Indian Journal of Ecology (2023) 50(5) (SI): 1608-1613
DOI: https://doi.org/10.55362/IJE/2023/4103

Manuscript Number: 4103
NAAS Rating: 5.79

Aquatic Weeds and Rice Chaff: Potential Inputs for Generation of Organic Manures in Rice Based Integrated Farming System

Anjali S., Sudha B.*, Shalini Pillai P., Jacob John[1] and Aparna B[2]

Department of Agronomy, College of Agriculture, KAU ,Vellayani -695 522, India
[1]Integrated Farming System Research Station, KAU, Karamana-695 002, India
[2]Department of Organic Agriculture, College of Agriculture, KAU, Vellayani-695 522, India
**E-mail: sudha.b@kau.in*

***Abstract*:** An experiment was carried out at Integrated Farming System Research Station (IFSRS), Kerala Agricultural University, India to assess the potential of aquatic weeds and rice chaff associated with rice-based IFS in generating good quality organic manures. In the study, different substrates like water hyacinth, salvinia, wild taro and rice chaff were co-composted using organic inputs *viz.,* cow dung, goat manure or poultry manure in the ratio 4:1:1 on volume basis. Parameters like time taken for composting, per cent recovery, pH, EC, C: N ratio and nutrient content of mature composts were analyzed. Co-composting of wild taro with cow dung and goat manure in the ratio 4:1:1 (v/v) resulted in significant earliness in maturity and narrower C: N ratio, comparable to water hyacinth + cow dung + goat manure. Percentage recovery was significantly higher in the co-composting treatment of rice chaff with cow dung and poultry manure. Regarding the macro nutrient content, co-composting of water hyacinth with cow dung and goat manure recorded significantly higher NPK content. The study therefore highlights the potential of bio resources in a rice-based IFS to generate good quality organic manures.

Keywords: Aquatic weeds, Co-composting, Rice chaff, Bio recycling, Rice-based IFS

The switchover to integrated farming systems from the traditional monoculture was felt during the context of Covid-19 pandemic in India. The fundamental principle of IFS; bio recycling gives thrust in reducing the purchase of external inputs and maximum utilization of bio resources within the system. The main concept of integrated farming systems is that the byproduct of one enterprise becomes the input for another. Efficient utilization of all possible organic resources generated in IFS therefore requires prime consideration (Sharma et al 2019). In this way, over dependence on chemical fertilizers can be reduced and eco-friendly farming is encouraged in an IFS. Ecofriendly farming techniques have multiple benefits especially on long term maintenance of soil health (Bhatia et al 2016).

Rice, is the main food crop of India and it has a great role in shaping the lives of people. Rice based integrated farming systems offer great scope for bio recycling and on farm generation of inputs (Sudha et al 2020). Aquatic weeds associated with rice growing wetlands and adjacent water bodies generate huge amount of biomass and contain plant nutrients, making them ideal substrates for composting (Dissanayaksa et al 2023). Rice chaff, a crop residue obtained during winnowing of paddy is yet another resource which could be effectively recycled (Thiyageshwari et al 2018). Besides, nitrogen rich manures from livestock also could be utilized for recycling. Aquatic weeds are often considered a menace due to their fast spread as well as negative impact on aquatic environment. Wild taro (*Colocasia esculenta*) is an aggressive weed that can form dense stands along waterways (Cozad et al 2018). Vast areas of lowland paddy in Kerala are badly infested with aquatic weeds *Eichhornia crassipes* and *Salvinia molesta,* hindering paddy cultivation and the losses caused by these weeds range from 30 to 60 per cent (Jayan and Sathyanathan 2012). Utilizing the biomass of these weeds for manure production offers dual benefits of weed control and nutrient generation. Rice chaff, obtained during winnowing of paddy is another abundantly available bio resource in a rice-based IFS. Rice chaff often considered as a waste product is a rich source of silica (Sekifuji and Tateda 2019) and the prospects of recycling rice chaff in such an angle is less studied in Kerala. The potential of aquatic weeds and rice chaff in bio recycling is immense. But there are certain factors that challenge the possibility of recycling these substrates. Rice chaff has a wide C: N ratio (Demir and Gulser 2015) as well as high cellulose and lignin contents (Singh 2018) hindering microbial degradation. Similarly, the aquatic weeds also have wide C: N ratio and ligno-cellulose content. Composting these substrates with nitrogen rich manures can only tackle this problem.

Composting is an effective method to sustainably recycle agro-wastes, weeds *etc*. into useful products and is an effective solid waste management technique for preparing nutrient rich manure from crop residues having wider C: N ratio (Waqas et al 2023). The use of co-composting technology is preferred for recycling many agricultural wastes into safer and more stable materials as soil amendment (Omar et al 2021). The prospects and possibilities of co-composting of organic resources in a rice based integrated farming system have been already proved in Kerala (Athira et al 2021). Many studies are oriented towards co-composting of water hyacinth and salvinia, but less studies are reported regarding the co-composting of rice chaff and wild taro. As reported by Singh et al (2015), composting of salvinia biomass with adequate quantity of cattle manure resulted in good quality compost. Addition of cattle manure and rice husk hastened the composting process of *Salvinia natans* (Singh 2015). Therefore, the present study aimed to generate good quality composts from the bio resources *viz.,* water hyacinth, salvinia, wild taro and rice chaff via co-composting with organic manures such as cow dung/ poultry manure or cow dung/goat manure in 4:1:1 ratio (v/v). The composts thus generated can substitute a part of chemical fertilizers thereby promoting ecofriendly farming.

MATERIAL AND METHODS

The experiment was carried out during September to December 2021 at the Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala under Kerala Agricultural University (KAU) located at 8° 28' 28” North latitude and 76° 57' 47” East longitude, at an altitude of 5 m above MSL. The composting study was laid out in completely randomized design with eight treatments and three replications. Different aquatic weeds were collected from the channels and bunds of IFSRS, Karamana and were given a wilting period of 10 days. Partially withered rice chaff obtained after 10 days of harvest from the variety Uma was also utilized for composting. Later these substrates were mixed with either cow dung/poultry manure or cow dung/goat manure in the ratio 4:1:1 on volume basis and filled in concrete pits of size 1 m^3 as per the treatments (Table 2). The nutrient content of manures and composition of different substrates used in the study are detailed in Table 1 and 3. The compost pits were turned once in a week to ensure aeration and easy decomposition. Adequate moisture levels were also maintained. Mature composts were sieved, shade dried and stored.

Observations such as time taken for maturity, per cent recovery (Table 4), chemical properties *viz.,* pH, EC and C: N ratio (Table 5) as well as nutrient content of mature composts (Table 6) were recorded by following standard procedures. Maturity of composts was determined initially based on visual observation and then confirmed upon C: N ratio narrowed down to less than 20 (Khater 2015). Per cent recovery was estimated by dividing the quantity of output to the quantity of input multiplied by 100. Samples obtained from each treatment on maturity were mixed with water in the ratio 1:5 and pH were measured using pH meter with glass electrode (Jackson, 1973). Compost-water solution used for determination of pH was again used for estimating electrical conductivity (EC) using conductivity meter (Jackson 1973). The carbon content of compost samples was determined using weight loss on ignition method (FAI 2017) and total N content was estimated by microkjeldhal method (Jackson 1973). The ratio of carbon to nitrogen was worked out and expressed as C: N ratio. For the estimation of P, nitric perchloric acid digestion (9:4) was followed by estimation with vanadomolybdate phosphoric yellow colour method

Table 1. Nutrient content of manures used in the study

Manure	N (%)	P (%)	K (%)
Cow dung	1.12	0.76	0.80
Poultry manure	1.79	0.75	0.98
Goat manure	2.30	0.81	1.24

Table 2. Co-composting of substrates using organic manures

T_1	Rice chaff + cow dung + poultry manure
T_2	Water hyacinth + cow dung + poultry manure
T_3	Salvinia + cow dung + poultry manure
T_4	Wild taro + cow dung + poultry manure
T_5	Rice chaff + cow dung + goat manure
T_6	Water hyacinth + cow dung + goat manure
T_7	Salvinia + cow dung + goat manure
T_8	Wild taro + cow dung + goat manure

Organic resources were mixed with manures in the ratio 4:1:1 (v/v basis)

Table 3. Composition of substrates before composting

Substrate	Lignin (%)	Cellulose (%)	C:N Ratio	N (%)	P (%)	K (%)
Rice chaff	20.28	41.12	61.34	0.90	0.49	0.97
Water hyacinth	18.60	29.35	39.30	1.07	0.67	1.18
Salvinia	17.71	35.15	58.54	0.73	0.61	0.47
Wild taro	15.25	23.76	39.12	0.63	0.25	0.38

using spectrophotometry (Jackson, 1973). K was estimated using nitric perchloric acid digestion (9:4) and flame photometry (Jackson 1973).

RESULTS AND DISCUSSION

Time taken for maturity: Different treatments had a significant influence on the time taken for maturity of composts. Co-composting of wild taro with cow dung and goat manure in the ratio 4:1:1 on volume basis recorded significant earliness in compost maturity, comparable to co-composting of water hyacinth with cow dung and goat manure. Significantly the longer time was observed in co-composting of rice chaff with cow dung and poultry manure in the ratio 4:1:1. Time taken for compost maturation was related to the initial composition of substrates *viz.,* lignin, cellulose contents and C: N ratio. The C: N ratio of different substrates used in this study followed the order; wild taro < water hyacinth < salvinia < rice chaff. As the C: N ratio of the composting substrate increases, the time taken by microbes to degrade those materials increases thereby prolonging the composting process (Yang et al 2021). The content of lignin and cellulose as well as C: N ratio was lower for the substrate wild taro; attributing to its early maturation. Factors such as wider C: N ratio, higher lignin and cellulose content of rice chaff could be related to the delay in compost maturation. Maruf et al (2017) opined that lignin and cellulose contents are high in rice chaff. High content of lignin in rice chaff hindered its decomposition by micro-organisms which in turn delayed the composting (Matin and Hadiyanto 2018). Thiyageshwari et al (2018) reported that the silica coating of rice chaff could also slow down composting process.

Recovery of compost: Recovery percentage indicates the quantity of output (compost) obtained per quantity of input (substrate) used for composting. T_1 (co-composting of rice chaff with cow dung and poultry manure in the ratio 4:1:1) recorded the highest recovery percentage (29.85 %) whereas the lowest recovery percentage (14.91 %) was recorded by T_8 (wild taro + cow dung + goat manure in 4:1:1 ratio). As compared to other substrates like salvinia, water hyacinth and wild taro, the moisture content was lower (16.91 %) and content of dry matter was higher in rice chaff which could be attributed to the higher recovery. Sreesvarna et al (2019) reported similar results of lower moisture content in rice chaff (8.64 %) which could result in higher recovery. Among the treatments, wild taro compost recorded significantly lower recovery. This could be related to the higher initial moisture content of wild taro (96.14 %) which added lesser biomass to the composting lot resulting in lesser recovery. Apart from this, the underground tubers of wild taro resist microbial degradation thereby reducing the recovery percentage. Wild taro has high moisture content (92.4 %) (Preiato, 2020) which reduces biomass addition to composting lot. In a composting trial conducted at United States using wild taro, Sembera et al (2019) reported that some of the propagules of wild taro remained undecomposed after composting and the propagules could be decomposed after an additional composting cycle only.

Table 4. Effect of different treatments on time taken for composting and percentage recovery

Treatments	Time taken (Days)	Recovery (%)
T_1	112.00	29.85
T_2	75.67	23.75
T_3	99.00	25.14
T_4	74.67	15.65
T_5	102.67	27.54
T_6	65.67	20.70
T_7	90.67	21.52
T_8	64.00	14.91
CD (p=0.05)	1.217	0.708

Table 5. Effect of different treatments on chemical properties of mature composts

Treatments	pH	EC (dS m^{-1})	C:N ratio
T_1	6.96	0.81	15.79
T_2	7.12	0.80	14.22
T_3	7.12	0.82	15.42
T_4	7.36	0.78	14.17
T_5	7.03	0.79	13.81
T_6	7.15	0.80	12.58
T_7	7.21	0.81	13.80
T_8	7.45	0.78	12.33
CD (p=0.05)	NS	NS	0.706

Table 6. Nutrient content of composts generated under different treatments

Treatments	N (%)	P (%)	K (%)
T_1	1.93	0.79	1.70
T_2	2.18	0.97	1.90
T_3	2.02	0.83	1.56
T_4	1.76	0.62	1.44
T_5	2.04	0.87	2.62
T_6	2.28	1.09	2.70
T_7	2.11	0.96	1.90
T_8	2.04	0.83	1.55
CD (p=0.05)	0.100	0.041	0.102

In the present study, among the different organic manures used for co-composting these substrates, poultry manure had an advantage over goat manure in terms of recovery percentage. Being low in moisture content, poultry manure added more of dry matter to the composting lot, naturally contributing to higher recovery. Guerra-Rodriguez et al (2000) had established the advantage of poultry manure in complete decomposition of composting material thereby avoiding wastage and hence better recovery. Yadav (2005) reported that, poultry manure added to the composting material in higher quantities could enhance the recovery of compost.

Major chemical properties of mature composts: The chemical properties *viz.,* pH and EC were not significantly influenced by different treatments. However, the C: N ratio differed significantly and the final C: N ratio had a connection with the type of substrate as well as organic manure combination used in the study. pH ranges from values 1 to 14. At the initial stages of composting, organic acids are produced which makes the pH acidic. Later on, the organic acids get neutralized and at the end of composting, the pH falls between 6 to 8. Different co-composting methods have no significant influence on the pH of composts. The pH of the composts generated in the study fell in the range of near neutral to slightly alkaline pH ranging from 6.96 to 7.45. Electrical conductivity varies depending on the release of mineral ions during decomposition. This can be influenced by the different N sources added to the composting substrate. Higher EC causes phytotoxicity and hence EC values of < 4 dS/m are preferred for composts (Yadav and Garg 2013). The EC values of different composts generated in the study were in safe limits (0.78 to 0.82 dS/m) and hence suitable for soil application. However, different composting methods could not significantly influence the EC of mature composts. C: N ratio regarded as the maturity index of composts is a key indicator of compost maturity. Different treatments had a significant impact on the final C: N ratio of mature composts. The best treatment in terms of significantly narrower C: N ratio (12.33:1) was T_8 which was comparable to T_6. The treatment with wider C: N ratio of mature compost was T_1 (co-composting of rice chaff with cow dung and poultry manure). This could be related to the initial C: N ratio of the substrates which followed the order; rice chaff > salvinia > water hyacinth > wild taro (Table 3). Co-composting could significantly reduce the C: N ratio of these substrates to the acceptable range of less than 30:1.

In the present study, C: N ratio of different composts varied from 12.33 to 15.79. The narrowing down of C: N ratio of different substrates could be related with the carbon usage during composting. Carbon is used up as an energy source for the metabolism of micro-organisms and the intense microbial activity results in a decrease in carbon content of the composting material. Simultaneous addition of N rich organic manures increases the N level as well as the activity of N fixing bacteria (Raj and Antil 2011). Because of these reasons C: N ratio of mature composts narrow down to the desired level. As the nitrogen content of organic manures used for composting increases, the C: N ratio of the final composts narrow down rapidly. The nitrogen content of different manures used in the current study followed the order; goat manure (2.30) > poultry manure (1.79) > cow dung (1.12). The treatments with cow dung and goat manure as organic sources had higher nitrogen content as compared to the poultry manure-cow dung combination thereby reducing the C: N ratio to a narrow value. This in confirmation with the results of a composting experiment done at KAU (Athira et al 2021).

The C: N ratio of final composts in the current study followed the order; wild taro compost < water hyacinth compost < salvinia compost < rice chaff compost. Sembera et al (2019) observed that the final C: N ratio of wild taro compost ranged between 12.4 to 13.4. Zuhair et al (2022) reported that taro leaves composted using cow dung as nitrogen source could result in a C: N ratio of 11.23 for mature compost. Similarly, the C: N ratio of water hyacinth considerably narrowed down up to 14.2 at the end of composting (Sasidharan et al 2013). In the current study, rice chaff compost recorded wider C: N ratio. Liu et al (2011) reported similar values of C: N ratio of rice chaff compost as 16.7.

Nutrient status of mature composts: Different co-composting treatments had a significant influence on the content of macro nutrients and all the composts had an enhanced nutritional value compared to the substrates used. The nitrogen content (%) of different substrates used in the study were rice chaff (0.9), salvinia (0.73), water hyacinth (1.07) and wild taro (0.63) (Table 3). The best treatment in terms of significantly higher nitrogen content was T_6. As compared to other substrates used in the study, the content of nitrogen, phosphorus and potassium were higher in water hyacinth. This was also reflected in the final nutrient status of water hyacinth compost. Addition of nitrogen rich goat manure along with cow dung enhanced the final nutrient content of water hyacinth compost (T_6). Composts with higher nitrogen content could be generated from water hyacinth by co-composting it with goat manure (Napoleon et al 2021). Among the co-composting treatments, T_4 recorded the least nitrogen content. This could be attributed to the lower nutrient status of wild taro and the higher moisture content of this weed. As the moisture content is high, the biomass addition and hence nutrient deposition was less. The leaching loss of nutrients during the wilting period of wild taro accounting to higher moisture content could also be related with this.

The initial phosphorus status (%) of substrates used were; rice chaff (0.49), salvinia (0.61), water hyacinth (0.67) and wild taro (0.25). The best treatment in terms of significantly higher phosphorus content was T_6. This might be due to the higher P content in water hyacinth over other substrates. Sasidharan et al (2013) reported the phosphorus content of water hyacinth compost as 2.72 per cent. Beesigamukama et al (2018) obtained P rich composts from water hyacinth by way of co-composting with poultry manure. The lowest phosphorus content was recorded in the co-composting treatment T_4. As the water content in wild taro is high, a large amount of nutrients is lost through leaching thereby reducing the nutritional content of final compost. In a composting trial, Sembera et al (2019) reported that the content of phosphorus in wild taro compost ranged between 0.31 to 0.43 per cent only. Composting wild taro leaves with cow dung generated compost with lower phosphorus content of 0.45 per cent (Zuhair et al 2022). The total K content was higher in T_6 and was comparable to T_5. The enhanced content of potassium in these co-composting treatments can be related with the initial higher potassium content of the substrates; water hyacinth (1.18) and rice chaff (0.97). In a composting trial, co-composting of water hyacinth resulted in a higher potassium content of 3.10 per cent (Seoudi 2013). Water hyacinth could be effectively used as a substitute for potash because of its richness in potassium content (Alam et al 2017). Similar results of higher initial K content in water hyacinth and generation of K rich composts were reported by Beesigamukama et al (2018). Abubakari et al (2019) reported that the rice husk is a potential source of potassium and addition of nutrient rich manures further improved the potassium content of the composts generated from it. Tyopine and Aondoaver (2014) concluded that potassium rich manures can be produced from rice husk. Among the co-composting treatments, the lowest potassium content was recorded in T_4 which is attributed to the lower content of potassium in wild taro stalks utilized for composting.

CONCLUSION

The aquatic weeds and rice chaff, associated with rice based integrated farming system can be effectively recycled for generating good quality composts. These substrates can be composted easily by the common and locally available manures such as cow dung, poultry manure and goat manure. Co-composting of wild taro with cow dung and goat manure in the ratio 4:1:1 ratio on volume basis resulted in the generation of composts rapidly and with significantly narrower C: N ratio, comparable to water hyacinth compost prepared from cow dung and goat manure. However, the recovery percentage of wild taro compost was significantly lower when compared to other treatments. Co-composting of rice chaff with cow dung and poultry manure recorded the highest recovery percentage; but the time taken for compost maturity was longer. Regarding the content of major nutrients, co-composting of water hyacinth with cow dung and goat manure in the ratio 4:1:1 (v/v) recorded significantly higher N, P and K content. From the view point of a farmer, co-composting of water hyacinth with cow dung and goat manure can be recommended as this compost can be generated within a shorter period of 66 days with significantly narrower C:N ratio (12.58) and a fair recovery percentage (20.7 %) with significantly higher content of macro nutrients. The compost generated via co-composting was nutritionally better than farmyard manure and incorporating these bio resources in crop production can reduce the over-dependence on chemical fertilizers.

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Received 04 April, 2023; Accepted 26 October, 2023