Co-composting of invasive weed water hyacinth (*Eichhornia crassipes* (Mart.) Solms) with organic manures

Harikrishnasagar V[1]., Susha V. S.[1]*, Ameena M[1], Shalini Pillai P.[1], Manju R. V.[2] and Anjali S.[1]

[1]*Department of Agronomy, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University, 695 522, India*

[2] *Department of Plant Physiology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University, 695 522, India*

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Abstract

Water hyacinth is an invasive weed causing serious damage to waterbodies of Kerala by way of blockage of water channels, eutrophication, sedimentation, water quality deterioration etc.Various treatment combinations were used to corroborate the bio utilization of water hyacinth infesting the Vellayani fresh water lake as a nutritive manure and its physico-chemical characterization was investigated through aerobic co-composting with organic manures *viz*. cowdung, pig manure and poultry manure on weight basis (1:1 and 2:1), effective microorganisms or EM (10:1.5), and with *Pleurotus* sp (1000:1.5). Co-composting of water hyacinth + poultry manure (2:1) recorded significantly higher N (2.557 %), P (1.397 %) and K (2.132 %) contents with lower C: N ratio (7.53:1) at 120 days after initiation (DAI) of composting. Micro nutrients such as Zn (309.00 mg/kg) and Cu (354.33 mg/kg) were higher in water hyacinth + pig manure (2:1). Significantly higher B (41.00 mg/kg), Mn (1839.33 mg/kg) and Fe content (5780.23 mg/kg) were recorded in water hyacinth + poultry manure (2:1), water hyacinth + poultry manure (1:1) and water hyacinth + cow dung (1:1) respectively. The time taken for maturity of compost was the least in water hyacinth + cow dung (1:1) (107 days) which was on par with water hyacinth + poultry manure (1:1) (108 days). The pH range of all the treatments were found to be near neutral (6.7 to 7.2). The EC of the co-composts were in the acceptable range of 1.46 to 2.72 dS/m. The co-compost of water hyacinth + cow dung at both the weight ratios recorded the lowest temperature (26.56 °C and 26.73°C respectively). The highest recovery percentage of compost was recorded in water hyacinth + poultry manure (1:1) (46.89%).

Keywords: Compost maturity, Micro nutrients, Poultry manure, Recovery per cent, Temperature

Introduction

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), native of Brazil is designated as one of the most pernicious aquatic plants, referred to as the 'Bengal terror'. In Kerala, its proliferation detrimentally affected agriculture, fisheries, inland transportation and local economies notably. Reports indicated that approximately two-third of water bodies in Kerala are afflicted by *Eichhornia crassipes*, and its rapid proliferation is typically attributed to eutrophication in aquatic ecosystems, promoting its unchecked expansion (Sasidharan et al., 2013). Its extensive presence in rice fields, lakes, streams and channels rendered a considerable portion of Kerala in accessible, unusable and non-navigable (Jayan and Sathyanathan, 2012).

Despite efforts to manage water hyacinth using mechanical, chemical and biological methods, effective control has not been achieved. An emerging approach for improved management

* Author for Correspondences: Phone :9846584835; Email: susha.vs@kau.in

involves bio-utilization. Utilizing water hyacinth as a resource for various purposes represents a groundbreaking strategy for their management. Composting has proven to be an effective and environmentally safe method for the efficient removal of aquatic weeds. Due to the vast amount of biomass that water hyacinth generates, it would be a feasible method to produce high-quality organic manure, and the issue of getting rid of these weeds might be largely resolved. Water hyacinth can be effectively bio-utilized to produce nutrient rich organic manure through suitable co-composting techniques resulting in greater economic and ecological benefits. An effective way to accelerate the process of composting is by combining with cattle manure, poultry manure, and molasses along with inoculation with beneficial micro-organisms resulting in reduction of nutrient losses (Beesigamukama et al., 2018). The current study focuses on co-composting methods involving water hyacinth and various organic manures, including cow dung, pig manure, poultry manure, effective microorganisms (EM), and *Pleurotus*, in different weight ratios. The aim is to facilitate the environmentally friendly disposal of water hyacinth through bio-utilization and to characterize its physicochemical properties.

Materials and Methods

The study was carried out at College of Agriculture, Vellayani (8° 25'43" N; 76°59'98" E) during 2021-2022 in completely randomized design with nine treatments and three replications. Fully grown water hyacinth plants sampled from Vellayani lake during February 2022 was utilised for evaluating compost production. Different treatments included,T1- water hyacinth + cow dung (1:1), T2- water hyacinth + cow dung (2:1), T3- water hyacinth + pig manure (1:1), T4- water hyacinth + pig manure (2:1), T5- water hyacinth + poultry manure (1:1), T6- water hyacinth + poultry manure (2:1), T7- water hyacinth + EM (10:1.5), T8- water hyacinth + Pleurotus (1000:1.5) and T9- water hyacinth alone. Water hyacinth without any added substrate acted as the control treatment. The mineral composition and compost production ability of the samples were also assessed. Effective micro-organisms present in the EM solution were identified as *Lactobacillus casei, Rhodopseudomonas palustris* and *Saccharomyces cerevisiae*. After deciding the proportion and quantity of co-composting, whole water hyacinth plants were shade dried for a week to remove excess moisture and cut into 4-5 cm pieces using a hedge shear. Subsequently, all co-composting constituents, including cow dung, poultry manure, pig manure, *Pleurotus,* and EM solution, were introduced into water hyacinth within earthen pots each in accordance with the designated treatment ratios. The weed biomass was mixed with manures in w/w basis in earthen pots of 30 cm diameter. The mixture was turned after sprinkling water at three day interval to facilitate aeration and to maintain proper moisture levels of 40-60 per cent for proper decomposition of organic matter.

Observations on time taken for maturity, per cent recovery, chemical properties *viz*., pH, EC, and C: N ratio as well as nutrient content of mature composts were recorded by following standard procedures. Maturity of composts was determined initially based on visual observation and then confirmed upon by C: N ratio narrowed down to less than 20. Per cent recovery was estimated by dividing the quantity of output to the quantity of input multiplied by 100. The samples were oven dried at 60ºC for two days thereafter subjected to analysis regarding pH, EC, nitrogen (Micro Kjeldahl) content, carbon (Walkey and Black) content, total potash (diacid extract), total phosphates (vanadomolybdo phosphoric yellow method), Cu, Zn, Fe, Mn and B contents using AAS. The data were analysed using ANOVA to test the significance level of variations in physico-chemical properties of compost.

Results and Discussion

Physico-chemical parameters of compost

Temperature, pH and EC: The co-composting treatments had significant effect on the temperature, pH and EC (Table 2) of compost at 120 days after initiation (DAI). The temperature of the surrounding air influenced the temperature of the composting process. Throughout the composting period, temperature levels exhibited an initial increase followed by a gradual decline towards the end, within the ambient temperature range of 20 to 34°C. Elevated levels of readily decomposable proteins and carbohydrates served as rapid energy substrates for microbial activity, facilitating their metabolic processes. The microbial activity was evident from the temperature rise. At 120 DAI, the co-compost of water hyacinth + cow dung at both the weight ratios recorded the lowest temperature (26.56 °C and 26.73°C respectively). Similar trend in temperature variations was observed by Tumuhairwe et al. (2009), Raj and Antil (2011), Prasad et al. (2013) and Beesigamukama et al. (2018). Also, significantly higher pH of 7.2 and 7.1 respectively were obtained in water hyacinth + cow dung (1:1 and 2:1) whereas, the remaining co-composts were comparable. During composting, pH levels initially increased and then dropped to 7.0, creating an optimal microbial environment (Singh and Kalamdhad, 2013). The increase in pH observed at the beginning of the composting process probably stemmed from the breakdown (decarboxylation) of organic acids and the liberation of ammonia. The ammonia thus generated, upon reacting with water, generated ammonium and free OH ions, leading to an elevation in pH levels (Wong and Selvam 2006; Lu et al., 2014). In contrast, a pH drop at later stage observed could be caused by the production of phenolic compounds and the nitrification process, or by the microbial absorption of CO_2 and production of organic acids (Singh et al., 2015).

Table 1. Initial characteristics of the composting material

	Cow dung	Poultry manure	Pig manure	Water hyacinth
N (%)	1.03	1.53	0.93	1.05
P (%)	0.52	0.7	0.58	0.6
K (%)	0.64	0.86	0.8	1.14
C:N ratio	19.2	13.6	26.5	39.1
Moisture content (%)	58.6	27.3	45.2	90.4
Fe (mg/kg)	1925.1	1069.2	1891.7	1328.4
Zn (mg/kg)	116.4	127.3	131.5	58.2
Mn (mg/kg)	314.5	388.4	294.8	612.7
Cu (mg/kg)	46.8	180.1	227.7	44.2
B (mg/kg)	14.57	16.19	15.52	18.33

Table 2. Effect of co-composting of water hyacinth on temperature, pH, and EC of compost at 120 DAI

Treatments	Temp.(°C)	pH	EC
Water hyacinth + cow dung (1:1)	26.73	7.20	1.89
Water hyacinth + cow dung (2:1)	26.57	7.10	1.68
Water hyacinth + pig manure (1:1)	27.76	6.86	2.46
Water hyacinth + pig manure (2:1)	27.70	6.80	2.54
Water hyacinth + poultry manure (1:1)	27.50	6.80	2.64
Water hyacinth + poultry manure (2:1)	27.46	6.83	2.72
Water hyacinth + EM (10:1.5)	28.53	6.80	1.62
Water hyacinth + *Pleurotus* (1000:1.5)	28.63	6.70	1.54
Water hyacinth alone	28.70	6.86	1.46
SE(m) (±)	0.09	0.06	0.05
LSD (0.05)	0.286	0.189	0.167

Electrical conductivity (EC) of the co-composts at 120 DAI was estimated and presented in table 2. The greater salt content was evidenced by a higher EC. The data pertaining to electrical conductivity of final composts revealed that all the co-composting treatments ranged from 1.46 – 2.72 dS/m at 120 DAI which is in accordance with the threshold value of 3 dS/m (Lazcano et al., 2008). Water hyacinth + poultry manure (2:1) showed significantly higher EC of 2.72 dS/m and the lowest EC (1.46 dS/m) was observed in the compost of water hyacinth alone. Towards the final stage of composting, the decline in EC may be attributed to processes such as ammonia volatilization and the precipitation of mineral salts (Kalamdhad et al., 2009; Mamo et al., 2021).

C: N ratio and NPK content: C:N ratio is considered as the most important determinant of compost maturity and the extent of decomposition. At 120 DAI, all treatments showcased a C:N ratio below 20 when compared to the initial C:N ratio of water hyacinth (39.1) (Table 1), denoting substantial decomposition across varied composting materials. Notably, irrespective of the compost constituents, a notable reduction in C:N ratio was observed in the final product compared to the raw materials, indicative of heightened compost decomposition

Table 3. Effect of co-composting treatments of water hyacinth on C:N ratio and NPK content (%) of compost at 120 DAI

Treatments	C:N ratio	N content	P content	K content
Water hyacinth + cow dung (1:1)	7.80	2.035	0.787	0.894
Water hyacinth + cow dung (2:1)	7.66	2.165	0.887	0.981
Water hyacinth + pig manure (1:1)	7.96	1.699	1.023	0.997
Water hyacinth + pig manure (2:1)	7.86	2.147	1.397	1.597
Water hyacinth + poultry manure (1:1)	7.70	2.128	1.117	1.699
Water hyacinth + poultry manure (2:1)	7.53	2.557	1.380	2.132
Water hyacinth + EM (10:1.5)	10.36	1.923	0.350	0.797
Water hyacinth + *Pleurotus* (1000:1.5)	10.70	1.941	0.360	0.765
Water hyacinth alone	10.96	1.475	0.377	0.833
SE(m) (±)	0.20	0.048	0.017	0.019
LSD (0.05)	0.602	0.1420	0.0505	0.0557

(Table 3). The control treatment (water hyacinth alone) exhibited the highest C: N ratio of 24.76, similar to water hyacinth + *Pleurotus* (1000:1.5) treatment. Conversely, the water hyacinth + poultry manure (2:1) treatment registered the lowest C: N ratio of 7.53 at 120 DAI. These findings align with those of Beesigamukama et al. (2018), who reported a comparable decrease in C: N ratio through co-composting, ranging from 5.9 to 7.5 for mature compost.

At 120 DAI, significant variation was evident in the N, P and K concentrations among the co-composting treatments (Table 3). Co-composting of water hyacinth with poultry manure (2:1) exhibited higher N, P, and K content (2.557% N, 1.397% P, and 2.132% K) compared to control (1.475% N, 0.377% P, and 0.833% K), highlighting the efficacy of co-composting. Moreover, the incorporation of additives such as EM and *Pleurotus* accelerated decomposition without providing a reservoir for soluble minerals, thereby leading to increased mineral losses. This finding aligns with Raj and Antil (2011), who noted that the addition of poultry manure and cow dung enhanced nitrification and ammonification by maintaining an aerated environment for decomposers. Similarly, Beesigamukama et al. (2018) reported N, P and K contents of 2.21%, 1.36%, and 1.5% respectively, in water hyacinth + poultry manure co-composting treatment using the pile method. Furthermore, Sultana et al. (2022) observed higher N, P and K concentrations with the combination of water hyacinth and poultry litter (1:1).

The water hyacinth + poultry manure in (2:1) produced the highest total phosphorus concentration at 1.397%, which was comparable to water hyacinth + pig manure composted at 2:1 ratio. This similarity can be attributed to the initially high phosphorus content in both poultry and pig manure. Detpiratmongkol et al. (2014) reported higher phosphorus content in pig manure (2.4%) and poultry manure (2.11%). In compost, phosphorus primarily exists as orthophosphate ions, which are relatively immobile. Consequently, minimal phosphorus is lost, as the orthophosphate ions form compounds with the cations and ligands of organic substances.

Enhanced K content observed in water hyacinth + poultry manure (2:1) treatment can be attributed to the initial K concentration present in both poultry manure and water hyacinth, as well as the high moisture levels facilitating complete mineralization of K. Additionally, apart from the K naturally occurring in water hyacinth biomass, the co-composting materials also contributed to the K content, further augmenting levels in the mature compost. Detpiratmongkol et al. (2014) reported high K content in poultry manure (2.33%), pig manure (1.88%), and cow manure (1.02%). To further mitigate losses of N, P and K, it is recommended to incorporate higher quantities of cow dung, poultry manure, and pig manure, either individually or in combination, during the composting process.

Micro nutrients: At 120 DAI, significant variations were observed in the micro-nutrient content among the co-composting treatments (Table 4). Notably, the water hyacinth + pig manure (2:1) treatment displayed a significantly higher Zn content at 309.0 mg/kg. This finding aligns with the study by Fan et al. (2015), who recorded a Zn content of 307 mg/kg in water hyacinth compost supplemented with 30 per cent pig manure. Importantly, none of the co-composts exceeded the permissible limit of 1000 mg/kg for zinc (DOA, 2013). Furthermore, the water hyacinth + cowdung in 1:1 revealed a significantly higher Fe content of 5780.23 mg/kg. Although the highest Fe content of 9184.13 mg/kg was reported by Indulekha (2016) using the Bangalore method of composting of water hyacinth, this treatment still showcased notable Fe levels. Conversely, the water hyacinth + poultry manure (1:1) and water hyacinth + pig manure (2:1) treatments exhibited comparable Mn content, with values of 1839.33 mg/kg and 1810.33 mg/kg, respectively. Prasad et al. (2013) reported a Mn content of 1182.5 mg/kg for water hyacinth + cattle manure compost, corroborating similar trends observed by Indulekha (2016) after 6 months of water hyacinth composting. Moreover, the highest Cu content was observed in the water hyacinth + pig manure (2:1) treatment at 354.33 mg/kg. This aligns with findings by Hölzel et al. (2012) and Li et al. (2015), who reported elevated levels of copper in pig manure, likely due to copper additions in animal diets for growth promotion and disease management (Lu et al., 2014). Additionally, the composting process led to an increase in total Cu concentration due to weight loss during organic matter decomposition and CO_2 and water emission (Singh and Kalamdhad, 2013). Furthermore, the water hyacinth + poultry manure (2:1) and water hyacinth + cow dung (2:1) treatments exhibited comparable B content, with values of 41 mg/kg and 39 mg/kg, respectively. Sultana et al. (2022) reported higher boron concentrations (414 mg/kg) in the co-composting treatment of water hyacinth + poultry litter (1:1), which was consistent with present findings.

Compost maturity and recovery percentage: Composting treatments had significant influence on both the maturityof compost and compost recovery percentage (Fig 1 & 2.). Among the different co-composting treatments, water hyacinth + cow dung (1:1) took the least number of days (107 days) for attaining maturity which was on par with water hyacinth + poultry manure (1:1) (108 days) and water hyacinth + poultry manure (2:1) (114 days).The observed influence could be attributed to the heightened microbial activity facilitated by the elevated moisture content present in cow dung and poultry manure. Nitrogen, an essential element for microbial growth and development, plays a pivotal role in composting processes. Both cow dung

Table 4. Effect of co-composting treatment of water hyacinth on Zn, Fe, Mn, Cu and B content of compost at 120 DAI, mg/kg

Treatment	Zn	Fe	Mn	Cu	B
Water hyacinth + cow dung (1:1)	220.66	5780.23	1210.0	115.66	34.33
Water hyacinth + cow dung (2:1)	257.66	4875.10	1381.33	139.66	39.00
Water hyacinth + pig manure (1:1)	282.33	4705.76	1454.0	327.33	33.33
Water hyacinth + pig manure (2:1)	309.00	4117.93	1810.33	354.33	34.00
Water hyacinth + poultry manure (1:1)	233.00	3931.70	1839.33	268.66	34.67
Water hyacinth + poultry manure (2:1)	267.66	3744.03	1645.0	294.33	41.00
Water hyacinth + EM (10:1.5)	149.66	3034.83	1346.33	188.66	31.33
Water hyacinth + *Pleurotus* (1000:1.5)	145.00	2851.43	1199.0	154.00	25.67
Water hyacinth alone	139.33	3058.26	1251.66	95.33	30.33
SE(m) (±)	3.68	59.77	30.55	3.62	0.79
LSD (0.05)	10.939	177.588	90.798	10.768	2.357

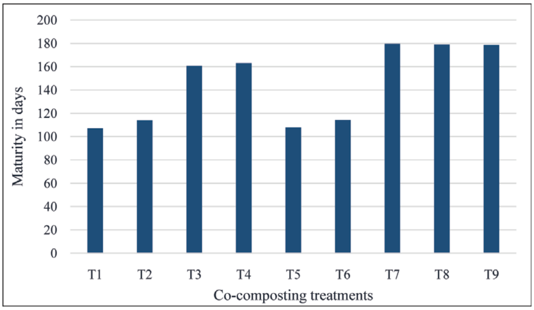

Figure 1. Effect of co-composting treatments of water hyacinth on compost maturity

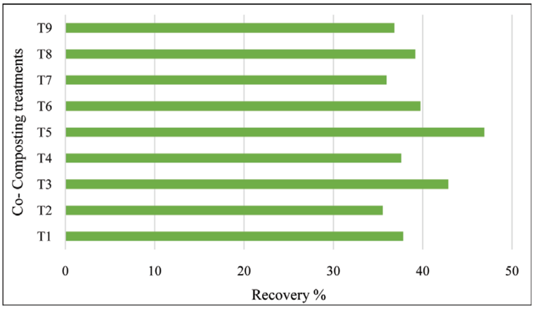

Figure 2. Effect of co-composting treatments of water hyacinth on recovery per cent

and poultry manure serve as readily available carbon sources for microbial metabolism. Factors such as wider C: N ratios, elevated lignin and cellulose content, among others, may contribute to the delayed maturation of compost.Similar studies focusing on co-composting water hyacinth with poultry manure, cow dung, and EM solution in pile method have reported accelerated compost maturity within a period of 42 days (Beesigamukama et al., 2018). Significantly higher compost recovery percentage was recorded in water hyacinth + poultry manure (1:1) (46.89%), followed by water hyacinth + pig manure (1:1) (42.86%). The least recovery was obtained in the co-composting of water hyacinth + cow dung in 2:1 ratio (35.53%) which was on par with water hyacinth + EM in 10:1.5 ratio (35.95 %) and water hyacinth + *Pleurotus* in 1000:1.5 ratio(39.17 %). The higher compost recovery observed could potentially be attributed to the lower moisture content and higher dry matter content present in poultry manure. Similar findings were reported by Guerra-Rodriguez et al. (2001) on the advantage of poultry manure in improving the recovery per cent of compost material thereby avoiding wastage. Yadav (2005) reported that, poultry manure added to the composting material in higher quantities could enhance the recovery of compost.

Conclusion

The study demonstrates the efficacy of co-composting water hyacinth with various types of manure, providing a practical method for managing this invasive species in Kerala's water bodies. The co-composting of water hyacinth with poultry manure in a 2:1 ratio was particularly effective, yielding compost with significantly higher levels of nitrogen (N), phosphorus (P), and potassium (K), along with a lower carbon-to-nitrogen (C: N) ratio. This indicates enhanced decomposition and faster compost maturity, resulting in a high nutrient recovery percentage and increased levels of micronutrients like manganese (Mn) and boron (B). Additionally, compost produced using a 2:1 ratio of water hyacinth to pig manure was noted for its higher zinc (Zn) content, while both poultry manure and cow dung combinations resulted in comparable boron (B) levels. The lowest nutrient recovery was observed in the combination of water hyacinth with cow dung, emphasizing the significance of selecting appropriate co-composting materials and ratios for optimal results. This study not only provides an eco-friendly solution to the problem of water hyacinth management but also contributes to sustainable agricultural practices by producing nutrient-rich compost that can enhance soil fertility and reduce dependence on chemical fertilizers.

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