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Production and Characterization of Mineral-Enriched Nadep Composts for Enhanced Soil Fertility

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Production and characterization of NADEP composts using aquatic weeds as substrates and enriched with different minerals, were conducted to evaluate its feasibility for agricultural purpose.
Study Design: The experiment was carried out using a completely randomized design comprising 12 treatments and three replications.

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Place and Duration of Study: The experiment was conducted at the model organic Farm of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, Kerala Agricultural University, between December 2023 and January 2024.
Methods: Aquatic weeds, *Limnocharis flava* and *Eichhornia crassipes*, were collected from Vellayani lake and mixed with banana pseudostem in different proportions for compost preparation. Once the compost reached maturity, it was enriched with minerals such as calcium apatite and epsom salt. The resultant compost was then analyzed for its physical, chemical, and biological properties.
Results: The NADEP compost, made from a 1:1 mixture of *L. flava* and *E. crassipes* and enriched with calcium apatite and epsom salt, was found to be the most effective treatment. It showed higher levels of macro and micronutrients, an ideal C**:** N ratio, improved enzyme activity, and a significant microbial load.
Conclusion: NADEP composting has emerged as a highly effective and environmentally sustainable approach to producing high-quality compost in a prompt and efficient way. This method transforms aquatic weeds, such as *Limnocharis* and *Eichhornia crassipes*, which pose a threat to aquatic ecosystems, into valuable compost, thereby promoting effective waste management and advancing sustainable agricultural practices.

Keywords: NADEP compost, organic farming; composting; limnocharis flava; eichhornia crasipes; calcium apatite, epsom salt, zeolite.

1. INTRODUCTION

Human interventions have brought about soil degradation and soil fertility continues to decline due to factors such as the excessive application of fertilizer inputs which have adverse effects on soil's physical, chemical and biological properties. Therefore, the strategy for this problem certainly has to be the adoption of integrated nutrient management and organic agricultural practices. These practices are beneficial for the restoration and preservation of soils as well as for higher crop yields. Integrated organic farming, which aims at sustainability as well as the use of agricultural chemicals, is quite useful not only in enhancing environmental conservation but also in the health and well-being of mankind and nature.

Aquatic weeds are recognized as one of the major hindrances to farming ecosystems, as they negatively affect the crops and water quality. Composting technologies tend to decompose waste materials and improve the ecosystem as well as the soil, increase agricultural output, and make nutrients easily available. Aquatic weeds like *L. flava* are efficiently composted utilizing a variety of techniques, such as vermicomposting and the use of Pleurotus florida, to produce high-quality compost with a high nutritional content (Jayapal et al. 2021). Aquatic weed biomass can be managed effectively by composting it, which turns it into nutrient-rich compost that promotes environmentally friendly farming practices (Gusain et al. 2018).

Different kinds of composting, like vermicomposting, bokashi composting, and NADEP composting, are all methods that can be used for the preparation of compost from aquatic weeds. Of these methods, NADEP composting is gaining popularity among the farming community. It is an aerobic composting technique developed by Sri Narayan Deotao Pandharipande (also called Nadep Kaka), a farmer in Maharashtra, India. This approach incorporates various organic substances, which are biologically active in generating high-quality compost (Edwards and Araya 2011). NADEP composting works differently as it does not follow the practices of traditional composting that require the frequent turning of the compost tank for aeration and also regular watering. As a result, this method is found to be the most effective way to generate compost during the dry season and is also useful at any time of the year when moisture is scarce (Chavan et al. 2015).

A permanently built tank is required for the production of NADEP composts. The filling of the tank follows a specific pattern. The first layer is filled with substrates, followed by the second layer filled with cow dung, and the final layer is plastered with soil. By plastering the compost tank, the process is optimized for efficient decomposition while retaining valuable nutrients and moisture essential for healthy soil enrichment. Therefore, by using composting techniques like the NADEP method, we can effectively manage aquatic weeds and produce high quality compost in a specified period of time.

2. MATERIALS AND METHODS

2.1 Production and Characterization of Enriched NADEP Compost

NADEP Compost was prepared in NADEP tanks using two commonly available aquatic weeds, *Limnocharis flava* (S_1) and *Eichhornia crassipes* (S_2). Banana pseudostem were added to the aforesaid aquatic weeds in a 1:1 ratio. Aquatic weeds from Vellayani Lake and banana pseudostem collected from Model Organic Farm, College of Agriculture, Vellayani were used to produce composts at the same farm. After the composting process was over, enrichment was carried out using minerals viz. calcium apatite and epsom salt. In all the treatments zeolite was added at 0.5 per cent. The study was carried out using 12 different treatments which are given below.

2.2 Statistical Analysis

NADEP compost was produced and characterized using a completely randomized design (CRD).

An F-test was performed in the ANOVA to assess the significance of the treatments, and the critical difference (CD) was calculated. Data analysis was carried out using the R package 'grapesagri1'.

3. RESULTS AND DISCUSSION

3.1 Proximate Constituents the of Resultant Mineral Enriched NADEP Composts

The highest value of cellulose was observed in T_{11} which is NADEP compost prepared from 1:1:1 mixture of *L. flava, E. crassipes* and banana pseudostem enriched with epsom salt and followed by T_5, T_{10}, T_6 and T_{12}. *E. crassipes* exhibited the highest cellulose content, up to 118.12 per cent, which was subsequently used for ethanol production (Nomeda et al. 2018). NADEP compost prepared from 1:1:1 mixture of *L. flava, E. crassipes* and banana pseudostem enriched with epsom salt recorded the highest lignin content and was found on par with T_{10}, followed by T_2, T_{12} and T_1. The cellulose and lignin content of different treatments is shown in Fig. 1.

Table 1. Treatment details of the resultant enriched NADEP compost

T_1	Yellow velvet leaf (*Limnocharis flava*) + Banana pseudostem (1:1) enriched with calcium apatite
T_2	Yellow velvet leaf (*Limnocharis flava*) + Banana pseudostem (1:1) enriched with epsom salt
T_3	Yellow velvet leaf (*Limnocharis flava*) + Banana pseudostem (1:1) enriched with calcium apatite+ epsom salt
T_4	Water hyacinth *(Eichhornia crassipes)* + Banana pseudostem (1:1) enriched with calcium apatite
T_5	Water hyacinth (*Eichhornia crassipes*) + Banana pseudostem (1:1) enriched with epsom salt
T_6	Water hyacinth (*Eichhornia crassipes)* + Banana pseudostem (1:1) enriched with calcium apatite+ epsom salt
T_7	Yellow velvet leaf *(Limnocharis flava)* + Water hyacinth (Eichhornia crassipes) (1:1) enriched with calcium apatite
T_8	Yellow velvet leaf (*Limnocharis flava)* + Water hyacinth *(Eichhornia crassipes*) (1:1) enriched with epsom salt
T_9	Yellow velvet leaf (*Limnocharis flava)* + Water hyacinth (*Eichhornia crassipes*) (1:1) enriched with calcium apatite+ epsom salt
T_{10}	Yellow velvet leaf (*Limnocharis flava)* + Water hyacinth *(Eichhornia crassipes*) + Banana pseudostem (1:1:1) enriched with calcium apatite
T_{11}	Yellow velvet leaf (*Limnocharis flava*) + Water hyacinth (*Eichhornia crassipes*) + Banana pseudostem (1:1:1) enriched with epsom salt
T_{12}	Yellow velvet leaf (*Limnocharis flava*) + Water hyacinth (*Eichhornia crassipes*) + Banana pseudostem (1:1:1) enriched with calcium apatite+ epsom salt

The composting process was completed over a period of 75 days. Following this zeolite was added to each treatment (T_1-T_{12}) at the rate of 0.5 per cent.

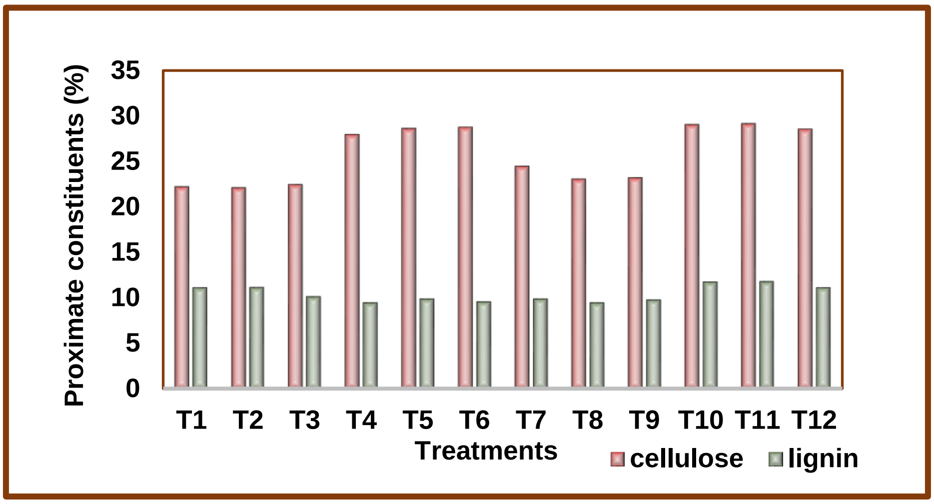

Fig. 1. Cellulose and lignin content of mineral enriched NADEP compost

3.2 Physical Properties of the Resultant Enriched NADEP Composts

The physical properties of the mineral enriched NADEP compost are shown in Table 2. Physical properties such as moisture content and bulk density were analyzed. The moisture content of the resultant NADEP composts varied from 25.40 per cent to 32.98 per cent. The highest moisture content was found in T_3, which is NADEP compost prepared from a 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt. The variations in moisture content between the compost samples could be linked to differences in the compost pile's temperature throughout the composting process (Khater 2015). Treatment 9 showed the lowest bulk density (0.26 g cm^{-3}), which might be due to the higher organic matter content of the compost (Brewer and Sullivan 2003).

3.3 Electro Chemical Properties of the Resultant Enriched NADEP Composts

The electro-chemical properties of soil such as pH and EC, are shown in Table 3. Mature compost generally had a pH range of 6.5 to 8, while immature compost was typically more acidic (Singh and Kalamdhad 2014). The pH of the resultant enriched NADEP compost varied from 6.87 to 7.28. The highest pH was observed in T_1 (7.24), which was NADEP compost prepared from a 1:1 mixture of *L. flava* and banana pseudo stem enriched with calcium apatite.

Table 2. Physical properties of the resultant enriched NADEP compost

Treatments	Bulk Density (Mg m^{-3})	Moisture content (%)
T_1	0.380	32.530
T_2	0.350	32.800
T_3	0.370	32.980
T_4	0.370	25.397
T_5	0.347	27.800
T_6	0.360	28.000
T_7	0.310	27.800
T_8	0.313	29.840
T_9	0.260	29.800
T_{10}	0.387	28.120
T_{11}	0.370	29.600
T_{12}	0.380	30.800
SEm (±)	0.009	0.38
CD(0.05)	0.026	1.108

The EC value of the compost is an important parameter as it reflects the salinity level, which directly affects plant growth. The highest EC value was found highest in T_{12}, NADEP compost prepared from a 1:1:1 mixture of *L. flava*, *E. crassipes*, and banana pseudo stem enriched with calcium apatite and epsom salt.

Table 3. Electrochemical properties of the resultant enriched NADEP compost

Treatments	pH	EC (dSm^{-1})
T_1	7.28	1.45
T_2	6.87	1.56
T_3	7.13	1.67
T_4	7.17	1.48
T_5	6.92	1.56
T_6	7.00	1.69
T_7	7.17	1.56
T_8	6.99	1.72
T_9	7.22	1.76
T_{10}	7.03	1.78
T_{11}	6.89	1.65
T_{12}	7.14	1.80
SEm(±)	0.084	0.023
CD(0.05)	2.44	0.066

3.4 Chemical Properties of the Resultant Mineral Enriched NADEP Compost

The organic matter content of mineral enriched NADEP composts was significantly influenced by the choice of substrates. T_7, (NADEP compost prepared from 1:1 mixture of *L. flava* and *E.crassipes* enriched with calcium apatite) exhibited the highest organic matter content, which was on par with T_1, followed by T_9, T_4, and T_{10}. As the composting process progressed, organic matter was broken down into minerals as microorganisms degraded proteins, cellulose, and hemicellulose, utilizing 60-70 per cent of the carbon while immobilizing 30-40 per cent. Total Organic Carbon (TOC) serves as a key metric for evaluating compost maturity (Shilpa 2020). The macro and micronutrient contents of the composts are shown in Table 4. The mineral enriched NADEP compost, prepared from a 1:1 mixture of *L. flava* and *E. crassipes* and enriched with calcium apatite, showed higher total nitrogen and phosphorus levels. In contrast to other composting methods, this process minimizes nitrogen loss through volatilization, denitrification, leaching, and immobilization. The potassium content was found highest in T_1. The elevated potassium content in these composts is primarily due to the banana pseudostem, which contains significantly higher potassium levels compared to *L. flava* (Anushma 2014).

The micronutrient content of the resultant mineral enriched NADEP compost is found maximum in T_9 (NADEP compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt), followed by T_6, T_7 and T_{10}. The increase in micronutrient concentration in the final compost might be due to the reduction in compost mass, resulting in a higher proportion of micronutrients like iron, zinc, copper, and manganese in the remaining material. Similarly, aquatic weeds like *L. flava* and *E. crassipes* contained more micronutrients than banana pseudo stem (Hellmann et al. 1997).

Table 4. Total organic carbon, primary and secondary nutrient content of mineral enriched NADEP composts

Treatments	Total organic carbon (%)	Total N (%)	Total P (%)	Total K (%)	Ca (%)	Mg (%)	S (mg kg^{-1})
T_1	35.79	3.22	0.51	2.39	0.35	0.14	22.50
T_2	32.12	2.80	0.37	1.64	0.28	0.22	28.00
T_3	30.70	2.80	0.59	2.20	0.37	0.27	29.50
T_4	34.47	2.89	0.44	2.39	0.31	0.13	15.50
T_5	31.20	2.56	0.52	1.95	0.26	0.23	21.50
T_6	32.70	2.70	0.60	2.15	0.33	0.24	24.00
T_7	35.90	3.31	0.61	1.85	0.29	0.13	21.75
T_8	32.11	2.80	0.50	1.74	0.25	0.22	28.50
T_9	34.77	3.03	0.62	1.80	0.32	0.26	30.00
T_{10}	32.78	2.95	0.57	2.35	0.34	0.14	18.00
T_{11}	31.33	2.64	0.51	2.05	0.28	0.23	23.17
T_{12}	31.43	2.89	0.59	2.10	0.38	0.28	25.34
SEm(±)	0.703	0.032	0.006	0.035	0.006	0.004	0.452
CD(0.05)	2.053	0.094	0.019	0.103	0.016	0.011	1.318

Table 5. Micronutrient content of mineral enriched NADEP composts

Treatments	Fe (%)	Mn (mg kg $^{-1}$)	Zn (mg kg $^{-1}$)	Cu (mg kg $^{-1}$)
T_1	1.19	141.49	51.00	22.49
T_2	0.95	131.00	31.60	21.50
T_3	1.25	157.00	53.00	24.50
T_4	1.20	153.00	43.49	18.99
T_5	1.05	142.00	28.00	17.00
T_6	1.37	171.00	45.10	21.00
T_7	1.28	156.00	52.80	23.00
T_8	1.19	144.50	43.40	21.99
T_9	1.40	179.00	56.19	26.00
T_{10}	1.20	148.00	43.29	17.50
T_{11}	0.97	159.00	26.40	13.99
T_{12}	1.25	169.96	44.70	21.00
SEm(±)	0.022	2.209	0.706	0.259
CD(0.05)	0.065	6.448	0.706	0.756

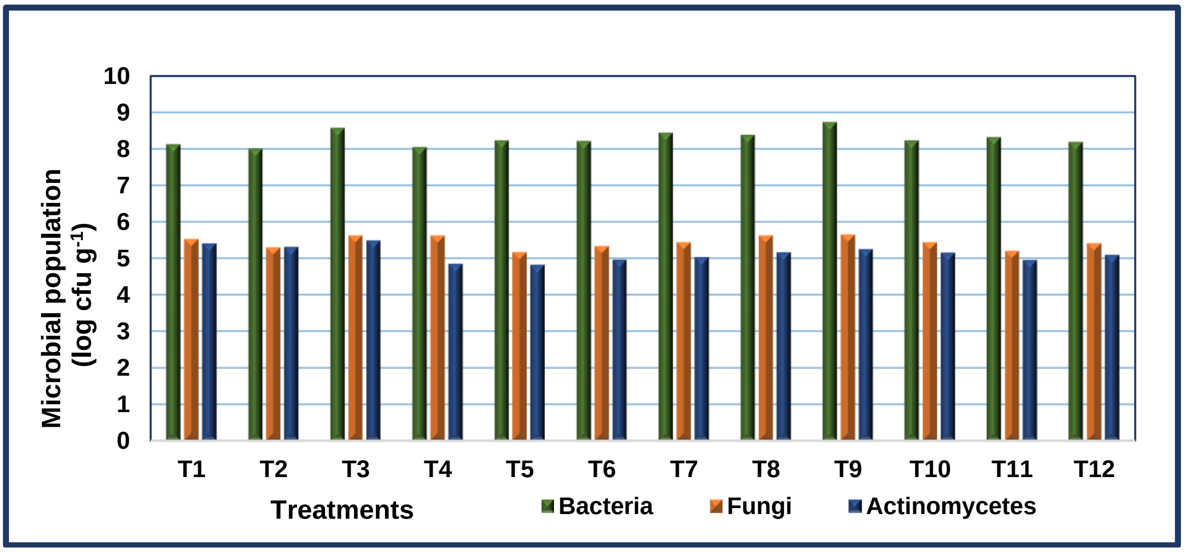

Fig. 2. Microbial population of mineral enriched NADEP compost

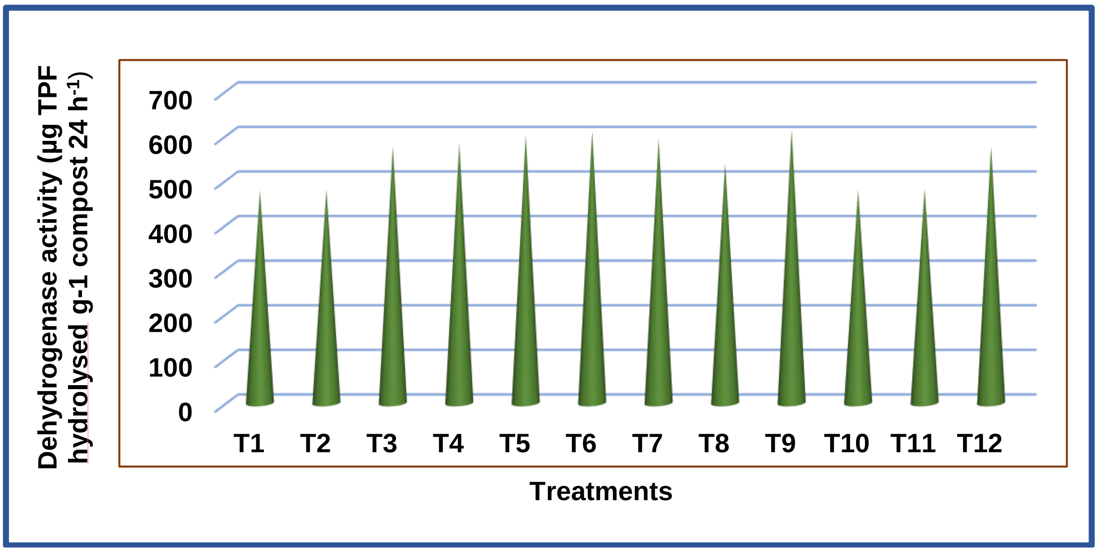

Fig. 3. Dehydrogenase activity of mineral enriched NADEP compost

3.5 Biological Properties of the Resultant Mineral Enriched NADEP Compost

Microorganisms play a key role in composting by decomposing organic matter and releasing CO_2, CH_4, and N_2O at different stages of the process (Lee 2016). The decomposition of organic materials into stable end products is facilitated by the sequential development of microbial communities, with bacteria, fungi, and actinomycetes playing key roles at different stages of the process (Guo et al. 2012).

The bacterial and fungal population was found highest in T_9 which is the mineral enriched NADEP compost, prepared from a 1:1 mixture of *L. flava* and *E. crassipes* and enriched with calcium apatite. Actinomycetes play a key role in organic matter decomposition, inhibit plant pathogens in the rhizosphere, and produce extracellular enzymes that enhance crop production. The NADEP compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt showed the highest population of actinomycetes.

The C: N ratio is crucial in composting as it affects microbial activity, decomposition rates, nutrient balance, and temperature regulation. The mean values of the C: N ratio ranged from 9.59 to 11.92. An ideal C: N ratio of around 25:1 to 30:1 provides microorganisms with a balanced supply of nutrients for growth, leading to faster and more efficient decomposition (Goyal et al. 2005). A decrease in the C: N ratio, resulting from a reduction in organic carbon and an increase in total nitrogen, was noted during the decomposition of organic matter (Nishanth and Biswas 2008, Bei et al. 2020).

Carbon dioxide evolution serves as an effective indicator of compost maturity because it directly reflects microbial respiration and biological activity. As microorganisms decompose organic matter, they release CO_2. Tracking CO_2 emissions offers valuable information about microbial activity, which tends to decline as compost matures, indicating stabilization and readiness (Kazemi et al. 2017). The higher value of CO_2 evolution was observed in T_9 which is NADEP compost prepared from a1:1 mixture of *L. flava* and *E. crassipes* enriched with calcium apatite and epsom salt (5.13 mg CO_2 g^{-1}).

Enzymatic activities can be used as indicators of composting progress and maturity, as their decline typically corresponds with a reduction in available organic compounds and increased compost stability (Raji et al. 2008). NADEP compost prepared from 1:1 mixture of *L. flava* and *E. crassipes* enriched with calcium apatite and epsom salt) recorded the highest dehydrogenase activity.

4. CONCLUSION

Based on a thorough evaluation of physical, chemical, and biological parameters, it was determined that the NADEP compost created with a 1:1 mixture of *L. flava* and *E. crassipes*, enriched with calcium apatite and epsom salt, was the most effective treatment. This composition not only shows considerable promise as an organic fertilizer but also provides a sustainable alternative to chemical fertilizers, significantly promoting plant growth and enhancing overall soil health. Moreover, implementing such organic methods can aid environmental sustainability by minimizing chemical runoff and enhancing soil biodiversity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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