Original Research Article

Effect of microbial consortium for nutrient dynamics and biological activity of paddy field under *insitu* decomposition

ABSTRACT

The production of rice and rice straw are directly proportional to each other and becomes a major problem in disposal of rice straw. Though there are many suitable methods in the reduction of rice straw few are bane to environment. Thus this study focuses only on the sustainable and ecofriendly manner of straw disposal. *Insitu* decomposition of rice stubbles using TNAU biomineralizer is the experimental study which was carried out in randomised block design with six Treatment and four replications. To determine the most effective methods of managing rice stubble, nutrient dynamics, and growth parameters of the rice crop, CO 53 variety of short duration was selected and laid down at Tamil Nadu Agricultural University, Coimbatore from 2021 to 2022. The six treatments includes T_1: Stubble (Natural degradation), T_2: Stubble+ balancing C:N ratio with urea, T_3: Stubble applied with TNAU biomineralizer @ 2kg /ton of residue, T_4: Stubbles applied with TNAU biomineralizer @ 2kg/ton of residue +balancing C:N ratio with urea, T_5: Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue, T_6: Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue + balancing C:N ratio with urea. The study findings showed that incorporation of straw with addition of biomineralizer for decomposition of straw @ 2kg/ton of residue along with balancing C:N ratio urea recorded the highest rice crop growth at harvest stage (115.70cm) and nutrient dynamics (N, P K) of 20.9 %, 4.6 % and 19.2 % higher at tillering stage and micro nutrients Cu-22.0 %, Zn- 20.9 %, Fe- 2.8 %, Mn- 9.7 % in panicle initiation stage of rice crop.

Keywords: Rice straw, insitu decomposition, Biomineralizer, Nutrient dynamics

1. INTRODUCTION

Rice is a staple meal for more than half of the world's population (Jena and Kim, 2020) [1]. India is a major rice grower in the globe. Rice nourishes the world's population with 782 million tonnes of rice produced per year (FAOSTAT 2020). Each year, India produces between 500 and 550 million tonnes of crop residue both on and off the field (Devi et al 2017) [2]. The massive amount of rice straw of 731 million tones is being produced. In India, it is reckoned that 22,289 Gg of paddy stubble biomass is generated annually and out of this, 13,915 Gg is blazed in the agricultural fields (Singh *et al.,*2016) [3]. In the field, for every tonne of harvested grain, roughly 1.35 tonnes of rice straw is produced, which is a massive amount. In India, large amounts of agricultural residues are collected each year. For example, roughly 106 mt of rice straw are created each year, adding 0.61, 0.27, and 1.71 mt of N, P, and K, respectively. (Vaiyapuri et al., 2016) [4]. According to farmers, it is simpler to burn crop residue after harvest in order to swiftly prepare the ground for the following sowing (of wheat or rice, as the case may be). Farmers are compelled to simply burn the stubble on the field in order to prepare the farmland for the subsequent planting, which releases a significant amount of dangerous pollutants (Keil et al., 2021) [5]. Lack of time between harvest and planting the following crop is another justification for burning the stubble (Ravindra et al., 2022) [6]. This open burning poses a major environmental concern as well as a health risk to the public. In one hectare of land, nearly 5 tons of paddy straw is ignited causing soil nutrient loss of nitrogen (339 kg ha^{-1}), phosphorus (6 kg ha^{-1}), potassium (140 kg ha^{-1}) and sulphur (11g ha^{-1}) (Joydeep Thakur, 2017) [7]. Haryana and Punjab alone produce 48% of the entire straw production in India, which is responsively burned in situ. Burning agricultural residue releases a variety of trace gases, including CO_X, CH_4, NO_X, SO_X, and a large quantity of particulates (PM_{10} and $PM_{2.5}$), all of which are harmful to human health. Eye discomfort, dryness of the eyes, and chest congestion are the most common symptoms that locals suffer. Chronic obstructive pulmonary disease (COPD), pneumoconiosis, pulmonary TB, bronchitis, cataract, ocular opacity and blindness were all associated with it (Singh *et al.,* 2016) [3]. The loss of critical plant nutrients and organic matter caused by the burning of straw.

Rice straw disposal is a severe challenge due to its high lignin and silica content. Incorporation of straw and stubble into wet (flooded) soil also causes N immobilization (Kaur *et al.,* 2016) [8]. Rice straw is mostly composed of cellulose (36-37%), hemicelluloses (23-24%) and lignin (15-16%) with a tiny amount of protein (Matias et al., 2019) [9]. Due to its high C:N ratio and resistance to microbial degradation, the disposal of rice stubbles is targetable one.

Rice stubbles collected from one hectare of land in one season may replenish around 30.5 kg nitrogen, 3.5 kg phosphorus, and 14 kg potassium, as well as large levels of micronutrients. Long-term studies carried out in India Since 1885, it has been evident that the balanced application of chemical fertiliser under intensive cultivation does not endure crop productivity but instead causes a significant loss in soil health, which over time causes the depletion of organic carbon and the availability of micronutrients in soil. (Vats et al., 2001) [10]. For preserving and maintaining the soil productivity, crop residue is a crucial natural resource. Crop residues are the main replacement for organic matter, and after they have mineralized, they supply vital plant nutrients. Additionally, residue absorption can enhance the physical and biological conditions of the soil and stop soil deterioration. It might be caused by the combination of all additions improving the soil's physical, chemical, and biological qualities (Arshadullah et al 2012) [11]. Crop wastes with a high C:N ratio are incorporated into soil, plant nutrients are temporarily immobilised, and phytotoxic chemicals are produced during the early stages of breakdown. Decomposition is a microbiological process that breaks down the substrate into a more stable product (Zaho *et al.,* 2019 [12]. In the breakdown process, different bacteria play distinct functions. Several fungi are involved in the decomposition of linocelluloses, while bacteria serve as cellulose degrading microorganisms (Singh and Nain, 2014) [13]. Microorganisms can create enzymes and metabolites that speed up the decomposition of organic waste and improve soil humus quality (Bakar *et al.,* 2018) [14]. This property comes in handy when dealing with rice crop wastes. Furthermore, waste management technology based on microbes could be one of the options for maximising the utilisation of available biomass while also being considerably more environmentally friendly. In lowland rice eco-systems, where whole sole cropping is the norm, low-energy in-situ composting could provide a significant contribution to solid waste recycling and long-term soil fertility maintenance. Rice stubble is successfully composted *insitu*, either by absorption into the soil or by aerobic decomposition in piles. Decomposition of crop residues is important for soil health because it raises water holding capacity.

As a result, it can be applied to the field in a positive way to increase soil fertility and health (Singh and Nain, 2014) [13]. So the rice stubbles are incorporated using Biomineralizer for faster decomposition of 45 days and which is fallowed with the rice crop again to enhance the growth and nutrient availability of the rice crop.

2. MATERIAL AND METHODS

2.1 Site description:

The experimental study was carried out during 2021 to 2022 at the Wetland, TNAU , Coimbatore, Tamil Nadu. Which has (11°N latitude and 77°E longitude with 426.7 altitude (MSL). The region falls under semi-arid tropical climate with an annual rainfall of 10.28 mm from December to June. The soil type is clay loam type which is slightly alkaline pH 7.1 and the EC of the experimental soil is 0.76 dsm^{-1} with organic carbon of 0.56%. The soil recorded medium Nitrogen, Phosphorus and Potassium i.e., 235.2 kg ha^{-1}, 14.57 kg ha^{-1},and 295 Kg ha^{-1} respectively. The soil sample were collected from 0-15cm depth, later dried and grounded in 2mm sieve and used for further analysis.

2.2 Experimental Description:

The experimental study was carried out under conventional method of rice cultivation with CO 53 as test variety during Navarai season (Dec- Jan). The research experiment was directed in (RBD) Randomized Block Design with replications of four of plot size 8 m X 5m respectively. The Six treatments were T_1: Stubble (Natural degradation), T_2: Stubble+ balancing C:N ratio with urea, T_3: Stubble applied with TNAU biomineralizer @ 2kg /ton of residue, T_4: Stubbles applied with TNAU biomineralizer @ 2kg/ton of residue +balancing C:N ratio with urea, T_5: Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue, T_6: Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue + balancing C:N ratio with urea. Recommended dose of chemical fertilizer for short duration rice 150:20:20 NPK kg/ ha were applied to the research land. CO 53 was the rice variety used for test purpose. It was transplanted at 21 DAS with 15 X 10 cm spacing. The nitrogen was sprayed in four stages: at 10 DAT, 25 DAT, 45 DAT and 65th DAT. Phosphorus was applied as basal. Along with N fertilizer, potassium was given in four splits. The experimental data were statistically analysed with the critical differences worked out at 5% (0.05) probability. (Pansey,1985) [15]. The type of Mean comparison used was LSD-Fisher.

List 1: Parameters Estimated:

Available Nitrogen	:	Alkaline Permanganate method	Subbiah and Asija, 1956 [16]
Available Phosphorus	:	Olsen's extractant method	Olsen *et al*., 1954 [17]
Available potassium	:	Neutral normal ammonium acetate method	Jackson, 1973 [18]
Soil enzyme	:	Colorimetric method	Cassida et al ., 1964 [19]
Micronutrients	:	DTPA Extractant method	Rattan *et al*., 2009 [20]

3. RESULTS AND DISCUSSION

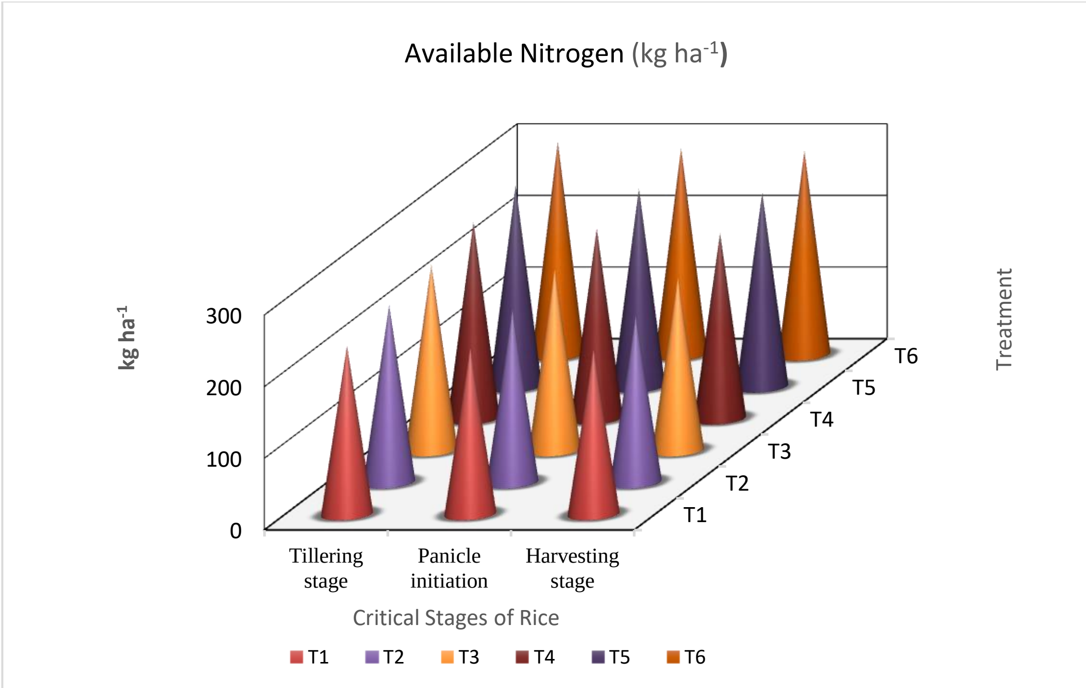
TABLE 1: The effect of residue management on rice crop's plant height

TREATMENT	Growth parameters (plant height in cm)		
	Tillering stage	Panicle initiation stage	Harvest stage
T_1	21.5	51.8	85.46
T_2	26.7	55.6	98.78
T_3	29.0	59.5	100.39
T_4	34.2	63.4	101.42
T_5	36.3	68.6	109.65
T_6	39.9	71.8	115.70
SEd	0.46	0.79	1.54
CD	1.00	1.68	3.29
P value	0.001	0.001	0.001

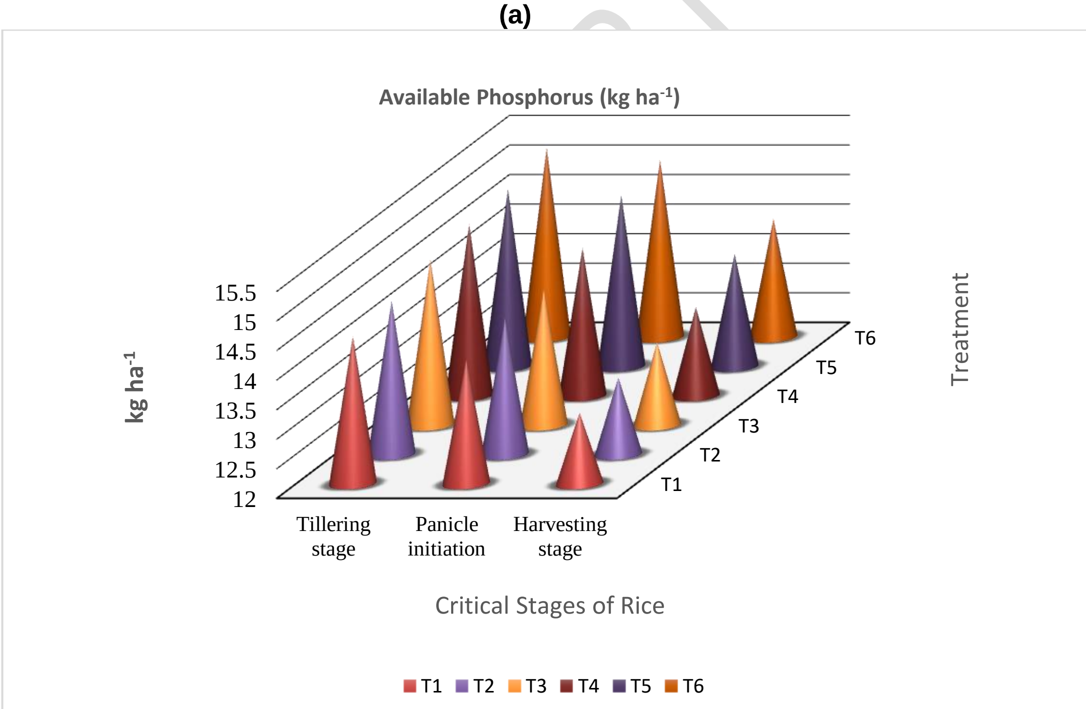
3.1 Effect of residue management on plant growth parameter:

The growth parameter of rice crop was recorded at the three different stages which was tabled in Table 1. The plant height was increased due to the positive effect of the rice stubble incorporation using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue + balancing C:N ratio with urea. The current results were akin to the findings of (Vaiyapuri et al., 2016) [4]. According to vaiyapuri et al., 2016 With the integration of straw as such, using a tractor mounted with a half cage wheel and rotovator, along with the use of biofertilizers for the decomposition of straw and incorporation later at 60 DAT, the higher plant height (85.50 cm) was reported, whereas, Plant height ranged from 21.5 to 39.9cm during tillering stage (45 DAT), 51.8 to 71.9 cm at panicle stage (60 DAT) and 85.46 to 115.70cm during harvest stage (110 DAT). The plant height was higher in treatment T_6- 39.9cm, 71.9 cm and 115.70 cm during tillering, panicle stage and harvest stage respectively. According to P value the height of the plant at all the three stages are significant.

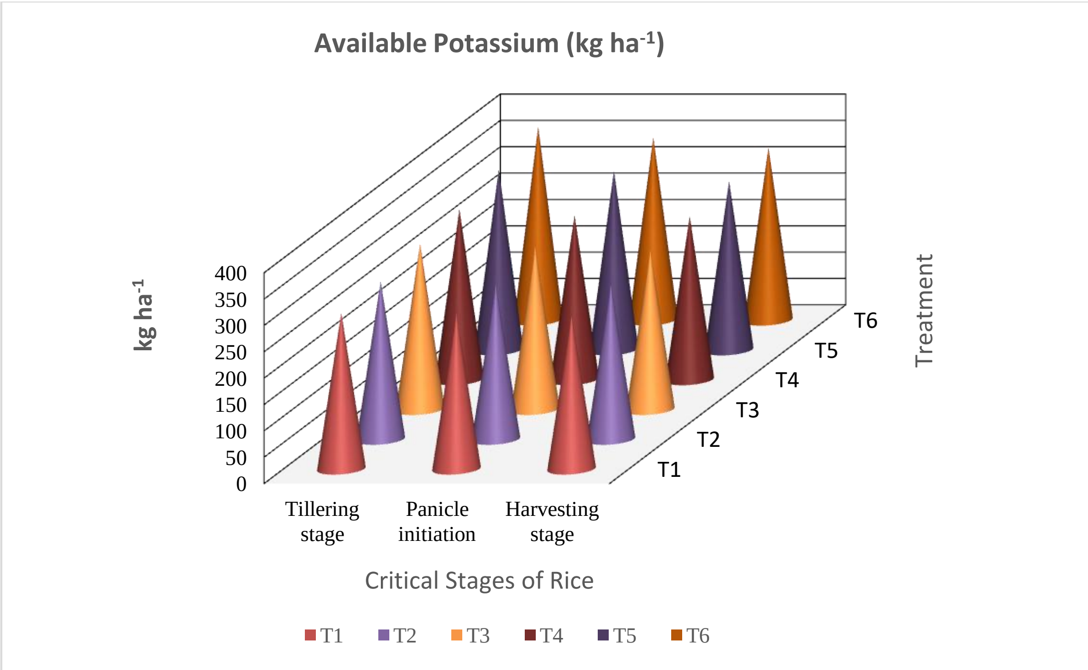
3.2 Effect of residue management on soil available nutrients:


Available Nitrogen (kg ha-1)
kg ha-1
300
200
100
0
Tillering stage
Panicle initiation
Harvesting stage
Critical Stages of Rice
T1
T2
T3
T4
T5
T6
Treatment

(a)


Available Phosphorus (kg ha-1)
kg ha-1
15.5
15
14.5
14
13.5
13
12.5
12
Tillering stage
Panicle initiation
Harvesting stage
Critical Stages of Rice
T1
T2
T3
T4
T5
T6
Treatment

(b)



(c)

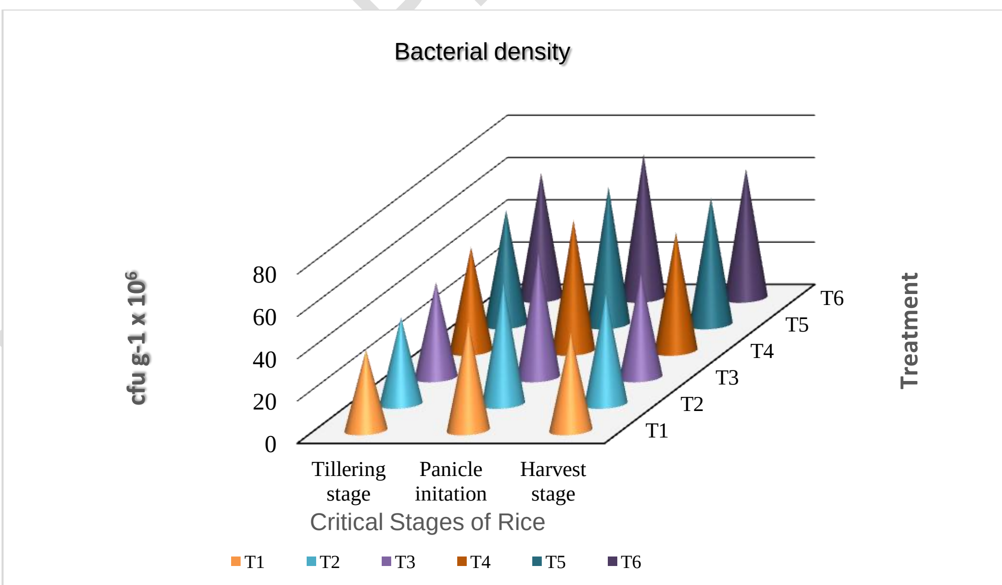
Figure 1 Effect of residue management in soil available (a) nitrogen, (b) phosphorus and (c) potassium status.

The available soil nutrients like N, P and K were estimated at three different critical stages of rice, tillering, panicle and harvest stage which is shown in figure 1. The majority of the nutrients are returned to the soil after the stubble is incorporated, which also contributes to the long-term preservation of soil nutrient reserves. (Dobermann and Fairhurst, 2002) [21]. The available nutrients present in the soil showed a steady decline from tillering stage to panicle stage which strengthen the findings of (Vijayaprabhakar et al., 2017) [22]. Without any additional ingredients, rice straw had the lowest levels of N and K availability because of a higher C-N ratio that led N to get immobilised, lowering the amount of N and K that was readily available (Mohanty et al., 2010) [23]. By adding more microbial load to the soil and incorporating rice straw, the application of additives may have encouraged the mineralization process of nitrogen in the soil, increasing the availability and increasing the uptake of nitrogen by rice crops (Mishra et al., 2001)[24]. Similar findings were noted by Jayadeva et al.,2010 [25].Adding straw increased the amount of phosphorus to the soil (Ghosh et al.,2012) [26]. By allowing for a time gap between the inclusion of stubbles and planting, as well as by adding additives, the degradation process was sped up and the amount of K that was readily available in the soil was raised. The reports was compatable to the findings of Singh et al. (2004 [27].

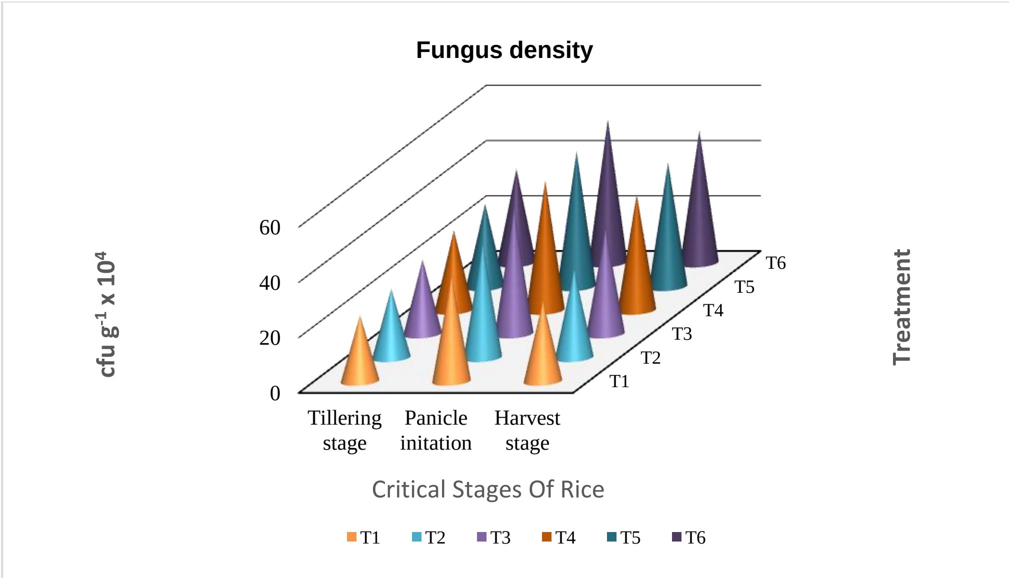
According to Fig 1 (a), Available N in the soil increased Slightly with the rice stubble incorporation using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue along with balancing C:N ratio with urea. The available N ranged from 235.2 to 297.7 kg ha^{-1} during tillering stage and 231.8 to 288.5 kg ha^{-1} during panicle stage. The available N was comparatively higher in T_6 in tillering, panicle and Harvest stage which was 297.7 kg ha^{-1}, 288.5 kg ha^{-1} and 285.3 kg ha^{-1} respectively. The available P status in the soil ranged from 14.57 kg ha^{-1} to 15.25 kg ha^{-1} in tillering stage,14.17 to 15.03 kg ha^{-1} during panicle stage and in 13.2 kg ha^{-1}to 14.0 kg ha^{-1} during harvest stage, among which T_6 showed highest in all three stages, i.e 15.2 kg ha^{-1} , 15.0 kg ha^{-1} and 14.0 kg ha^{-1} respectively. The available K value in the soil ranged from 296.0 to 366.7 kg ha^{-1} , 295.0 to 346.8 kg ha^{-1} and 291.0 kg ha^{-1} to 326.8 kg ha^{-1} during tillering, panicle and harvest stage respectively. In three critical stages of rice , the available K status was 366.7 kg ha^{-1}, 346.8 kg ha^{-1} and 326.8 kg ha^{-1} which was higher in T_6 respectively.

3.3 Effect of residue management on soil micro organisms:

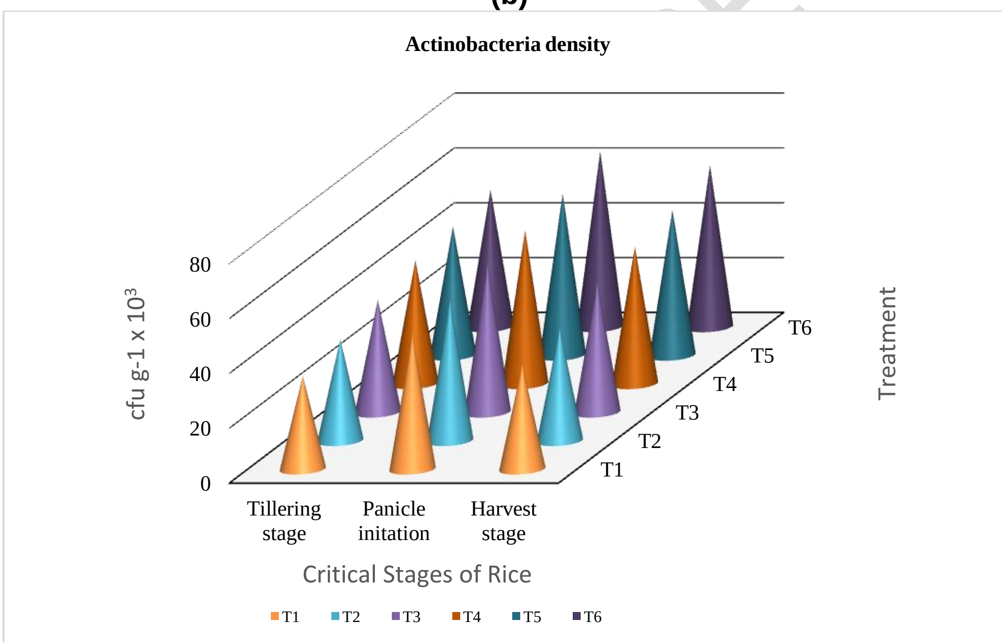
Microbial density in the experimental soil was determined at three critical stages of the rice crop. The density of the microbes increased at tillering and panicle stages of rice but decreased at harvest stage while comparing to panicle stage which was akin to the findings of vijayaprabhakar *et al*., 2017).[22]. The bacterial density in the rice soil during Tillering stage ranged from 38 to 59 (cfu g^{-1} x 10^{6}), 51 to 68 (cfu g^{-1} x 10^{6}) during panicle stage and 46(cfu g^{-1} x 10^{6}) to 61 (cfu g^{-1} x 10^{6}) during harvest stage of rice crop. The bacterial density was higher in T_6 during tillering, panicle, and harvest stages 59 (cfu g^{-1} x 10^{6}) ,68 (cfu g^{-1} x 10^{6}) and 61 (cfu g^{-1} x 10^{6}) respectively. Fungal density value ranged from 24 to 34 (cfu g^{-1} x 10^{4}) in tillering stage, 38- 52 (cfu g^{-1} x 10^{4}) during panicle stage and 29 to 48 (cfu g^{-1} x 10^{4}) at harvest stage. In all the critical stages the fungal density was higher in treatment T_6 whose values are 34, 52 and 48 (cfu g^{-1} x 10^{4}) at tillering, panicle stage and harvest stage. The density of actinobacteria ranged from 34 to 50 (cfu g^{-1} x 10^{3}), 49 to 64 (cfu g^{-1} x 10^{3}) and 38 to 59 (cfu g^{-1} x 10^{3}) at three critical stages respectively. The population density was considerably higher at T6 in all three stages of rice. The values are 50 (cfu g^{-1} x 10^{3}) at tillering stage, 64 cfu g^{-1} x 10^{3} at panicle stage and 59 (cfu g^{-1} x 10^{3}) at harvest stage of rice crop.



(a)



(b)



(c)

Figure 2 Effect of biomeralizer in soil (a) bacterial, (b) fungus and (c) actinobacteria density

3.4 Effect of residue management on the soil micro- nutrients and soil enzyme activities:

The soil micro nutrients get increased after the application of the organic substances like rice stubble incorporation in the saline soil and also enhancing the saline soil fertility through soil enzymatic activity (Swarup, 1985) [28]. If the incorporation of the paddy stubbles prolongs for long term then there will be a considerable increase in micronutrient such as Cu, Fe, Zn and Mn in the soil. (BS Sindhu and Beri, 2008).[29]. The soil micronutrient i.e, Cu, Zn, Mn, Fe in tillering stage was higher in T6, 0.59, 0.81, 1.43 and 4.21 $mgkg^{-1}$ of soil respectively. The same is observed in panicle stage in which T_6 was higher of all Four micro nutrients, i.e, Cu- 0.57, Zn – 0.80, Fe- 4.19 and Mn- 1.39 $mgkg^{-1}$ of soil. All four micronutrients are higher in T6 at harvest stage also. Soil enzyme activities get increased on further crop growth stages of rice (Y.Gu *et al*., 2009) [30]. The soil enzyme activities was also influenced and enhanced in T_6 at tillering, panicle stage and harvesting stage. According to Table 2, the Fe content in the soil is non significant while comparing with all other micronutrients.whose P value 0.516 at all the three stages.

Table 2. Effect of residue management in soil micro nutrient dynamics of rice ($mgkg^{-1}$)

Treatment	Micronutrient status of soil											
	Tillering stage ($mgkg^{-1}$)				Panicle initiation ($mgkg^{-1}$)				Harvest stage ($mgkg^{-1}$)			
	Cu	Zn	Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn	Fe	Mn
T_1	0.46	0.64	4.09	1.29	0.45	0.63	4.08	1.27	0.39	0.59	4.01	1.21
T_2	0.52	0.68	4.14	1.32	0.51	0.67	4.12	1.29	0.41	0.64	4.09	1.26
T_3	0.54	0.71	4.15	1.34	0.52	0.69	4.13	1.31	0.48	0.65	4.11	1.28
T_4	0.56	0.72	4.17	1.36	0.53	0.70	4.15	1.33	0.51	0.69	4.12	1.30
T_5	0.58	0.76	4.18	1.38	0.55	0.74	4.16	1.35	0.52	0.71	4.13	1.33
T_6	0.59	0.81	4.21	1.43	0.57	0.80	4.19	1.39	0.54	0.79	4.16	1.34
SEd	0.06	0.01	0.06	0.01	0.006	0.01	0.06	0.01	0.005	0.007	0.06	0.01
CD	0.01	0.02	0.13	0.03	0.014	0.02	0.13	0.03	0.011	0.016	0.12	0.04
P Value	0.001	0.001	0.516	0.001	0.001	0.001	0.516	0.550	0.001	0.001	0.516	0.001

Table 3. Effect of residue management in soil enzyme activities of rice

Treatment	Soil Enzyme Activity								
	Tillering stage			Panicle initiation			Harvest stage		
	Urease µg NH_4-N g^{-1} of soil hr^{-1}	Phosphatase µg of p-nitrophenol g^{-1} of soil h^{-1}	Dehydrogenase µg of TPF g^{-1} of soil h^{-1}	Urease µg NH_4-N g^{-1} of soil hr^{-1}	Phosphatase µg of p-nitrophenol g^{-1} of soil h^{-1}	Dehydrogenase µg of TPF g^{-1} of soil h^{-1}	Urease µg NH_4-N g^{-1} of soil hr^{-1}	Phosphatase µg of p-nitrophenol g^{-1} of soil h^{-1}	Dehydrogenase µg of TPF g^{-1} of soil h^{-1}
T_1	8.5	12.4	9.0	10.4	16.5	10.2	9.1	15.8	9.2
T_2	8.9	12.9	9.4	10.9	16.9	11.5	10.6	16.2	10.5
T_3	9.3	13.6	9.7	11.6	17.4	11.9	10.9	16.9	10.9
T_4	9.7	13.8	10.2	11.8	17.8	12.4	11.2	17.3	11.4
T_5	10.1	14.5	10.8	12.5	18.1	12.7	11.8	17.7	12.9
T_6	10.5	15.1	11.5	12.9	18.6	13.1	12.1	18.0	12.6
SEd	0.13	0.19	0.17	0.19	0.15	0.17	0.13	0.31	0.21
CD	0.28	0.42	0.37	0.40	0.34	0.36	0.29	0.66	0.45
P Value	0.001	0.516	0.001	0.001	0.001	0.001	0.001	0.001	0.001

4. CONCLUSION

Based on the study, soil nutrient dynamics, enzymatic activities and microbial density were discussed. From this, it revealed that the microbial consortium (Bio-mineralizer) acted well on decomposing the paddy straw at *Insitu* level followed by providing the growth promoting substances to the rice crop. Among the different treatment, Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue along with balancing C:N ratio with urea showed the best performance in all the estimated parameters i.e., nutrients like N, P and K along with the micro nutrients and soil microbial density when compared to all other treatments. Treatment stubble incorporation using Rotovator, Urea and Biomineralizer, showed increase in N,P,K and soil microbial density compared to treatment Stubble incorporation without any additives makes delay in decomposition and this practice was usually followed by most of the farmers, hence delay in sowing for next season crop occurs. This can be overcome by the incorporation of stubbles in soil using rotovator and TNAU biomineralizer @ 2kg/ton of residue along with balancing C:N ratio with urea. Thus the microbial density (Bacteria, Fungi and Actinobacteria increased by 25 %, 26% and 23.4% respectively at panicle stage . This study concludes that the Stubbles incorporated in soil using rotavator and applied with TNAU biomineralizer @ 2kg/ton of residue along with balancing C:N ratio with urea not only enhances the decomposition rate but also provides the additional nutrients for the plant growth and increases the soil fertility by increasing the microbial density in the soil.

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