INFLUENCE OF SILICA RICH BIO-DEGRADED LIGNIN APPLICATION ON C SEQUESTRATION IN AEROBIC RICE (*ORYZA SATIVA* L.) VAR. TPS 5 WHILE DEVELOPING AN INTEGRATED SOLID WASTE MANAGEMENT STRATEGY FOR THE APPTA MARKET

PRABAKARAN, C.

Subject Matter Specialist (Environmental Sciences) ICAR-KVK, Needamangalam-614404, Thiruvarur, Tamil Nadu, India
(e-mail: prabakaran.c@tnau.ac.in)

(Received 15th Aug 2023; accepted 13th Jun 2024)

Abstract. Lignin and silica rich organic waste of Agricultural Product Producers and Traders Association (APPTA) market waste was attempted to convert into enriched bio-compost through aerobic heap method using microbial suspension. A field experiment was conducted at the Agricultural Research Station, Thirupathisaram in order to utilize the enriched compost to enhance carbon sequestration potential of aerobic rice (Oryza sativa L.) var. TPS 5. The recommended dose of fertilizer applied along with 5 t ha^{-1} of enriched bio-compost increased the total carbon stocks from 15.39 to 20.18 t ha^{-1}. A 70% increase in carbon stocks in the plant biomass was recorded and a 4% increase in soil over control/check. Higher carbon input to the soil and the system, carbon sequestration rates, straw yield (5.8 t ha^{-1}), and grain yield (8 t ha^{-1}) were also recorded. A 263% increase over control in grain yield and a 353% increase over control in straw yield were also recorded due to the application of the recommended dose of fertilizer applied along with 5 t ha^{-1} of enriched bio-compost. phytolith-occluded carbon (PhytOC) content of rice increased due to the application of APPTA market waste bio-compost with 75% N fertilizer. From this study, it is found that the APPTA market waste should be composted and the bio-compost should be applied to aerobic paddy at the rate of 5 t ha^{-1} along with the recommended dose of fertilizers with an objective to increase the yield as well as long-term sequestration of carbon.
Keywords: *bio-compost, aerobic rice, carbon sequestration, carbon fractionation, straw yield, and grain yield*

Introduction

Increased concentrations of greenhouse gases increased the global average temperature (global warming) leading to drought conditions or changing rainfall patterns. Increased water scarcity due to climate change implies a need for the development of alternate crops along with the development of rice systems with less water requirement than traditional puddled paddy. Moreover, rice grown under traditional puddled paddy (flooded conditions) is one of the sources of CH_4 emission that has 28 times more global warming potential (GWP) than CO_2 over a 100-year time horizon (IPCC, 2013). An aerobic rice system is sown directly in non-puddled un-flooded aerobic soil with a limited water supply and recommended fertilizer application.

Carbon sequestration is the capturing, removal and storage of CO_2 from the atmosphere of the earth. It is recognized as a key method for removing carbon from the earth's atmosphere. Soil is considered the largest carbon pool (C) of the terrestrial biosphere (Kang et al., 2011). The main objective of soil carbon sequestration is to convert atmospheric CO_2 into stable long-lived soil carbon pools that help to mitigate global warming. Phytoliths also referred to as plant stone (silica bodies) produced by plants as a result of the process called bio-mineralization and facilitating the occlusion

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

of carbon within the phytoliths (PhytOC). Carbon occluded within phytoliths of crop plants such as rice and sugarcane is an important fraction of SOC that can remain in the soil for a longer period (millennia) (Par and Sullivan, 2005). Therefore, by enhancing the PhytOC production in crop plants and subsequent accumulation in the soils, terrestrial carbon sequestration can be greatly improved.

PhytOC research suggested that carbon occluded in phytoliths are easy to quantify besides demonstrating the benefits on a long-term basis. Future research must focus more on soil carbon sequestration in phytoliths in order to witness real-time sequestration and promote carbon trading (Rajkishore et al., 2015).

Rapid urbanization and consumerism increased significant quantities of waste generation in residential and commercial areas leading to disposal problems. Integrated Solid Waste Management (ISWM) represents an advanced and orderly planned approach to solid waste management. One of the components or functional elements of ISWM includes recycling and composting to maximize resource use efficiency. Recycling and composting of wastes pushes forward the concept of a circular economy where smaller quantities to no material are wasted (cent percent is used). Composting is a carbon sink because the net greenhouse gas impact from composting all types of organics is negative, which means composting stores more carbon in the soil than it emits to the air.

According to the Tamil Nadu Pollution Board (TNPCB), Tamil Nadu generates 14,000 metric tons of compostable waste per day, and 50% of waste is disposed of through landfill. In Nagercoil town itself, 110 MT of compostable waste (Garbage) is generated per day. APPTA market generates a quantity of 1200 MT per year (Prabakaran, 2020) creating disposal problems. (Nagercoil is the only Indian town in Tamil Nadu to receive heavy rainfall during both the monsoon (northeast and the southwest monsoon) that created hotspots of diseases like dengue *etc.*). Hence an integrated solid waste management strategy was identified to compost and recycle the APPTA market waste in an efficient manner.

At the world level, rice (*Oryza sativa* L.) is grown in an area of more than 150 million ha which is a staple food for more than 50% of the world's population. More than ninety 90% of the rice grown worldwide is cultivated and consumed in Asia. India and China together occupy about half the world's rice area. India ranks second in terms of production of rice (105.24 Mt.) next to China.

According to the Department of Agriculture, the Government of Tamil Nadu the net sown area of 74,712 ha accounts for 44.6% of the total area. Paddy is the major food crop grown in two seasons *viz.,* Kannipoo (April–June) and Kumpapoo (September–October). Knnipoo season is direct sown aerobic rice. Rice variety TPS 5 was developed at the Agricultural Research Station, Thirupathisaram of Tamil Nadu Agricultural University and released in 2014 has a normal yield of 6,301 kg ha^{-1} with 118 days duration.

Composting and maturity assessment of APPTA market waste as demonstrated by Prabakaran (2021). The literature regarding the influence of APPTA market waste bio-compost on C sequestration, phytolith accumulation, and yield of aerobic rice is scanty. Hence, an attempt was made to compost the organic waste generated in the APPTA market using TNAU bio-mineralizer (a consortium of microorganisms recommended for composting all the agro wastes), and evaluate the APPTA market waste bio-compost to improve carbon sequestration, phytolith accumulation, and yield of aerobic paddy var. TPS 5 cultivation.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

Materials and methods

Approximately 10 t of waste were collected from the APPTA market after its closure and transported to the Agricultural Research Station, Thirupathisaram, using the market authority's regular vehicle. Waste was segregated to be free of plastic and the compostable part of the waste was shredded using a tractor-operated shredder. Chemical analysis of APPTA market waste revealed that it had 20% of silica with lignin. Hence, the shredded waste was composted using the aerobic heap method Microbial suspension was prepared using a 10:1 ratio of water to TNAU bio-mineralizer. Twenty liters of water was mixed with 2 kg of bio-mineralizer (obtained from the Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore). Twenty liters of prepared microbial suspension and 4 kg of N through synthetic fertilizer (SPIC urea) were added to the waste material. The mixture was then thoroughly mixed, heaped and plastered with a layer of clay mud slurry. Aerobic holes were provided to ensure proper aeration. Regular turning, heaping, sprinkling water to maintain moisture levels between 50% and 60%, plastering with mud slurry again and provision of aeration holes at weekly intervals) on 250 GSM HDPE sheets (Prabakaran, 2020) obtained from Arjun Tarpaulins, Salem, Tamil Nadu. After the composting process was complete, the bio-compost was allowed to cure for 30 days under shade. After a period of approximately 90 days, the bio-compost was inoculated with beneficial microbes, including Azospirillum, Phosphobacteria, Azotobacter, and Pseudomonas, at a rate of 2 kg each per ton of bio-compost. It was then incubated for 2 days before being used in field experiments to allow the microbial inoculants to establish in the compost. The composition of compost revealed that it has a C:N ratio of 20:1. N, P and K content of the compost was 0.5%, 0.4% and 0.8%, respectively.

A field experiment was conducted in Agricultural Research Station, Thirupathisaram in a Randomized block design with four replications. The main field was prepared by a plow. Standard-sized plots (5 × 4 m) were laid with buffer channels. Total area harvested is 280 m^2. Initial soil characteristics reveal that the organic carbon content of the soil was low (0.47%) It is clay soil with high CEC (50.2) classification neutral in reaction (pH = 7.4) non-saline (EC = 0.17 dS m^{-1}). Soil has low in N and K and medium in P with an initial carbon stock of 5.22 t ha^{-1}

Bio-compost was applied as per the treatment. The entire dose of P fertilizer is added to the soil along with bio-compost except for absolute control. Similarly, K fertilizers are applied to the soil as per the recommendations of TNAU. N fertilizers are applied to the soil in split doses as per recommendation and as per treatments.

Treatments consisted of T_1-Control (absolute), T_2-100%N, 150 kg ha^{-1}, T_{-3} – APPTA market waste bio-compost@ 2.5 t ha^{-1}, T_{-4} – APPTA market waste bio-compost@ 5 t ha^{-1}, T_{-5} – APPTA market waste bio-compost@ 7.5 t ha^{-1}, T_6- APPTA market waste bio-compost@ 2.5 t ha^{-1} + 100%N:150 kg-ha^{-1}, T_7 - APPTA market waste bio-compost@5 t ha^{-1} + 100%N, T_8- APPTA market waste bio-compost@ 7.5 t ha^{-1} + 100%N, T_9- APPTA market waste bio-compost@ 2.5 t ha^{-1} + 75% N:112 kg ha^{-1}, T_{10}-APPTA market waste bio-compost@ 5 t ha^{-1} + 75% N, T_{11}- APPTA market waste bio-compost@ 7.5 t ha^{-1} + 75% N, T_{12}- APPTA market waste-bio-compost@ 2.5 t ha^{-1} + 50% N: 75 kg ha^{-1}, T_{13}- APPTA market waste bio-compost@ 5 t ha^{-1} + 50% N, T_{14}-APPTA market waste-bio-compost@7.5 t ha^{-1} + 50% N.

Seeds were directly sown in the respective plots using a manually-operated seed drill on June 1 2018 in anticipation of seasonal rain locally called Kumbapoo season with a row by row spacing of 20 cm with a plant density of 160-229 plants per square meter. It was harvested on 26 September 2018.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

The above-ground biomass samples were dried in an oven at 60°C for 3 days, then weighed. For below-ground biomass, cores were gently loosened by hand and shaken in a 5% solution of sodium hexametaphosphate for 3 h. Soil was washed away from roots, stolons, and rhizomes through a 500 µm sieve, allowing fine debris to be removed while retaining fragments. Fragments on the sieve were combined with the main portion of below-ground biomass and dried at 60°C for three days before being weighed to calculate below-ground biomass.

Observations were recorded on carbon stored in above-ground biomass, below-ground biomass and soil by destructive direct measurements using CHNX elemental analyzer manufactured by Eltra and soil carbon fractionations were measured by following standard procedures. Total carbon stocks were determined by measuring carbon stocks in the plant biomass and carbon stocks in the soil. Carbon input into the soil and carbon input into the ecosystem (experimental environment) during the experimental period was determined by deducting the quantity of carbon stocks stored in the soil and system before the start of the experiment along with the quantity of carbon added to the soil by APPTA market waste bio-compost from the total carbon stacks recorded during the cropping period.

The phytolith content of rice was extracted through a microwave digestion system (Gao et al., 2019). The extracted phytolith was dried in an oven at 65°C for 48 h and the weight of the extracted phytolith was recorded. A solution of 0.8 M potassium dichromate ($K_2Cr_2O_7$) was used to release the phytolith from bounded organic molecules. The alkali spectrophotometric method was used for estimating released PhytOC (Chen et al., 2018). The observed procedure consisted of (mixing a known quantity of phytolith (0.01 g) with 0.5 mL of 10 M NaOH and keeping it at room temperature for 12 h. Then the solution obtained was treated with 1.0 mL of 0.8 M $K_2Cr_2O_7$, followed by the addition of 4.6 mL of concentrated H_2SO_4 to release the bound organic C. Then kept in the water bath for 1 h by maintaining the temperature of the water bath at 98°C. In continuation, the concentration of PhytOC was determined by using a UV-vis spectrophotometer at 590 nm wavelength. To prepare a standard graph, different working standards ranging from 0-100 ppm were prepared from the standard organic stock solution (1000 ppm 45 KHP) (EPA, 2015). The chemicals used for the phytolith isolation were used in the tubes and the above procedure was repeated without a sample. The solution obtained was centrifuged at 2500 rpm for 10 min and read at 590 nm using a UV–vis spectrophotometer (Han et al., 2018). A standard graph was constructed from the values obtained. The values obtained for the sample were compared with the standard graph to get the concentration of PhytOC.

The statistical analysis was performed using the MATLAB software package. Statistical comparisons were done to assess significance at the 5% level. The standard error of the difference (SEd) and the critical difference (CD) were employed wherever statistically significant differences were observed.

Results and discussion

The results of the field experiment are presented in *Tables 1–6*. Carbon stored in the above-ground biomass, below-ground biomass, soil and total carbon stocks are presented in *Table 1*. Carbon stored in the above-ground biomass at harvest stage of rice var. TPS 5 ranged from 3.43 to 7.78 t ha^{-1}. Significant differences existed between

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

treatments. Among the treatments, higher values were recorded in the plots that received 5 t (5 t ha^{-1}) of APPTA market waste bio-compost with 75% N (7.78 t ha^{-1}) followed by the plots that received 5 t of market waste bio-compost with 100% N. Absolute control recorded the lowest values. In the current study, below-ground biomass was found to contribute to carbon sequestration by storing carbon in roots and soil, comprising approximately one-fifth to one-fourth of the total biomass. Carbon stored in the below-ground biomass at harvest stage of rice var. TPS 5 ranged from 1.1 to 2.0 t ha^{-1}. Application of APPTA market waste bio-compost at the rate of 5 t ha^{-1} with 75% N inorganic fertilizer for aerobic rice increased the accumulation of. below ground biomass (2.0 t ha $^{-1}$). Absolute control recorded lower below ground biomass. Carbon stored in the soil at harvest stage of aerobic rice var. TPS 5 ranged from 9.72 to 11.72 t ha^{-1}. Significant differences existed between treatments. Among the treatments, application of bio-compost 7.5 t ha^{-1} with 75% N recorded increased Carbon stored in soil followed by application of bio-compost alone at 7.5 t ha^{-1}. Control recorded lower carbon stored in the soil at harvest stage of rice var. TPS 5.

Table 1. *Effect of APPTA market waste bio-compost on carbon stocks at harvest stage of rice var. TPS-5*

Treatments	Carbon stored in above-ground biomass (t ha^{-1})	Carbon stored in below-ground biomass (t ha^{-1})	Carbon stored in soil (t ha^{-1})	Total carbon stocks (t ha^{-1})
Con. (Absolute)	3.43	1.10	9.72	14.25
100% N (150 kg ha^{-1})	5.61	1.34	9.92	16.87
Bio-compost 2.5 t ha^{-1}	3.57	1.23	10.06	14.77
Bio-compost 5.0 t ha^{-1}	4.63	1.75	10.53	16.91
Bio-compost 7.5 t ha^{-1}	3.59	1.40	10.72	15.77
Bio-compost 2.5 t ha^{-1}+100%N	3.60	1.35	10.l4	15.09
Bio-compost 5 t ha^{-1}+100%N	6.68	1.87	10.63	18.68
Bio-compost 7.5 t ha^{-1}+100%N	6.50	1.90	10.73	18.13
Bio-compost 2.5 t ha^{-1}+75%N	6.40	1.20	10.25	17.60
Bio-compost 5 t ha^{-1}+75% N	7.78	2.00	10.33	18.43
Bio-compost 7.5 t ha^{-1}+75%N	6.41	1.81	11.72	19.03
Bio-compost 2.5 t ha^{-1}+50%N	6.23	1.30	10.22	17.75
Bio-compost 5 t ha^{-1}+50%N	5.88	1.68	10.33	17.89
Bio-compost 7.5 t ha^{-1}+50%N	5.65	1.9	10.44	17.99
SEd	0.24	0.12	0.42	1.1
CD	0.51	0.26	0.90	2.4

The quantity and caliber of organic material deposited into the soil, including crop remnants, manure, and plant debris, profoundly impact carbon retention. Increased organic material input typically results in heightened carbon storage (Mockeviciene et al., 2023).

Soil physico-chemical properties at initial and at end of the experiment under rice var. TPS-5 are presented in *Table 2*. Soil reaction (pH) ranged from 7.12 to 8.65 and 7.11 to 7.44 at the start of the experiment and end of the experiment. Electrical

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

Conductivity (EC) at the start of the experiment and at the end of the experiment ranged from 0.17 to 0.99 and 0.13 to 0.74 dS m^{-1}, respectively. There are no significant differences in pH or EC of the soil at any stage due to application of enriched bio-compost.

Table 2. *Effect of APPTA market waste bio-compost on soil physico-chemical properties at initial and at end of the experiment under rice var. TPS-5*

Treatments	**pH**		**EC (dS m^{-1})**	
	Initial	**End of the experiment**	**Initial**	**End of the experiment**
Con. (Absolute)	7.42	7.41	0.17	0.14
100% N (150 kg ha^{-1})	8.65	7.32	0.18	0.13
Bio-compost 2.5 t ha^{-1}	7.23	7.42	0.19	0.15
Bio-compost 5.0 t ha^{-1}	7.12	7.22	0.24	0.18
Bio-compost 7.5 t ha^{-1}	6.97	7.23	0.43	0.35
Bio-compost 2.5 t ha^{-1}+100%N	7.62	7.36	0.77	0.45
Bio-compost 5 t ha^{-1}+100%N	7.55	7.22	0.99	0.44
Bio-compost 7.5 t ha^{-1}+100%N	7.45	7.11	1.22	0.63
Bio-compost 2.5 t ha^{-1}+75%N	7.55	7.44	0.65	0.55
Bio-compost 5 t ha^{-1}+75% N	7.33	7.40	0.77	0.65
Bio-compost 7.5 t ha^{-1}+75%N	7.25	7.32	0.99	0.75
Bio-compost 2.5 t ha^{-1}+50%N	7.53	7.42	0.66	0.54
Bio-compost 5 t ha^{-1}+50%N	7.49	7.33	0.75	0.64
Bio-compost 7.5 t ha^{-1}+50%N	7.40	7.21	0.90	0.74
SEd	0.72	0.22	0.51	0.41
CD	NS	NS	NS	NS

Carbon input into the soil and ecosystem ranged from 0.20 to 1.01 and 5.87 to 12.98 t ha^{-1}, respectively (*Table 3*). The carbon input into the soil represents the amount of carbon sequestered in the soil during the cropping season or during a period of time. Root and shoot residues after the harvest undergoes decomposition and accumulates as soil organic carbon (SOC).

Increased C input to soil was recorded in the plots applied with 5 t of APPTA market waste bio-compost along with the application of 75% N (1.01 t ha^{-1}) was on par with similar treatments received above 5 t of APPTA market waste bio-compost along with more than 50% N. C input into the ecosystem was increased due to application of APPTA Market bio-compost along with application of 75% N was followed by application of 5 t of APPTA market bio-compost along with application of 100% N. Minimum carbon input in the soil was recorded in the absolute control treatments whereas minimum carbon input in the ecosystem was recorded in the treatments that received bio-compost alone 2.5 t ha^{-1}.

Carbon sequestration rate in the soil and ecosystem ranged from 0.62 to 3.13 and 15.70 to 32.40 t ha^{-1} per annum, respectively (*Table 4*). More carbon sequestration was recorded in the plots that received APPTA market bio-compost 5 t ha^{-1} with 75% N was followed by plots that received APPTA market bio-compost 7.5 t ha^{-1} with 75% N. Increased Carbon sequestration in above ground biomass was recorded due to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

application of bio-compost 5 t ha^{-1} with 100% N was on par with application of bio-compost 5 t ha^{-1} along with 75% N. Lower carbon sequestration rate in the soil as well as in the ecosystem was recorded in the absolute control plots.

***Table 3.** Effect of APPTA market waste compost on carbon input into the soil and ecosystem during the cropping season under aerobic rice var. TPS-5*

Treatments	Carbon input into the soil (t ha^{-1})	Carbon input into the ecosystem (t ha^{-1})
Con. (Absolute)	0.20	5.87
100% N:150 kg ha^{-1}	0.40	9.43
Bio-compost 2.5 t ha^{-1}	0.51	5.22
Bio-compost 5.0 t ha^{-1}	0.61	7.53
Bio-compost 7.5 t ha^{-1}	0.65	7.44
Bio-compost 2.5 t ha^{-1}+100%N:150 kg ha^{-1}	0.55	10.22
Bio-compost 5 t ha^{-1}+100%N	0.88	10.42
Bio-compost 7.5 t ha^{-1}+100%N	0.89	10.06
Bio-compost 2.5 t ha^{-1}+75%N:112.5 kg ha^{-1}	0.88	9.55
Bio-compost 5 t ha^{-1}+75% N	1.01	12.98
Bio-compost 7.5 t ha^{-1}+75%N	0.89	10.22
Bio-compost 2.5 t ha^{-1}+50%N: 75 kg ha^{-1}	0.65	9.22
Bio-compost 5 t ha^{-1}+50%N	0.81	9.48
Bio-compost 7.5 t ha^{-1}+50%N	0.88	9.6
SEd	0.12	1.20
CD	0.26	2.42

***Table 4.** Effect of APPTA market waste bio-compost on carbon sequestration rate of aerobic rice var. TPS-5*

Treatments	Carbon sequestration rate in the soil (t ha^{-1} annum^{-1})	Carbon sequestration rate in the ecosystem (t ha^{-1} annum^{-1})
Con. (Absolute)	0.62	17.9
100% N:150 kg ha^{-1}	1.24	28.7
Bio-compost 2.5 t ha^{-1}	1.33	15.7
Bio-compost 5.0 t ha^{-1}	1.94	22.9
Bio-compost 7.5 t ha^{-1}	1.15	22.3
Bio-compost 2.5 t ha^{-1}+100%N:150 kg ha^{-1}	1.62	30.1
Bio-compost 5.0 t ha^{-1}+100%N	2.54	32.4
Bio-compost 7.5 t ha^{-1}+100%N	2.75	30.2
Bio-compost 2.5 t ha^{-1}+75%N:112.5 kg ha^{-1}	2.64	28.5
Bio-compost 5.0 t ha^{-1}+75% N	3.13	31.0
Bio-compost 7.5 t ha^{-1}+75%N	2.86	30.2
Bio-compost 2.5 t ha^{-1}+50%N: 75 kg ha^{-1}	1.95	27.7
Bio-compost 5.0 t ha^{-1}+50%N	2.54	28.8
Bio-compost 7.5 t ha^{-1}+50%N	2.64	28.6
SEd	0.22	1.1
CD	0.45	2.2

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

Effect of APPTA market waste bio-compost on soil carbon and its fractionation at harvest stage of rice var. TPS-5 is presented in *Table 5*. Soil organic carbon (SOC) at harvest stage ranged from 0.48% to 0.53%. More soil organic C was recorded in the plots that received 7.5 t of APPTA market bio-compost with 75% N followed by application of 7.5 t of APPTA market bio-compost with 100% N. Lower soil organic carbon was recorded in absolute control where no manure or fertilizers applied. Soil carbon is not only considered the most logical sink for atmospheric CO_2 but it is also an important soil quality component playing role in controlling soil fertility (Bhardwaj et al., 2019) and stability which is influenced by different management practices (Sahoo et al., 2019).

Table 5. *Effect of APPTA market waste bio-compost on soil carbon fractionation at harvest stage of rice var. TPS-5*

Treatments	**Soil organic carbon (SOC) %**	**Active pools**		**Passive pools**	
		Very labile (VLC) g kg^{-1}	**Labile (LC) g kg^{-1}**	**Less labile (LLC) g kg^{-1}**	**Non-labile (NLC) g kg^{-1}**
Con. (Absolute)	0.48	1.51	1.37	1.27	0.66
100% N:150 kg ha^{-1}	0.49	1.89	1.69	1.26	0.65
Bio-compost 2.5 t ha^{-1}	0.49	1.90	1.87	1.52	0.72
Bio-compost 5.0 t ha^{-1}	0.50	1.95	2.44	1.63	0.82
Bio-compost 7.5 t ha^{-1}	0.51	1.80	2.52	1.66	0.88
Bio-compost 2.5 t ha^{-1}+100%N:150 kg ha^{-1}	0.50	3.22	1.72	1.70	0.92
Bio-compost 5.0 t ha^{-1}+100%N	0.51	3.19	2.53	1.39	0.74
Bio-compost 7.5 t ha^{-1}+100%N	0.52	1.90	2.55	1.70	0.92
Bio-compost 2.5 t ha^{-1}+75%N:112.5 kg ha^{-1}	0.51	1.88	1.68	1.52	0.92
Bio-compost 5.0 t ha^{-1}+75% N	0.52	2.51	2.33	1.43	0.76
Bio-compost 7.5 t ha^{-1}+75%N	0.53	2.34	2.44	1.28	0.98
Bio-compost 2.5 t ha^{-1}+50%N:75 kg ha^{-1}	0.50	1.94	1.65	1.42	0.88
Bio-compost 5.0 t ha^{-1}+50%N	0.51	2.74	2.08	1.52	0.78
Bio-compost 7.5 t ha^{-1}+50%N	0.52	1.88	2.92	1.65	0.97
SEd	0.005	0.02	0.02	0.03	0.02
CD	0.01	0.04	0.04	0.06	0.04

Soil organic carbon in active pools consists of very labile carbon (VLC) and less labile carbon (LLC) whereas passive pools consist of less labile carbon (LLC) and non-labile carbon (NLC). The carbon stored in the active pool was more when compared to the passive pool. Carbon in active pools *viz.*, very labile (VLC) and labile (LC) ranged from 1.51-3.22 and 1.37-2.55 g kg^{-1}, respectively. More VLC was recorded in the plos applied with 2.5 t of APPA market bio-compost applied plos along with application of 100% N was on par with application of 5 t of APPTA market bio-compost with 100% N. Application of bio-compost 7.5 t ha^{-1} increased the LC with 50% N followed by application of 7.5 t of bio-compos with 50% N. Absolute control recorded lower VLC and LC. in which no manure or fertilizer is applied.

Carbon in passive pools *viz.*, less labile (LLC) and non-labile (NLC) pools ranged from 1.26 to 1.70 and 0.65 to 0.98 g kg^{-1}. More LLC was recorded due to application of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

composted APPTA market waste 2.5 t with 100% N was on par with APPTA market bio-compost alone 7.5 t ha^{-1} and application of APPTA Market bio-compost 7.5 t with 50% N. Lower LLC was recorded in the plots applied with 100% N alone. Increase in NLC was recorded due to application of 7.5 t of APPTA market waste bio-compost with 75% N was on par with application of APPTA market waste bio-compost with 50% N. Application of 100% N alone recorded decreased NLC.

Phytolith occluded carbon (PhytOC) stocks in above ground biomass and below ground biomass at harvest of rice in the present study ranged from 39.0 to 66.3 and from 22.2 to 39.6 kg ha^{-1}, respectively (*Table 6*). Higher accumulation of PhytOC stocks in above ground biomass was recorded due to application of bio-compost 5.0 t ha^{-1} was on par with application of bio-compost 5 t ha^{-1} with 100% N. Application of 100% N alone through fertilizer recorded lower PhytOC stocks above ground biomass. Increased PhytOC in below ground biomass was recorded due to application of bio-compost 5 t ha^{-1} along with 75% N was on par with application of bio-compost along with 100% N. Lower PhytOC in below ground biomass was recorded due to application of bio-compost alone at 2.5 t ha^{-1}. Anjum and Prakash (2023) reported that 1 to 6% of organic carbon within phytoliths is crucial for long-term carbon storage in agroecosystems.

Table 6. *Effect of APPTA market waste bio-compost on PhytOC stocks*

Treatments	**Above-ground biomass (kg ha^{-1})**	**Below-ground biomass (kg ha^{-1})**
Con. (Absolute)	47.4	27.3
100% N:150 kg ha^{-1}	39.0	22.2
Bio-compost 2.5 t ha^{-1}	42.2	20.3
Bio-compost 5.0 t ha^{-1}	43.8	22.0
Bio-compost 7.5 t ha^{-1}	44.2	24.4
Bio-compost 2.5 t ha^{-1}+100%N:150 kg ha^{-1}	46.4	26.6
Bio-compost 5.0 t ha^{-1}+100%N	64.2	38.4
Bio-compost 7.5 t ha^{-1}+100%N	60.2	32.6
Bio-compost 2.5 t ha^{-1}+75%N:112.5 kg ha^{-1}	58.0	30.4
Bio-compost 5.0 t ha^{-1}+75% N	66.3	39.6
Bio-compost 7.5 t ha^{-1}+75%N	60.2	32.5
Bio-compost 2.5 t ha^{-1}+50%N: 75 kg ha^{-1}	52.6	31.3
Bio-compost 5.0 t ha^{-1}+50%N	60.0	34.5
Bio-compost 7.5 t ha^{-1}+50%N	60.1	34.0
SEd	3.1	2.0
CD	6.0	4.1

The research findings suggest that rice has the potential to accumulate phytoliths, which are a significant component of the passive carbon pool. This accumulation in soil could enhance the production of PhytOC, thus contributing to terrestrial carbon sequestration. Consequently, further investigation into the factors influencing long-term sequestration, particularly focusing on below-ground biomass, is warranted in the study of PhytOC in aerobic direct sown rice cultivation. The increase in PhytOC in rice could be attributed to higher silica content, suggesting that silica fertilization could be an

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

effective management practice for boosting PhytOC levels, as suggested by Liu et al. (2014). Moreover, considering that the APPTA market is predominantly banana-based, it is possible that the waste from banana contains higher silica levels, potentially leading to increased biomass production, Si uptake, and ultimately, phytolith carbon sequestration, as noted by Song et al. (2017).

Effect of APPTA market waste bio-compost on grain yield, the straw yield of aerobic rice var. TPS-5 ranged from 3.6 to 6.0 and 4.5 to 8.7 t ha^{-1}, respectively (*Table 7*). Application of APPTA market waste bio-compost along with 50% N through fertilizers increased the grain yield was on par with application of bio-compost 5 t with 100% N. Grain yield increase over control was 263% due to application bio-compost along with 50% N through fertilizers. Straw yield was increased due to application of bio-compost 5 t ha^{-1} with 100% N followed by application of bio-compost 7.5 t ha^{-1} with 100% N. Control recorded the lower values for grain and straw yield. Straw yield increase over control was 353% due to the application of APPTA market waste bio-compost with 100% N.

Table 7. *Effect of APPTA market waste bio-compost on grain yield, the straw yield of aerobic rice var. TPS-5*

Treatments	**Grain yield (t ha^{1})**	**Straw yield (t ha^{1})**
Con. (Absolute)	3.6	4.5
100% N:150 kg ha^{-1}	5.0	7.9
Bio-compost 2.5 t ha^{-1}	4.0	5.0
Bio-compost 5.0 t ha^{-1}	4.4	5.5
Bio-compost 7.5 t ha^{-1}	4.5	5.6
Bio-compost 2.5 t ha^{-1}+100%N:150 kg ha^{-1}	5.3	6.2
Bio-compost 5.0 t ha^{-1}+100%N	5.9	8.7
Bio-compost 7.5 t ha^{-1}+100%N	5.6	8.2
Bio-compost 2.5 t ha^{-1}+75%N:112.5 kg ha^{-1}	5.2	8.0
Bio-compost 5.0 t ha^{-1}+75% N	6.0	7.8
Bio-compost 7.5 t ha^{-1}+75%N	5.4	8.0
Bio-compost 2.5 t ha^{-1}+50%N: 75 kg ha^{-1}	5.1	6.9
Bio-compost 5.0 t ha^{-1}+50%N	5.4	7.0
Bio-compost 7.5 t ha^{-1}+50%N	5.6	7.5
SEd	0.09	0.20
CD	0.20	0.43

Conclusion

The results of the study revealed that the application of a recommended dose of N fertilizer with bio-compost at the rate of 5 t ha^{-1} (best treatment) increased the plant biomass and soil carbon stocks with more carbon in the active pool. A 70% increase in carbon stocks in the plant biomass was recorded and a 4% increase in soil due to the best treatment over control/check. Decreased carbon content in the passive pool was recorded in the plots applied with 100% N alone. Straw yield (8 t ha^{-1}) and grain yield (5.8 t ha^{-1}) were also increased due to the application of APPTA market waste bio-compost along with 100% N through fertilizers. A 263% increase over control in grain yield and a 353% increase over control in straw yield were recorded due to the best treatment. The accumulation of PhytOC in rice soil may be further increased by adding the straw back to the soil will enhance the carbon sequestration in the soil and reduce the effect of dangerous global warming and mitigate climate change and enhance the ecological services of rice ecosystems. Future research should be focused on the role of silica in the APPTA market waste bio-compost for enhancing the organic PhytOC in rice and the factors affecting the PhytOC accumulation in soil.

Acknowledgments. The author acknowledges the APPTA market administrators for bringing the waste free of cost to the Experimental field Author greatly acknowledges the Professor and Head, ARS for allotting the field for experimenting. Special thanks to the Professor and Head for supplying bio-mineralizer pockets free of cost for conducting the composting study.

REFERENCES

[1] Anjum, M., Prakash, N. B. (2023): Production of phytolith and PhytOC and distribution of extractable Si pools in aerobic rice as influenced by different Si sources. – Front. Plant Sci. 14: 1146416. DOI: 10.3389/fpls.2023.1146416.

[2] Bhardwaj, A. K., Rajwar, D., Mandal, U. K., Ahamad, S., Kaphaliya, B., Minhas, P. S., Prabhakar, M., Banyal, R., Singh, R., Chaudhari, S. K., Sharma, P. C. (2019): Impact of carbon inputs on soil carbon fractionation, sequestration and biological responses under major nutrient management practices for rice-wheat cropping systems. – Sci. Rep. 9(1): 9114. DOI: 10.1038/s41598-019-45534-z.

[3] Chen, C., Huang, Z., Jiang, P., Chen, J., Wu, J. (2018): Belowground phytolith-occluded carbon of monopodial bamboo in China: an overlooked carbon stock. – Front. Plant Sci. 9: 1615. DOI: 10.3389/fpls.2018.01615.

[4] EPA (2015): Measurement of Total Organic Carbon, Dissolved Organic Carbon and Specific UV Absorbance a 254 nm in Source Water and Drinking Water. – Office of Research & Development. Method 415.3.

[5] Gao, H., Zhai, S., Sun, Z., Liu, J., Tong, C. (2019): Differences in biomass and silica content in typical plant communities with ecotones in the Min River estuary of Southeast China. – PeerJ 7: e7218. DOI: 10.7717/peerj.7218.

[6] Han, N., Yang, Y., Gao, Y., Hao, Z., Tian, J., Yang, T., Song, X. (2018): Determining phytolith-occluded organic carbon sequestration using an upgraded optimized extraction method: indicating for a missing carbon pool. – Environ. Sci. Pollut. Res. 25: 24507-24515. DOI: 10.1007/s11356-018-2706-7.

[7] IPCC (2013): Climate Change 2013: The Physical Science Basis. – In: Stocker, T. F, Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P. M. (eds.) Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge University Press, Cambridge.

[8] Kang, X., Hao, Y., Li, C., Cui, X., Wang, J., Rui, Y., Niu, H. and Wang, Y. (2011): Modeling impacts of climate change on carbon dynamics in a steppe ecosystem in Inner Mongolia, China. – Journal of Soils and Sediments 11. 562-576. 10.1007/s11368-011-0339-2.

[9] Liu, X., Li, L., Bian, R., Chen, D., Qu, J., Wanjiru Kibue, G., Pan, G., Zhang, X., Zheng, J., Zheng, J. (2014): Effect of bio-char amendment on soil-silicon availability and rice uptake. – J. Plant Nutr. Soil Sci. 177: 91-96. DOI: 10.1002/jpln.201200582.

[10] Mockevičienė, L., Karčauskienė, D., Repšienė, R. (2023): The response of Retisol's carbon storage potential to various organic matter inputs. – Sustainability 15: 11495. https://doi.org/10.3390/su151511495.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378

[11] Parr, J. F., Sullivan, L. A. (2005): Soil carbon sequestration in phytoliths. – Soil Biology and Bio-Chemistry 37: 117-124.
[12] Prabakaran, C. (2020): Survey, characterization, and composting studies of agricultural product producers and traders association market (APPTA) wastes of Kanyakumari District of Tamil Nadu (India). – Chemijournal 8(Special Issue 4): 395-399.
[13] Prabakaran, C. (2021): Maturity assessment of market waste during composting. – Multi Logic in Science 10(XXXVI): 1419-1422.
[14] Rajkishore, S. K., Manikandan, A., Vignesh, N. S., Balusamy, A. (2015): Carbon sequestration in rice soils: a review. – The Ecoscan 9(1&2): 427-434.
[15] Sahoo, U. K., Singh, S. L., Gogoi, A., Kenye, A., Sahoo, S. S. (2019): Active and passive soil organic carbon pools as affected by different land use types in Mizoram, Northeast India. – PLoS One 14(7): e0219969.
[16] Song, Z., Liu, H., Strömberg, C. A. E., Yang, X., Zhang, X. (2017): Phytolith carbon sequestration in global terrestrial biomes. – Sci. Total Environ. 603-604: 502-509. DOI: 10.1016/j.scitotenv.2017.06.107.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_43674378