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In situ Rice Straw Decomposition-Different Cutting Heights and Microbial Consortia, its Impact on Soil Microbial Population and Decomposition Rate

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ABSTRACT: This study was to examine the impact of different cutting heights of rice straw and microbial inoculants on microbial population and C: N ratio. The residual amount of rice straw produced by different cutting methods 10 cm, 20 cm and full rice straw was 920 kg ha^{-1}, 1,560 kg ha^{-1}, 4320 kg ha^{-1} rice straw respectively. The experiment was laid out in split plot design and replicated thrice. The main plot contains different heights of rice straw *i.e.*, 10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e.*, Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7). The higher number of bacteria, fungi and actinomycetes was recorded in different cutting heights of rice straw decomposition (10 cm, 20 cm and full rice straw) with the application of bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%). The lower decomposition rate and microbial population was recorded in the control plot where the paddy straw was not sprayed with microbial consortia, cow dung and urea.

Keywords: Rice straw, Bio mineralizer, Cow dung, Urea, Decomposition, C: N ratio.

INTRODUCTION

In India, rice is grown in an area of 43.66 M. ha annually with a production of 118.87 million tonnes and average productivity of 2722 kg ha^{-1} (Indiastat, 2020). Thus, it generates a huge amount of residue in the form of straw when rice crop is harvested. Rice was harvested manually by cutting method or using machinery. In cutting method, the harvested rice straw and grain were taken to a threshing yard to separate rice straw and grain. As a result, a small amount of straw was left infield itself. While in machine harvesting the total paddy straw was dumped in the field which was unutilized by the farmers. Based on the type of harvesting the amount of residue left over in the field is varying from small to huge amounts. The farmers were considering the left over paddy straw as a waste product and it was burned in field itself.

Rice straw contains 0.57% N, 0.07% P_2O_5, 1.5% K_2O, 0.1% (sulfur) S, and 5% silicon (Si) (Dobermann and Fairhurst 2002) and also reported that, at harvest stage the rice straw contains contain 0.5–0.8% N, 0.07–0.12% P_2O_5, 1.16–1.66% K_2O, and 4–7% Si. The study conducted by Gupta *et al.* (2007) was proved that the in-situ incorporation of rice straw into the soil improves nutrient cycling, soil organic carbon (C), and yields of succeeding crops. The nutrient status of the paddy straw is well known but at the same time rice straw have the lower decomposition rate due to higher C: N ratio (50 to 60).

In this condition, if sowing is taken up immediately after the rice straw incorporation, the establishment of the crop is affected due to this wider C: N ratio and poor microbial population (Udayasoorian *et al*., 1997). In this connection the present study was taken up with the combinations of different cutting heights of paddy straw, microbial consortia alone and also with the combination of cow dung and urea to know the decomposition rate and microbial population at different intervals.

MATERIALS AND METHODS

Field experiment was conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu during February 2020 to evaluate the impact of left-over rice straw after harvesting at different cutting heights (10 cm, 20 cm, and full rice straw) on microbial populations and decomposition rate. The experiment was laid out in split plot design and replicated thrice. The main plot contains different heights of rice straw *i.e.*, 10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e.*, Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7).

Rice is harvested manually with sickle as per the treatments. For M_1 and M_2 treatment plots, rice straw was harvested by leaving 10 cm and 20 cm stubble heights from the ground level butin M_3 treatment plot only economic parts are harvested by leaving the total rice straw in field itself. The left-over paddy straw was chopped by using tractor mounted shredder in their respective plots. Strengthen the already presented bunds and buffer channels all around to avoid seepage of water along with the nutrients. Drainage channels were provided all around the experimental field for effective drainage. The bio mineralizer, SSB were made in to slurry with water in 2: 40 proportion, cow dung slurry (5 %) and urea (1 %) were prepared and sprinkled on the rice straw as per the treatments schedule.

Soil samples were collected from the experimental plots at 15 days and 30 days interval. The soil samples powdered, sieved through 2 mm sieve and used for chemical and biological analysis. The decomposition rate was estimated from C: N ratio of the soil whereas the chemical and biological analysis was done by the following methods.

The analytical data of soil were subjected to statistical scrutiny as per the procedure given by Gomez and Gomez (1984). Wherever, the treatment differences were found significant (F test), critical differences were worked out at 5 per cent probability level and the values were furnished in the respective table. The treatment differences that were not significant were denoted as "NS".

RESULTS AND DISCUSSION

Effect of *in situ* rice straw decomposition on microbial populations. Microbial population *i.e.*, bacteria, fungi and actinomycetes were examined. Rice straw with different cutting heights and microbial inoculants had a significant impact on bacteria, fungi and actinomycetes population (Table 1, 2, 3).

With respect to in situ rice straw decomposition with different cutting heights higher microbial population of bacteria (at 15 days 36 cfu g^{-1} soil × 10^6 and at 30 days 67 cfu g^{-1} soil × 10^6), fungi (at 15 days 32 cfu g^{-1} soil × 10^4 and at 30 days 63 cfu g^{-1} soil × 10^4), actinomycetes (at 15 days 41cfu g^{-1} soil × $10^3$and at 30 days 58cfu g^{-1} soil × 10^3) were recorded under the full rice straw decomposition treatment (M_3) and the least microbial population of bacteria (at 15 days 33 cfu g^{-1} soil × 10^6 and at 30 days 60 cfu g^{-1} soil × 10^6), fungi (at 15 days 29 cfu g^{-1} soil × 10^4 and at 30 days 57 cfu g^{-1} soil × 10^4) and actinomycetes (at 15 days 37 cfu g^{-1} soil × 10^3 and at 30 days 52 cfu g^{-1} soil × 10^3) were recorded under 10 cm rice straw incorporation (M_1).

The data regarding to the microbial consortia, higher microbial population was observed under the application of bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2) (bacterial count at 15 days was 39 cfu g^{-1} soil × 10^6 and at 30 days 73 cfu g^{-1} soil × 106, fungal count at 15 days 35 cfu g^{-1} soil × 10^4 and at 30 days 68 cfu g^{-1} soil × 10^4 and actinomycetes count at 15 days 45 cfu g^{-1} soil × 10^3 and at 30 days 62cfu g^{-1} soil × 10^3).

Nutrient	Methods adopted
N content	Kjeldahl method (Piper, 1966)
Organic carbon	Chromic acid wet digestion method (Walkley and Black, 1934)
Microbial Population	Medium Used
Bacterial population	Nutrient glucose Agar medium (Allen, 1953)
Fungi population	Rose bengal agar medium (Martin, 1950)
Actinomycetes population	Kenknights agar medium (Allen, 1953)

Table 1: Effect of treatments on bacterial population (cfu g^{-1} soil × 10^6).

	Bacteria(cfu g^{-1} soil x 10^6)								
	15 days					30 days			
	M_1	M_2	M_3	Mean		M_1	M_2	M_3	Mean
S_1	35	37	41	38		64	69	75	69
S_2	36	39	43	39		66	72	79	73
S_3	29	30	29	29		54	55	54	54
S_4	31	32	33	32		57	59	61	59
S_5	34	37	40	37		63	68	74	68
S_6	35	38	42	39		65	71	79	71
S_7	29	27	26	27		53	51	49	51
Mean	33	34	36			60	63	67	
	M	**S**	**Mx S**	**Sx M**		**M**	**S**	**Mx S**	**Sx M**
SEd	0.18	0.37	0.65	0.65		0.49	0.98	1.65	1.70
C. D. (p=0.05)	0.50	0.76	1.32	1.32		1.37	1.99	3.47	3.46

10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e.*, Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7).

Table 2: Effect of treatments on fungal population (cfu g^{-1} soil × 10^4).

	Fungi(cfu g^{-1} soil × 10^4)								
	15 days					30 days			
	M_1	M_2	M_3	Mean		M_1	M_2	M_3	Mean
S_1	31	33	36	33		60	65	71	65
S_2	32	35	38	35		62	68	73	68
S_3	26	26	26	26		50	51	50	51
S_4	27	28	29	28		54	55	57	55
S_5	30	32	35	33		59	63	69	64
S_6	31	34	37	34		61	66	73	67
S_7	25	24	23	24		50	48	46	48
Mean	29	30	32			57	59	63	
	M	S	Mx S	Sx M		M	S	Mx S	Sx M
SEd	0.31	0.31	0.59	0.54		0.25	0.74	1.21	1.28
C. D. (p=0.05)	0.88	0.63	1.33	1.10		0.71	1.50	2.50	2.60

10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e.*, Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7).

Table 3: Effect of treatments on Actinomycetes population(cfu g^{-1} soil × 10^3).

	Actinomycetes (cfu g^{-1} soil × 10^3)								
	15 days					30 days			
	M1	M2	M3	Mean		M1	M2	M3	Mean
S1	40	43	47	43		56	60	65	60
S2	42	45	49	45		58	63	68	63
S3	34	34	34	34		47	48	47	47
S4	36	37	38	37		50	51	53	51
S5	40	42	46	43		55	59	64	59
S6	41	44	48	44		56	61	67	62
S7	33	32	31	32		46	44	43	44
Mean	38	40	42			52	55	58	
	M	S	Mx S	S X M		M	S	Mx S	S x M
SEd	0.11	0.29	0.48	0.51		0.56	0.70	1.25	1.21
C. D. (p=0.05)	0.32	0.59	1.00	1.03		1.56	1.41	2.72	2.45

10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e.*, Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7).

This was on par with the application of silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6) (bacterial count at 15 days was 39 cfu g^{-1} soil × 10^6 and at 30 days 71cfu g^{-1} soil × 10^6, fungal count at 15 days 34 cfu g^{-1} soil × 10^4 and at 30 days 67cfu g^{-1} soil × 10^4 and actinomycetes count at 15 days 44 cfu g^{-1} soil × 10^3 and at 30 days 61 cfu g^{-1} soil × 10^3). The lower microbial population of bacteria (at 15 days 27 cfu g^{-1} soil × 10^6 and at 30 days 51 cfu g^{-1} soil × 10^6), fungi (at 15 days 24 cfu g^{-1} soil × 10^4 and at 30 days 48cfu g^{-1} soil × 10^4) and actinomycetes (at 15 days 31 cfu g^{-1} soil × 10^3 and at 30 days 44 cfu g^{-1} soil × 10^3) were observed in the control plot *i.e.,* without any microbial inoculant application.

The interaction effect of the *in-situ* paddy straw incorporation at different cutting heights and microbial inoculant showed the significant effect. The higher amount of microbial population *i.e.*, at 15 days 43 cfu g^{-1} soil × 10^6 and at 30 days 79 cfu g^{-1} soil × 10^6), fungi (at 15 days 38 cfu g^{-1} soil × 10^4 and at 30 days 73 cfu g^{-1} soil × 10^4) and actinomycetes (at 15 days 48 cfu g^{-1} soil × 10^3 and at 30 days 68cfu g^{-1} soil × 10^3) was observed under full rice straw along with the application of bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (M_3S_2) recorded and it was on par with full rice straw incorporation along with the application of silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (M_3S_6) (at 15 days 42 cfu g^{-1} soil × 10^6 and at 79 days 51 cfu g^{-1} soil × 10^6), fungi (at 15 days 37 cfu g^{-1} soil × 10^4 and at 30 days 73 cfu g^{-1} soil × 10^4) and actinomycetes (at 15 days 48 cfu g^{-1} soil × 10^3 and at 30 days 67 cfu g^{-1} soil × 10^3). The lowest microbial population (at 15 days 26 cfu g^{-1} soil × 10^6 and at 30 days 49 cfu g^{-1} soil × 10^6), fungi (at 15 days 23 cfu g^{-1} soil × 10^4 and at 30 days 46 cfu g^{-1} soil × 10^4) and actinomycetes (at 15 days 30 cfu g^{-1} soil × 10^3 and at 30 days 42 cfu g^{-1} soil × 10^3) was observed in full rice straw incorporation alone without any application of microbial consortia, cow dung and urea (M_3S_7).

The combined application of chemical fertilizer and straw significantly increased soil microbial count over the control (Nie *et al.,* 2007). According to Esther *et al.,* (2013), in-situ incorporation of straw was showed maximum amount microbial count in soil and increased their content on soil over the control treatment. In field experiment, these results were in agreement with the findings of Mandal *et al.,* (2004) who reported that microbial activity was higher in residue incorporated into the soil and the higher microbial biomass could be obtained through residue incorporation than their removal or burning.

Effect of *in situ* rice straw decomposition on C: N ratio. C:N ratio of paddy straw was analysed at 15 and 30 Days and the ratio was declined with time. The C:N ratio was ranged from 37.40: 1 to 55.30: 1 at 15 days and progressively it declined to 20.10: 1 to 48.49: 1 at 30 days. The different cutting heights of rice straw incorporation with microbial inoculants, cow dung and urea cause the significant variation in C: N ratio between the treatments (Table 4).

At 15 days. The lower C: N ratio was recorded under the rice straw decomposition with the cutting of 10 cm (M_1) (41: 1) and this was followed by the rice straw with the cutting height of 20 cm (M_2) (48: 1). The higher C: N ratio was recorded in the treatment with the full rice straw decomposition (M_3) (53: 1).

With respect to microbial inoculations, at 15 days the least C: N ratio was observed under the treatment bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2) (45: 1). The highest C: N ratio was recorded under Control treatment without microbial, cow dung (5%) and urea (1%) application (S_7) (50: 1).

Interaction effect showed that least C: N ratio was found in full rice straw decomposition with bio mineralizer (2 kg/ tonne of residue) + cow dung slurry (5 %)+ urea (1 %) (M_3S_2) (52: 1) which was on par with full rice straw decomposition with Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (M_3S_6) (54: 1).

At 30 days. The lower C: N ratio was found in 10 cm rice straw incorporation (M_1) (22: 1), 20 cm rice straw incorporation (M_2) (27: 1) and the higher C: N ratio was recorded infull rice straw decomposition (M_3) (45: 1).

The least C: N ratio was observed in bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2) (30: 1) and the higher C: N ratio was noted in Control (S_7) (35: 1).

Interaction effect at 30 days showed that least C: N ratio was found in full rice straw decomposition with bio mineralizer (2 Kg/ tonne of residue) + cow dung slurry (5%) + Urea (1%) (M_3S_2) (20: 1) and it was on par with 10 cm rice straw decomposition with bio mineralizer (2 Kg/tonne of residue) + cow dung slurry (5%) + Urea (1%) (M_1S_2) (20: 1) and 20 cm rice straw incorporation bio mineralizer (2 Kg/tonne of residue) + cow dung slurry (5%) + urea (1%) (M_2S_2) (20.32: 1) and the lower C: N ratio was registered in full rice straw decomposition without microbial consortia, cow dung and urea (M_3S_7) (45: 1).

The different rice straw management practices helped to bring the C: N ratio by varying degree. Among the residue management practices, the rice straw decomposition with the cutting height of 10 cm, 20 cm and full rice straw along with the application of (2 kg/ tonne of residue) + cow dung (5 %) + urea (1%) (M_1S_2) decreased the C: N ratio. Gaur *et al.,* (1987) was reported that effectiveness of inoculation with a suitable microorganism will speed up the bio degradation process and reduction in C: N ratio. The effective biodegradation of residue was confirmed with microbial inoculants to bring down the C: N ratio to an arrow level (Esther *et al.,* 2013).

Rice residue (straw and stubbles) contains high amount of silica, cellulose and lignin, these major chemical constituents were easily degraded by using microbial inoculants (bio-mineralizer and cow dung slurry), it favours the gradual release of nutrient and 25 kg additional N enhanced the initial crop growth. These results are in line with the findings of Singh *et al*. (2005); Kumari *et al*. (2008); Singh *et al*. (2008).

The C: N ratio was reduced in all the treatments with passage of time but there was wide variation in the treatments this was due to the microbial development during the time gap which increased the degradation process and released the available nutrients present in the added rice straw to bring down the C: N ratio. This was in agreement with the findings of Azmal *et al.,* (1997).

Table 4. Effect of treatments on C: N ratio.

	C: N ratio								
	15 days					30 days			
	M1	M2	M3	Mean		M1	M2	M3	Mean
S1	37	46	51	45		26	26	26	26
S2	38	47	52	46		20	20	20	20
S3	40	47	53	47		41	41	45	42
S4	44	47	54	48		25	25	26	25
S5	44	49	54	49		32	33	33	33
S6	45	50	55	50		24	24	25	24
S7	45	50	55	50		44	42	46	44
Mean	42	48	54			30	30	32	
	M	S	M × S	S × M		M	S	M × S	S × M
S.Ed	0.31	0.60	1.01	1.04		0.12	0.35	0.57	0.60
C. D. (p=0.05)	0.86	1.22	2.13	2.11		0.33	0.70	1.17	1.22

10 cm rice straw incorporation (M_1), 20 cm rice straw incorporation (M_2), full rice straw (M_3) and sub plots contains different microbial consortia along with cow dung and Urea *i.e*., Bio mineralizer (2 kg/ tonne) (S_1), Bio mineralizer (2 Kg/ tonne of residue) + Cow dung slurry (5%) + Urea (1%) (S_2), Pleurotus (5 kg/ ha) (S_3), Pleurotus (5kg/ ha) + Cow dung slurry (5%) + Urea (1%) (S_4), Silica solubilizing bacteria (5kg/ha) (S_5), Silica solubilizing bacteria (5kg/ha) + Cow dung slurry (5%) + Urea (1 %) (S_6), Control (S_7).

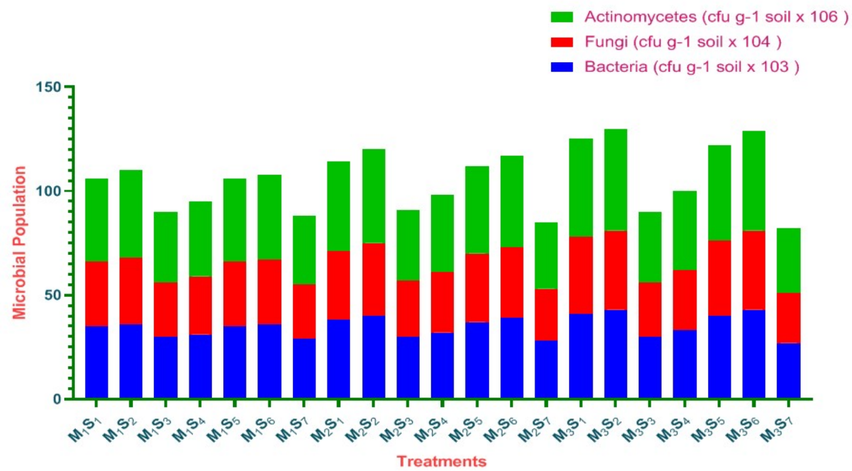

Fig. 1. Effects of treatments on microbial population at 15 days.

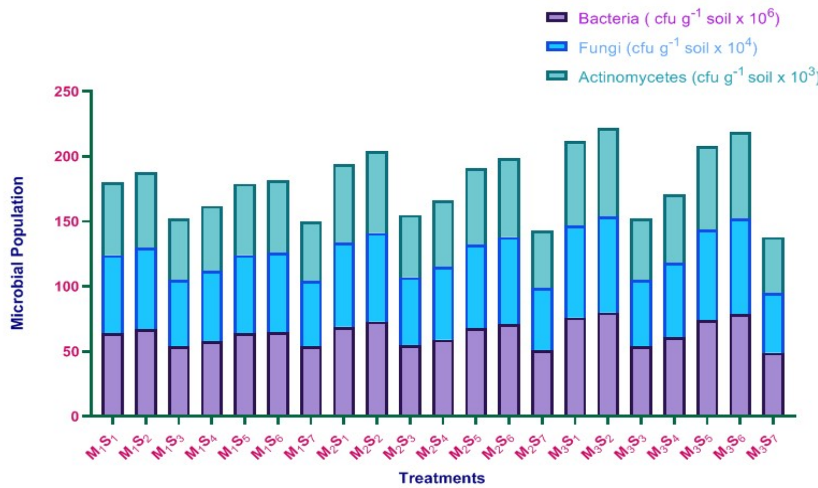

Fig. 2. Effects of treatments on microbial population at 30 days.

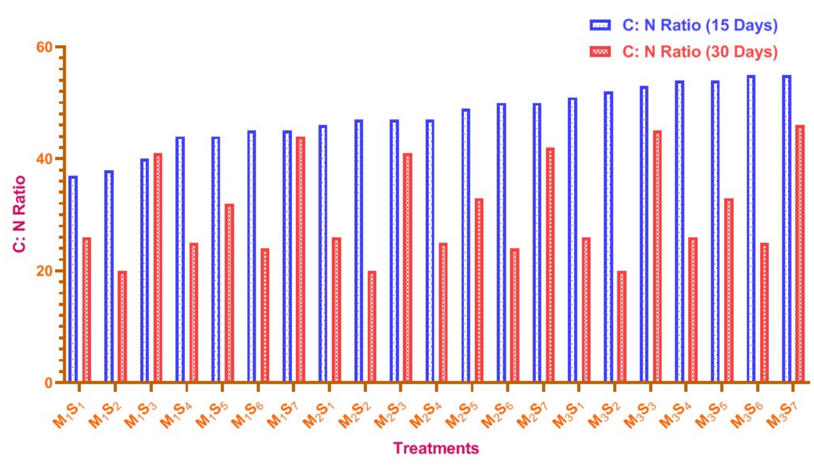

Fig. 3. Effects of treatments on C: N ratio.

CONCLUSION

The conclusion of the study was the application of microbial inoculants along with cow dung and urea is essential for decomposition of rice straw and narrow down the C: N ratio. In addition to this, application of TNAU bio mineralizer and silica solubilizing bacteria along with cow dung slurry (5 %) and urea (1 %) increases the rate of decomposition, narrow C: N ratio and soil microbial count which increases the nutrient availability for succeeding crop. Hence, the *in-situ* decomposition of paddy straw with different cutting heights (10 cm, 20 cm and full rice straw)with the application of bio mineralizer (2 kg/ tonne of residue) + cow dung slurry (5%) + Urea (1 %) is the best option to increase the rice straw decomposition rate, microbial population and nutrient availability for the next crop.

FUTURE SCOPE

The future scope of this research experiment is to record the decomposition and nutrient releasing patterns by using IARI fungal cocktail or Pusa decomposer capsules and the effect of in situ decomposition of rice straw on different crops and cropping systems.

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