (T_2) was 0.024 g kg^{-1} soil which was on par with OMF 1 (T_1) (0.021 g kg^{-1} soil). The lowest available phosphorus content was observed in T_4 (control) (0.012 g kg^{-1} soil). At 30 DAI, T_3 recorded significantly higher available phosphorus content (0.037 g kg^{-1} soil) followed by OMF 2 (T_2) (0.034 g kg^{-1}). The lowest available phosphorus content was observed in T_4 (control) (0.013 g kg^{-1} soil). At 45 DAI, T_3 (KAU POP) and T_2 (OMF 2) recorded higher available phosphorus content (0.038 g kg^{-1} soil) which were statistically comparable. The lowest available phosphorus content was observed in T_4 (control) (0.012 g kg^{-1} soil). At 60 DAI, OMF 2 (T_2) recorded significantly higher available phosphorus content (0.042 g kg^{-1} soil). The available phosphorus content of OMF 1 (T_1) was 0.038 g kg^{-1} soil which was comparable with T_3 (0.037 g kg^{-1} soil). The lowest available phosphorus content was observed in T_4 (control) (0.013 g kg^{-1} soil). At 75 DAI, OMF 2 (T_2) recorded significantly higher available phosphorus content (0.046 g kg^{-1} soil) followed by T_1 (0.043 g kg^{-1} soil). The lowest available phosphorus content was observed in T_4 (control) (0.013 g kg^{-1} soil). At 90 DAI, OMF 2 (T_2) showed higher available phosphorus content (0.048 g kg^{-1} soil) and was on par with T_1 (0.046 g kg^{-1}). The lowest available phosphorus content was observed in T_4 (control), (0.014 g kg^{-1} soil).

The absolute phosphorus release over time is shown in Table. 4. At 15 DAI, the conventional fertilizer treatment released 80 per cent of the applied phosphorus. In contrast, phosphorus release from OMF 1 and OMF 2 was slower. For OMF 1, phosphorus release rates were 45.65 per cent, 19.56 per cent, 6.52 per cent, 10.87 per cent, 10.87 per cent, and 6.52 per cent at 15, 30, 45, 60, 75, and 90 DAI, respectively. For OMF 2, phosphorus release was 50 per cent, 20.83 per cent, 8.33 per cent, 8.33 per cent, 8.33 per cent, and 4.16 per cent at the same intervals. The graphical representation of absolute release of phosphorus is shown in figure 2.

The slower phosphorus release from OMF 1 and OMF 2, compared to conventional fertilizers, can be attributed to several factors. In cow dung-based OMF, phosphorus interacts with organic matter, leading to adsorption and binding that limits its immediate availability in the soil solution. These binding forms stable complexes with organic matter, making phosphorus less accessible for plant uptake (Veprikova *et al.*, 2018) [11]. Additionally, the gradual decomposition of organic matter in cow dung supports a controlled, slow release of nutrients, including phosphorus (Lima *et al.*, 2023) [4]. Research also shows that phosphorus incorporated into biochar often exists in less soluble forms, such as calcium or magnesium phosphates, which limits its immediate availability. Phosphorus bound within biochar is more resistant to leaching, contributing to a prolonged release period. Upon application of biochar-based fertilizers, phosphorus can adsorb onto soil particles or bind further with organic matter, slowing its release into the soil solution. Biochar's porous structure enhances nutrient retention, including phosphorus, leading to a slower release compared to conventional mineral fertilizers (Qudus *et al.*, 2021) [6].

Table 3: Effect of organo-mineral fertilizers on available phosphorus on incubation, g kg^{-1} soil

Treatment	Available Phosphorus					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T1 (OMF 1)	0.021	0.030	0.033	0.038	0.043	0.046
T2 (OMF 2)	0.024	0.034	0.038	0.042	0.046	0.048
T3 (KAU POP)	0.032	0.037	0.038	0.037	0.038	0.040
T4 (Control)	0.012	0.013	0.013	0.014	0.013	0.014
SEm (±)	0.001	0.001	0.001	0.001	0.001	0.001
CD (0.05)	0.004	0.002	0.002	0.002	0.002	0.002

DAI- Days after incubation, OMF- organo-mineral fertilizers

Table 4: Absolute release of phosphorus during incubation period, g kg^{-1} soil

Treatment	Absolute Release Rate of Phosphorus					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T_1 (OMF 1)	0.021	0.009	0.003	0.005	0.005	0.003
T_2 (OMF 2)	0.024	0.01	0.004	0.004	0.004	0.002
T_3 (KAU POP)	0.032	0.005	0.001	0	0	0.002
T_4 (Control)	0.012	0.001	0	0.001	0	0

DAI- Days after incubation, OMF- organo-mineral fertilizers

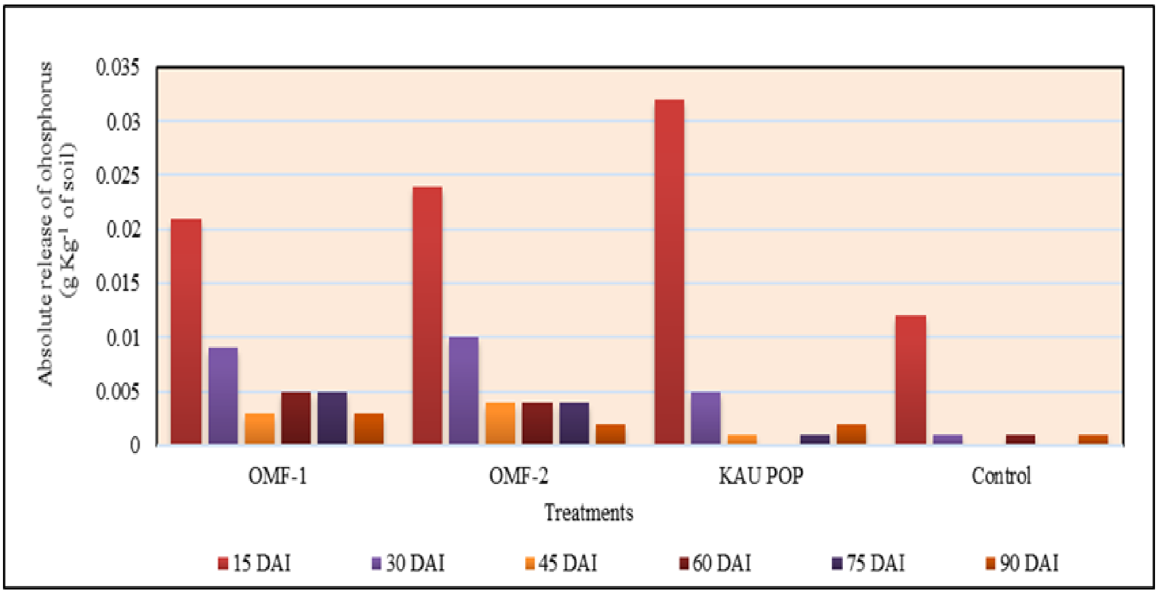

Fig 2: Absolute release of phosphorus during incubation

Available potassium

Significant difference was observed in soil available potassium among treatments during the entire period of study and the data are presented in Table 5. At 15 DAI, T_3 recorded significantly higher available potassium content (0.478 g kg^{-1} soil) followed by T_2 (0.265 g kg^{-1} soil). The lowest available potassium content was observed in T_4 (control) (0.054 g kg^{-1} soil). At 30 DAI, T_3 recorded significantly higher available potassium content (0.509 g kg^{-1} soil) followed by T_2 (0.390 g kg^{-1} soil). The available potassium content in OMF 1 (T_1) was 0.364 g kg^{-1}. The lowest available potassium content was observed in T_4 (control) (0.059 g kg^{-1} soil). At 45 DAI, T_3 showed significantly higher available content (0.517 g kg^{-1} soil) followed by OMF 2 (T_2) (0.466 g kg^{-1} soil). The available potassium content in OMF 1 (T1) was 0.434 g kg^{-1}. The lowest available potassium content was observed in T4 (control) (0.059 g kg^{-1} soil). At 60 DAI, OMF 2 (T_2) showed significantly higher available potassium content (0.532 g kg^{-1} soil). The application of conventional fertilizer (T_3) (KAU POP) resulted in available potassium content of 0.522 g kg^{-1} soil which was on par with OMF 1 (T_1) (0.516 g kg^{-1} soil). The lowest available potassium content was observed in T_4 (control) (0.059 g kg^{-1} soil). At 75 DAI, OMF 2 (T_2) recorded higher available potassium content (0.567 g kg^{-1} soil) which was comparable with OMF 1(T_1) (0.553 g kg^{-1} soil). The available potassium content in T_3 was 0.526 g kg^{-1} soil. The lowest available potassium content was observed in T_4 (control) (0.063 g kg^{-1} soil). At 90 DAI, OMF 2 (T_2) recorded significantly higher available potassium content (0.613 g kg^{-1} soil) followed by T_1 (0.594 g kg^{-1} soil). The available potassium content in T_3 was 0.532 g kg^{-1} soil. The lowest available potassium content was observed in T_4 (control) (0.062 g kg^{-1} soil).

The absolute potassium release over time is shown in Table 6. For the conventional fertilizer treatment, potassium release at 15 days after incubation (DAI) was 89.85 per cent of the applied amount. In contrast, potassium release from OMF 1 was 40.40 per cent, 20.87 per cent, 11.78 per cent, 13.80 per cent, 6.22 per cent, and 6.90 per cent at 15, 30, 45, 60, 75, and 90 DAI, respectively. For OMF 2, potassium release was 43.23 per cent, 20.39 per cent, 12.39 per cent, 10.76 per cent, 5.71 per cent, and 7.5 per cent for the same intervals. The graphical representation of absolute release of potassium is shown in figure 3.

The data demonstrate that potassium release from OMF 1 and OMF 2 were slower compared to conventional mineral fertilizers. The higher cation exchange capacity (CEC) of the organic components in OMFs supports effective potassium ion retention, enabling a gradual release into the soil solution. The porous structure of biochar within the OMFs also provides multiple sites for potassium adsorption, ensuring sustained availability rather than an immediate surge (Li *et al.*, 2022)[3]. Moreover, the inclusion of biostimulants and other additives likely influences the release dynamics by enhancing microbial activity or altering the chemical environment (Chowdury *et al.*, 2024) [1]. This controlled, steady release pattern aligns well with the critical potassium needs of crops, supporting balanced nutrient availability throughout the growth cycle.

Table 5: Effect of organo-mineral fertilizers on available potassium on incubation, g kg^{-1} soil

Treatment	Available Potassium					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T1 (OMF 1)	0.240	0.364	0.434	0.516	0.553	0.594
T2 (OMF 2)	0.265	0.390	0.466	0.532	0.567	0.613
T3 (KAU POP)	0.478	0.509	0.517	0.522	0.526	0.532
T4 (Control)	0.054	0.059	0.059	0.059	0.063	0.062
SEm (±)	0.005	0.002	0.003	0.002	0.005	0.003
CD (0.05)	0.014	0.008	0.009	0.006	0.014	0.009

DAI- Days after incubation, OMF- organo-mineral fertilizers

Table 6: Absolute release of potassium during incubation period, g kg^{-1} soil

Treatment	Absolute Release Rate Of Potassium					
	15 Dai	30 Dai	45 Dai	60 Dai	75 Dai	90 Dai
T_1 (OMF 1)	0.24	0.124	0.07	0.082	0.037	0.041
T_2 (OMF 2)	0.265	0.125	0.076	0.066	0.035	0.046
T_3 (KAU POP)	0.478	0.031	0.008	0.005	0.004	0.006
T_4 (Control)	0.054	0.005	0	0	0.004	0

DAI- Days after incubation, OMF- organo-mineral fertilizers

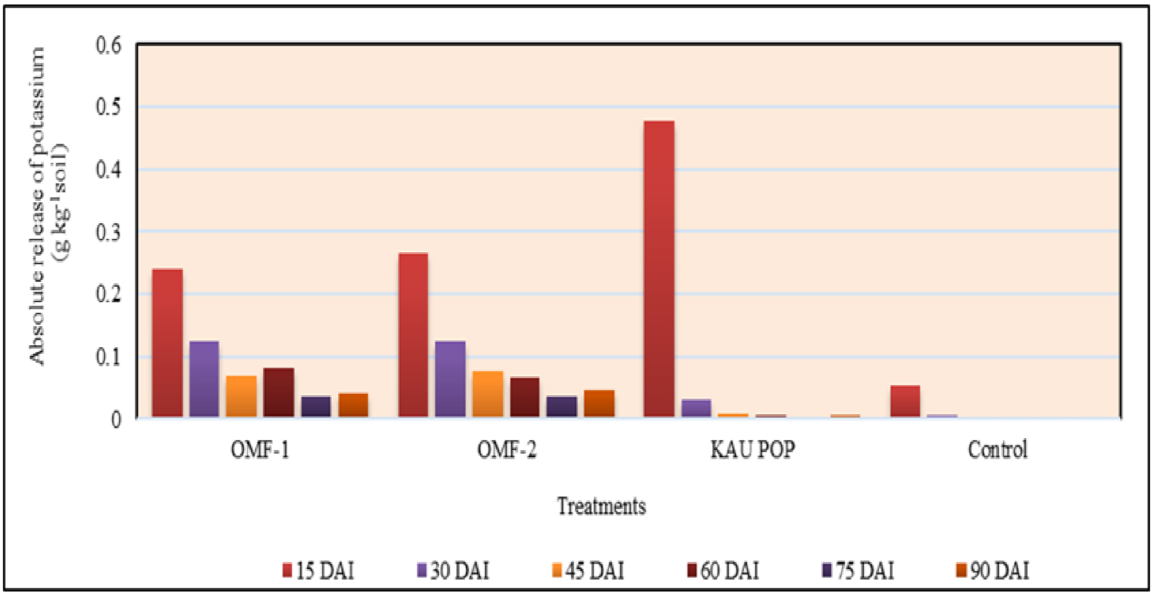

Fig 3: Absolute release of potassium during incubation

Conclusion

The study highlights distinct nutrient release patterns between conventional fertilizers and organo-mineral fertilizers (OMF) over time. At 15 days after incubation, the conventional fertilizer (T3) demonstrated significantly higher nutrient release, with 89.99% nitrogen, 80% phosphorus, and 89.85% potassium released. In contrast, the organo-mineral fertilizers (OMF 1 and OMF 2) exhibited comparatively slower initial nutrient release, with OMF 1 releasing 53.18% nitrogen, 45.65% phosphorus, and 40.40% potassium, and OMF 2 releasing 53.22% nitrogen, 50% phosphorus, and 43.23% potassium. However, over the longer incubation periods (45, 60, 75, and 90 days), OMF 1 and

OMF 2 outperformed the conventional fertilizer in sustaining nutrient release, indicating a more controlled and prolonged nutrient availability. These findings suggest that while conventional fertilizers provide a rapid nutrient supply beneficial for early crop growth, organo-mineral fertilizers are more effective in maintaining steady nutrient availability over an extended period. This sustained release pattern makes OMF 1 and OMF 2 promising options for improving nutrient use efficiency, reducing leaching losses, and ensuring long-term soil fertility, particularly in Sesamum cultivation.

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