ENHANCING VERMICOMPOST QUALITY WITH *Azolla pinnata:* ENRICHED GOAT DUNG FOR SUSTAINABLE AGRICULTURE

ABSTRACT

In regenerative agriculture, this study explores the potential of *Azolla pinnata*-enriched goat dung vermicompost as a sustainable and nutrient-rich organic fertilizer. Goat dung was collected from integrated farming units established at Krishi Vigyan Kendra, Vridhachalam and farmers holdings of the Cuddalore district. Goat dung was pre-treated by soaking in *Azolla* cultivated water and fronds of *Azolla* and composted with African earthworms (*Eudrilus eugeniae*) to enhance the nitrogen and carbon content of the vermicompost. Over 120 days, the vermicompost was monitored for key physicochemical properties, including pH, electrical conductivity, total carbon, nitrogen, phosphorus, and potassium. Experimental results proved that the *Azolla*-enriched goat dung vermicompost (T_3) exhibited a significant increase in total carbon (266.24 g/kg), nitrogen (19.95 g/kg), and potassium (27.18 g/kg) compared to control with goat dung manure alone (T_1) and goat dung vermicompost (T_2). The pH of the *A. pinnata*-enriched goat dung vermicompost was slightly acidic at 6.6. This study underscores the efficacy of integrating *Azolla* with goat dung in vermicomposting to produce organic manure that enhances soil fertility and fosters environmentally sustainable farming practices. The findings suggest that adopting such a system in integrated farming could lead to increased farm productivity, better resource recycling where *Azolla* cultured water and Goat dung serves as inputs for vermiculture for improving the quality with enhanced nitrogen content, offering a viable approach for regenerative agriculture.

Keywords: *Azolla*, Goat dung, Vermicompost, Nutrients, Regenerative farming.

INTRODUCTION

Azolla, also known as fairy moss, water velvet, feathered aquatic fern, mosquito fern, or duckweed, is a highly beneficial input and a key element in integrated farming, agriculture, and animal husbandry owing to its efficacy as feed for animals. *Azolla microphylla* and *Azolla pinnata* are the most commonly available species of *Azolla* in India. It possesses high protein due to the presence of symbiotic Cyanobacterial partner, namely Blue Green Algae (BGA), low lignin content for easy digestion by animals, and essential amino acids for ruminant diet, making it an economically viable option for farmers seeking to reduce feed supplement costs for livestock. Apart from animal feed, it is used in rice-dual cropping systems to reduce nitrogen usage and weed control in wetlands. However, the use of *Azolla* as vermicomposting substrate is very limited. *Azolla*, poultry waste, urea, and cattle dung were evaluated as nitrogen sources to optimize the carbon-to-nitrogen ratio in sugarcane waste composting. Results showed that *Azolla* was particularly effective in speeding up the composting process (Shinde *et al*., 2023).

Vermicomposts and vermiwash are being advocated for use in integrated soil fertility management as they nourish the soil to support crop growth, offering essential nutrients, humic acid, plant growth hormones, Nitrogen fixing and Phosphorous solubilizing microbes, enzymes and vitamins. These natural fertilizers are usually produced from cow dung wastes, farm yard manure and other plant or vegetables wastes. But in a climate-resilient farming system, the goat possesses an important place under the small ruminant category with a large feed conversion ratio. Loh *et al*. (2005) indicated that Goat dung plays a crucial role in enhancing the resilience of agriculturally depleted soils in extremely arid environments where biomass production is severely limited. Further, goat dung manure contained more concentration of phosphorous and potassium rather than nitrogen and carbon. Research has demonstrated the positive effect of vermicompost on the growth parameters and yield of strawberries (Singh *et al*., 2024).

In the context of regenerative agriculture where the waste of one enterprise is a nutrient for another component for added economic returns, cattle wastes are traditionally used for vermicomposting due to the bulky availability of cow dung in farms. Goat dung takes a long time to decompose and it is hard to break or make into a powder without a mechanical pressing. Goat dung can serve as a nutrient-rich substrate, transforming into compost through vermicomposting with earthworms (Katakula *et al*., 2021). Ramadevi *et al.* (2023) examined the impact of applying goat manure on the growth and productivity of *Amaranthus* and found that it enhanced organic carbon, nitrogen and phosphorus levels in the soil. This nutrient improvement in the soil led to a significantly higher yield that sustained even upto the fifth harvest of vegetative leaves of *Amaranthus*. Hence, if the goat dung is crushed and soaked in *Azolla*-grown water, it would help to

enrich with added nitrogen and biomass carbon of the *Anabaena azollae* that lives in symbiotic association with *Azolla pinnata.*

MATERIALS AND METHODS

Preparation of *Azolla*-enriched goat dung vermicompost

The experiment was conducted at ICAR-TNAU, Krishi Vigyan Kendra, Vridhachalam, Cuddalore district, Tamil Nadu, India in the year 2022-2024. The modified method of Rekha *et al.* (2018) was used for the production of *Azolla*-enriched goat dung vermicompost. Goat dung was collected from the slatted goat house of the integrated farming unit comprising farm pond + fish + *Azolla* + vermicompost + Goat + border vegetables + border fodder crops maintained in 6 different locations of Cuddalore district was used as the main raw material to prepare vermicompost. The goat dung was crushed using a tractor-mounted roller crusher and pre-treated with *Azolla*-cultivated excess water by soaking in the *Azolla*-grown water for almost 20 days to dissolve the contents well. Fresh fronds of *Azolla pinnata* @ 20 kg were mixed with one ton of pre-treated goat dung. The contents were mixed well, and allowed with African earthworms (*Eudrilus eugeniae*) @ 2 kg per tonne for multiplication in vermibed measuring (LxBXH) size of 3m x 1m x 1m (Ansari and Sukhraj, 2010), and the maintenance protocol suggested by Ramnarain *et al.* (2019) were followed during the entire process of composting upto 120 days. The process of vermicomposting with goat dung is shown in Fig. 1. The vermicompost bed was moistened by sprinkling two litres of borewell water once a week and this continued upto the seventh week. The raw materials were gently turned every 15 days. Goat dung alone (T_1) served as the control, Goat dung vermicompost (T_2), *Azolla*-enriched goat dung vermicompost (T_3). After 120 days, vermicompost from all the treatments were harvested.

Analysis of pH, EC, total carbon and major nutrients

Samples from six distinct locations were gathered and three different treatments were tested for pH, electrical conductivity, total carbon, total nitrogen, phosphorus, and potassium. The pH was measured using a digital pH meter (Jones, 2001); total carbon was determined by the dry combustion method; total nitrogen was estimated via the Kjeldahl method (Bremner and Mulvaney, 1982); phosphorus content was analyzed using the Olsen method (Olsen *et al.*, 1954); and exchangeable potassium was measured with a flame photometer (Jackson, 1967).

Statistical analysis

The data obtained from the single factor ANOVA of the Completely Randomized Design of the experiment were statistically analyzed using OPSTAT software (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

The experimental results from six different locations indicate that total carbon and nitrogen levels are considerably higher in T_3, the goat dung vermicompost enriched with *Azolla pinnata*, than in goat dung manure alone (Table 1). The pH value of *A. pinnata*-enriched Goat dung vermicompost (T_3) was in the acidic range of 6.6 when compared to the Goat dung manure and Goat dung vermicompost. The higher EC content of 1.40 µS/cm was recorded in T_3 and much closely followed by T_1 of 1.34 µS/cm. In the T_3 treatment, the total carbon content was significantly maximum of 266.24 g/kg followed by T_2 of 257.12 g/kg. Among the major nutrients such as N, P and K, the amount of P was much lower in all the treatments and was comparatively higher in T_3 of 3.24 g/kg. There was a drastic increase in nitrogen content of 19.95 g/kg in T_3 which was significantly higher than T_1 which recorded only 14.15 g/kg of nitrogen. Potassium was also on the higher side in T_3 at 27.18 g/kg which was 22% higher than the control T_1.

Table 1: Physico-chemical properties of different organic manures

S. No.	Treatments	Physico-chemical properties					
		pH	**Electrical Conductivity (µS/cm)**	**Total Carbon (g/kg)**	**Nitrogen (g/kg)**	**Phosphorous (g/kg)**	**Potassium (g/kg)**
1.	T_1- Goat dung manure alone (Control)	7.4	1.38	251.09	14.15	2.98	21.22
2.	T_2- Goat dung vermicompost alone	7.5	1.34	257.12	16.65	3.01	23.34
3.	T_3- *Azolla pinnata*-enriched Goat dung vermicompost	6.6	1.40	266.24	19.95	3.24	27.18
	CD (0.05%)	**0.09**	**0.02**	**1.09**	**1.85**	**1.39**	**0.26**
	SE(d)	**0.04**	**0.01**	**0.51**	**0.65**	**0.49**	**0.12**

***The values indicated in the table are the mean of six replicates**

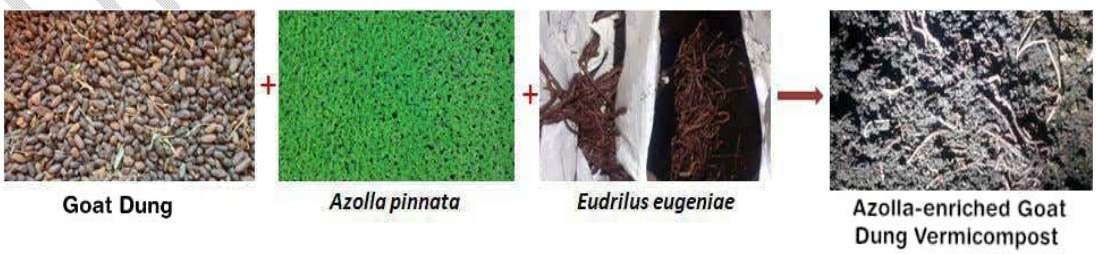

Fig. 1: Process of *Azolla pinnata*-enriched Goat dung based vermicompost

In Dhal Lake, Kashmir an innovative experiment was conducted by Najar and Khan (2010) to utilize the nuisance *Azolla* in water systems for feeding earthworms to turn into vermicompost with enhanced nitrogen and organic carbon content. The phosphorus content in the vermiwash from the vermicast was notably higher than in regular vermicompost. The current study also observed an increase in carbon and nitrogen levels, likely due to the higher nutrient content of *Azolla*. In a similar study, Jamaludin *et al.* (2012) used *Lumbricus* sp. of earthworms to decompose spent mushroom substrate and goat dung manure. It was indicated in their work that vermicomposting of goat dung along with spent mushroom waste improved the nutrient conversion ratio. Further, Natarjan *et al*. (2024) have elaborately discussed the attributes of sheep penning in agro-pastoral economy and soil fertility, where cattle and goat vermicasts were found to be comparatively rich in organic carbon, phosphorus and Potassium. The results of the present study also indicate that the use of *Azolla*-grown spent water along with fresh *Azolla* fronds in goat dung vermicomposting recorded increased total carbon content to the tune of 5.7% from the control.

Studies of Arora and Kaur (2019) on increasing agronomic value and decomposing pattern of paddy straw using *"Azolla pinnata*, *Aspergillus terreus* and *Eisenia fetida"* very well substantiates the present study. In their study, a comparative evaluation was carried out to assess the aerobic composting and vermicomposting of paddy straw with cow dung, *Azolla*, *Aspergillus terreus* and *Eisenia fetida*. The findings demonstrated that *Azolla*, when combined with cow dung, effectively degraded paddy straw and significantly boosted the phosphorus content. However, the phosphorous content is slightly increased without any significant difference in this study. Gichaba *et al*. (2020) experimented with goat manure and goat dung vermicompost to test the efficacy of both in improving the yield of organic garlic in Kenya. It was found that goat manure-based vermicompost improved the yield and also the content of major nutrients in the soil. The results of the current findings are concurrent with the above findings in witnessing the drastic increase in major nutrients. Purba *et al.* (2021) conducted a field trial in mustard crop under ultisol soil, to compare the effect of vermicompost administration derived from cow dung, and showed that the tissue N uptake and absorption is higher at the dosage of 30 tonnes per hectare. Chatterjee *et al*. (2021) have utilized plant biomass waste to enrich the nutrient content of the vermicompost and narrow down the C:N ratio of the organic substrates. Similarly, the present study utilizes the Azolla cultured water and goat dung instead of cow dung to culture worms. Sarker *et al*. (2021) compared the physico-chemical properties of cow, horse and goat manure for pH, EC, organic matter, dry matter and crude fiber. It was noted that the organic matter content in goat manure was higher than cow dung and horse dung manure. The findings of this study are consistent with the observation and findings of the present research. Harisudan *et al.* (2024) conducted multi-location trials to evaluate the potential of goats in integrated farming systems aimed at profit maximization. Their study

revealed that goat urine and dung produced a substantial yield of goat manure, generating an income of Rs. 1.2 lakhs from 15 sheep in a model combining fish, poultry, sheep, and crop farming. The present research samples were taken from the IFS models established with farm pond + fish + *Azolla* + vermicompost + Goat + border vegetables + border fodder crops and found to be a viable method for the regenerative agriculture.

CONCLUSION

This study will necessarily help the researchers to carry out further investigation that will help in devising the technological interventions required for integrated farming systems. *Azolla* + Goat dung + Earthworms will produce nitrogen and potassium-rich organic sources of manure. Simple enrichment of goat dung with *Azolla* fronds to produce vermicompost with added nitrogen and organic matter will serve as nutrient-rich manure in various enterprises like crop production, horticulture, animal husbandry, forestry, fisheries *etc*., and thereby lead to the overall farm productivity and recycling of resources in the farm, and conservation of natural resources even for the small land holders. Farmers can adopt the integrated farming system involving farm pond + fish + *Azolla* + vermicompost + Goat + border vegetables + border fodder crops as a system instead of crops alone to sustain the farming activity and improve their livelihood.

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 the writing or editing of this manuscript.

REFERENCES

Ansari, A.A., Sukhraj, K. (2010). Effect of vermiwash and vermicompost on soil parameters and productivity of Okra (*Abelmoschus esculentus*) in Guyana. *African Journal of Agricultural Research, 5*(14), 1794-1798.

Arora, M., Kaur, A. (2019). *Azolla pinnata, Aspergillus terreus* and *Eisenia fetida* for enhancing the agronomic value of paddy straw. *Scientific Reports, 9*(1), 1341. doi:10.1038/s41598-018-37880-1.

Bremner, J.M., Mulvaney, C.S. (1982). Nitrogen-total. *In*: Methods of Soil Analysis, part 2, Chemical and Microbiological Properties. *American Society of Agronomy*.

Chatterjee, D., Dutta, S.K., Kikon, Z.J., Kuotsu, R., Sarkar, D., Satapathy, B.S., Deka, B.C. (2021). Recycling of agricultural wastes to vermicomposts: Characterization and application for clean and quality production of green bell pepper (*Capsicum annuum* L.). Journal of Cleaner Production. 315 (4):128115. DOI:10.1016/j.jclepro.2021.128115.

Gichaba, V.M., Ndukhu, H.O., Muraya, M., Odilla, G.A., Ogolla, F.O. (2020). Preparation and evaluation of Goat manure-based vermicompost for organic Garlic production in Manyatta sub-country, Kenya. *International Journal of Environment Agriculture and Biotechnology, 5*(1), 2456-1878.

Harisudan, C., Subrahmaniyan, K., Veeramani, P., Kalaiselvi, T., Parthipan, K., Gayathry, G., Baskaran, R. (2024). Integrating veterinary and poultry components with rice-based farming systems for effective utilization of resources. Environmental Restoration and Profitability. *International Journal of Veterinary Sciences and Animal Husbandry, 9*(2S), 324-326. doi:10.22271/veterinary.2024.v9.i2Se.1317.

Jackson, M.L. (1967). Soil chemical analysis. New Delhi: Prentice Hall of India.

Jamaludin, A.A., Mahmood, N.Z., Abdullah, N. (2012). Waste recycling: Feasibility of sawdust-based spent mushroom substrate and goat manure in vermicomposting. *Sains Malaysiana, 41*(11), 1445-1450.

Jones, J.B. (2001). Laboratory guides for conducting soil tests and plant analysis. Boca Raton: CRC press.

Katakula, A.A.N., Handura, B., Gawanab, W., Itanna, F., Mupambwa, H.A. (2021). Optimized vermicomposting of a goat manure-vegetable food waste mixture for enhanced nutrient release. *Scientific African, 12*, e000727. doi: 10.1016/j.sciaf.2021.e00727.

Loh, T.C, Lee, Y.C., Liang, J.B., Tan, D. (2005). Vermicomposting of cattle and goat manures by *Eisenia foetida* and their growth and reproduction performance. *Bioresource Technology, 96*(1), 111-114. doi: 10.1016/j.biortech.2003.03.001.

Najar, I.A., Khan, A.B. (2010). Vermicomposting of invasive species *Azolla pinnata* with *Eisenia fetida*. *The Bioscan, 5*(2), 239-241.

Natarajan, K., Gayathry, G., Jayalakshmi, T., Sunitha, R., Harisudan, C., Sugumaran, M.P. (2024). Sheep penning for agro-pastoral economy and restoration of soil fertility. *International Journal of Veterinary Sciences and Animal Husbandry, 9*(4), 586-589. https://doi.org/10.22271/veterinary.2024.v9.i4i.1615.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Purba, T.R.R., Prasetyo, R.T.A., Murcitro, B.G., Nusantara, A.D., Suprijono, E. (2021). Vermicompost of cow dung and goat manure to increase N absorption, mustard (*Brassica rapa* L.) growth and yield in ultisols. *TERRA*: *Journal of Land Restoration, 4*(1), 23-28. doi:10.31186/terra.4.1.23-28.

Ramadevi, L., Sivaranjani, S., Vijaya Samoondeeswari, S., Ramabhai, V., Arulnangai, R., Murugesan, R. (2023). Comparative study of organic manure (cow dung, goat dung and chicken

manure) on the vegetative growth of *Amaranthus dubius*. *Agricultural and Biological Research, 39*(4), 1-7.

Ramnarain, Y.I., Ansari, A.A., Ori, L. (2019). Vermicomposting of different organic materials using the epigeic earthworm *Eisenia foetida*. *International Journal of Recycling of Organic Waste in Agriculture, 8*(1), 23-36.

Rekha, G.S., Kaleena, P.K., Elumalai, D., Srikumaran, M.P., Maheswari, V.N. (2018). Effects of vermicompost and plant growth enhancers on the exo-morphological features of *Capsicum annum* L. Hepper. *International Journal of Recycling of Organic Waste in Agriculture, 7, 83-88.* doi: 10.1007/s40093-017-0191-5.

Sarker, M.A., Hashem, M.A., Murshed, H.M., Kamal, M.T., Haque, M.R., Rahman, M.M. (2021). Production and evaluation of vermicompost from different types of livestock manures. *Journal of Agriculture Food and Environment, 2*(2), 62-67. doi: 10.47440/JAFE.2021.2211.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C., Pannu, R.S. (1998). Statistical Software Package for Agricultural Research Workers. Recent Advances in Information Theory, Statistics and Computer Applications by D.S. Hooda and R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar, 139-143.

Shinde, S. J., Dixit, A. D., Shanbag, R. J., Kulkarni, Y., Borde, M. Y., Lokhande, V. H. (2023). A Case Study on Role of Microbial Consortia Assisted Decomposition of Agro-waste for Improvement of Soil Organic Carbon–A Step Towards Sustainable Development. *International Journal of Plant and Environment, 9*(4), 312-322.

Singh, A. K., Siddiqui, M. H., Nayyer, M. A., Singh, A., Pratap, D., Rai, D., Vaishya, K. (2024). A review Biofertilizer and Organic Manures in Strawberry Production. *International Journal of Plant and Environment, 10*(01), 114-119. DOI: 10.18811/ijpen.v10i01.15.