

Original Research Article

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Impact of Combine Harvested Rice Straw Management Options on Soil Microbial Population and Straw Decomposition Rate in Succeeding Rice Field

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ABSTRACT

Field experiment was conducted at Agricultural College and Research Institute, Killikulam, Tamilnadu during October, 2014 to February, 2015 to study the effect of rice residue management options on soil microbial population and straw decomposition rate under combine harvested rice field. The experiment was laid out in Randomized Block Design and replicated thrice. The treatments comprised rice residue with and without additives [25 kg additional N ha⁻¹ as basal, bio-mineralizer (2 kg t⁻¹ rice residue), cow dung slurry (5%)]. The additives applied individually, in combination of two and combined application of all additives in order to find out the effect of additives on soil microbial population and decomposition rate. The various residue management options significantly influenced the soil microbial population and straw decomposition rate at various growth stages of rice crop. Among the different treatments, straw incorporated with 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry (T₈) significantly registered the highest population of bacteria (58, 76 and 68 g⁻¹ x 10⁶ at TL, FL and HA), fungi (51, 70 and 59 g⁻¹ x 10⁴ at TL, FL and HA), and actinomycetes (58, 67 and 62 g⁻¹ x 10³ at TL, FL and HA) at all stages. In relation to that, highest decomposition rate (C: N ratio: 26.7, 20.3 and 14.4 at TL, FL and HA) also observed in that same treatment (T₈). The lowest population of soil bacterial (41, 58 and 49 g⁻¹ x 10⁶ at TL, FL and HA), fungi (26, 43 and 22 g⁻¹ x 10⁴ at TL, FL and HA) and actinomycetes (34, 49 and 34 g⁻¹ x 10³ at TL, FL and HA) observed in treatment (T₉), where straw removed (control). The lowest decomposition rate (C: N ratio: 48.6, 35.5 and 19.2 at TL, FL and HA) observed in the treatment (T₁), where straw was incorporated without any additives.

Keywords

Residue, Microbial population, C: N ratio, Bio-mineralizer, Cow dung slurry.

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Introduction

India has world's largest area under rice with 42.75 million ha and is the second largest producer (105 million tonnes - 2013) next only to China. It contributes 22.34 % of global rice production. The productivity of

rice is only 2462 kg/ha (2012-13) against the global average productivity of 4329 kg/ha (Indiastat, 2015). At the current growth rate of population (1.98%), Indian population is expected to reach 1.63 billion by 2050. This

would be transformed into the requirement of about 136 million tonnes of rice for an expected population of 163 million by the year 2050 for consumption purpose alone (DRR, 2014). Hence, it is necessary to augment the rice production from 105 million tonnes to 136 million tonnes by 2050 AD. However this attempt will make heavy loss in our country's economic resources. Thus the future food security of India depends on the ability to achieve a continuous improvement in the productivity and the profitability of intensive rice farming system. Continuous, indiscriminate use of chemical fertilizers as well as energy crisis leads to the concept of integrated nutrient management (INM) and sustainability for rice. So to fulfill the yield gap, adoption of INM which envisages the use of the locally available organic manures, inorganics, biological sources, adoption of low cost technology and their integration is necessary. Among the organics, farmyard manure, green manure and crop residue are commonly used as nutrient source (Bhandari *et al.*, 1992). The estimated annual production of residues by crops in India is 500 million tonnes, containing 8.02 million tonnes of NPK (MNRE, 2009). About one third of the residues produced are available for direct recycling on the land and if used can add 2.19 mt of NPK annually. Jain (1993) reported that in India, large quantities of crop residues are made available every year by paddy 326.2 mt, wheat 105.5 mt, maize 29.7 mt, sorghum 62.3 mt, barley 3.7 mt, pulses 15.7 mt, soybean 3.7 mt etc and only a small portion of this being effectively utilized, but large quantities remain as waste. In recent years, labour availability in Indian farms is becoming scarce day by day. Even if available, they demand for high wages. During peak seasons of agricultural operations especially transplanting, weeding and harvesting, farmers find it difficult to get the labourers. Hence, the level of awareness and adoption of farm machines by our farmers is steadily

increasing. Scientific research proved that agricultural production can be increased by 25 to 28 per cent by using machines in Indian farms. In most of the rice growing areas, rice crop over a large area comes to harvest at same time which results in labour shortage. Due to delay in harvesting process, most part of the produce goes as waste due to shattering and also reduces turn-around time for taking the next crop. So, Government has introduced combine harvester for rice which have its own advantages as capable of doing harvesting, threshing, cleaning and packing at a time. The main disadvantage during the combine harvesting is leaving the straw in entire field area in chopped form, which possess difficulty in collecting and feeding it to the cattle. A huge quantity of such rice straw in chopped form has been burnt in the field, which may result in pollution problems and wastage of valuable resources. Hence, an alternate way to effectively utilize the combine harvested straw become essential. In India, about 106 mt of rice straw is produced annually and it adds about 0.61, 0.27 and 1.76 mt of N, P and K respectively (Manna and Ganguly, 1998). Rice straw contains 0.5 to 0.8 per cent N, 0.16 to 0.27 per cent P, 1.4 to 2.0 per cent K, 0.05 to 0.10 per cent S and 4 to 7 per cent silica (Si) in its dry matter (Dobermann and Fairhurst, 2002). Though the nutrient availability of rice straw is well known at the same time rice straw have lower decomposition rate due to its higher C:N ratio (33) compared to cow dung and Dhaincha (Chowdhury *et al.*, 2002) Under such condition, if planting is taken up immediately after incorporating the straw of preceding crop, the establishment of the succeeding rice crop may be hampered by wide C: N ration and poor microbial population (Udayasoorian *et al.*, 1997). To overcome these problems, combine harvester paddy straw is incorporated along with additional N source, Bio mineralizer, cow dung slurry and its combinations to know the microbial

population and degradation pattern of straw at different growth stages of rice crop.

Materials and Methods

A field experiment was conducted at Agricultural College and Research Institute, Killikulam during *Pishanam* season of October 2014 - February 2015, to study the impact of rice residue management options on soil microbial population and residue decomposition rate in combine harvested rice field. The farm is geographically situated in the southern part of Tamil Nadu at 8°46' N latitude and 77°42' E longitude at an altitude of 40 m above mean sea level. The experimental site is situated in semi-arid tropical region. The mean annual rainfall is 786.6 mm received in 40 rainy days. The mean maximum and minimum temperature of the location are 33.4 °C and 23.6 °C, respectively. The relative humidity ranges from 60 to 80 per cent. Five soil samples at 15 cm depth were collected at random in the experimental field before laying out the experiment and composite soil sample was obtained by quartering method and processed for analyzing biological characters. It shows 0.36 % total organic carbon, 0.01 % total nitrogen, 32 cfu g⁻¹ × 10⁶ of Bacterial population, 18 cfu g⁻¹ × 10⁴ of fungal population and 27 cfu g⁻¹ × 10³ of actinomycetes population were observed. Rice variety ADT (R) 45 with the duration of 110 days was used as a test variety in this experiment.

After combine harvesting, the rice straw retained on the field was collected and quantified (5 t ha⁻¹). The rice straw was uniformly distributed to all the plots except control. TNAU Bio-mineralizer was made into slurry by mixing with water (for 2 kg of material 40 liters of water) and Cow dung slurry (5%) was prepared then sprinkled on the straw of respective experimental plots on

the next day of combine harvest of preceding rice crop i.e. 15 days ahead of transplanting. The experiment was laid out in Randomized Block Design with nine treatments and replicated thrice with nine treatments [T₁ - Incorporation of rice straw without additives; T₂ - T₁ + 25 kg additional N ha⁻¹ as basal; T₃ - T₁ + Bio-mineralizer (2 kg t⁻¹ rice residue); T₄ - T₁ + Cow dung slurry (5%); T₅ - T₁ + 25 kg additional N ha⁻¹ as basal + Bio-mineralizer (2 kg t⁻¹ rice residue); T₆ - T₁ + 25 kg additional N ha⁻¹ as basal + Cow dung slurry (5%); T₇ - T₁ + Bio-mineralizer (2 kg t⁻¹ rice residue) + Cow dung slurry (5%); T₈ - T₁ + 25 kg additional N ha⁻¹ as basal + Bio-mineralizer (2 kg t⁻¹ rice residue) + Cow dung slurry (5%); T₉ - Control (no residue)]. The gross and net plot sizes are 45 m² (7.5 m × 6.0 m) and 38.5 m² (7.0 m × 5.5 m).

Layout was taken and each plot was separated by buffer channels and bunds all around to avoid seepage of water. Drainage channels were provided all around the experimental field for effective drainage. After combine harvesting, the rice straw was quantified on the field at an average of 5 t ha⁻¹ and distributed uniformly on the experiment field based on the size of the individual plot. After 15 days of harvest, every plot was individually puddled and leveled properly. Package of practices for ADT (R) 45 strictly followed during the entire crop period, which recommended by TNAU. Along with this, as per the treatment schedule, 25 kg additional N ha⁻¹ as basal added to appropriate experimental plots.

Soil samples were collected from the experimental plots at tillering, flowering and harvest stage. The soil samples were air dried under shade, sieved through 2 mm sieve and used for chemical and biological analysis. The decomposition rate was estimated from C: N ratio of the soil. The total N content of soil by

Kjeldahl method (Piper, 1966) and organic carbon by chromic acid wet digestion method (Walkley and Black, 1934) were determined at active tillering, flowering and harvest stages. The soil bacterial population estimated from the culture prepared by Nutrient glucose Agar medium (Allen, 1953), fungi population by Rose bengal agar medium (Martin, 1950) and Kenknights agar medium (Allen, 1953). 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 paddy straw incorporation on soil microbial population

At different growth stages of rice crop, the microbial population of bacteria, fungi and actinomycetes were determined.

Bacteria (Table 1)

Significant impact of straw incorporation along with microbial inoculants, organic and inorganic source on bacterial density in the soil was evidenced at different growth stages of rice. It increased steadily with the crop growth stages. The bacterial density in the soil ranged from 41 to 58 cfu g⁻¹ soil x 10⁶ at tillering, 58 to 76 cfu g⁻¹ x 10⁶ at flowering and from to 49 to 68 cfu g⁻¹ soil x 10⁶ at harvest stages. Among the treatments, T₈ (incorporation straw with application of 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry) recorded the highest bacterial density of 58, 76, 68 cfu g⁻¹ soil x 10⁶ at tillering, flowering and at harvest stages respectively. It was followed by straw

incorporation with 25 kg additional N ha⁻¹ as basal and cow dung slurry (T₆). The lowest bacterial population was associated with T₉ (41, 58, 49 cfu g⁻¹ soil x 10⁶) at respective stages.

Fungi (Table 2)

Great influence of straw incorporation along with microbial inoculants, organic and inorganic source on fungal density in the soil was observed at different growth stages of rice. It increased steadily with the crop growth stages. The fungal density in the soil ranged from 26 to 51 cfu g⁻¹ soil x 10⁴ at tillering, 43 to 70 cfu g⁻¹ soil x 10⁴ at flowering and from 32 to 59 cfu g⁻¹ soil x 10⁴ at harvest stages of soil. Among the treatments, T₈ (incorporation straw with application of 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry) recorded the highest fungi density of 51, 70, 59 cfu g⁻¹ soil x 10⁴ at tillering, flowering and harvest stages, respectively followed by T₆ with 49, 68, 57 cfu g⁻¹ soil x 10⁴ at tillering, flowering and harvest stages, respectively. The lowest fungi population was associated with T₉ (26, 43, 32 cfu g⁻¹ soil x 10⁴) at respective stages.

Actinomycetes (Table 3)

Profound impact of straw incorporation along with microbial inoculants, organic and inorganic source on actinomycetes density in soil was observed at different growth stages of rice. The actinomycetes density in the soil ranged from 34 to 58 cfu g⁻¹ soil x 10³ at tillering, 49 to 67 cfu g⁻¹ soil x 10³ at flowering and from 34 to 62 cfu g⁻¹ soil x 10³ at harvest stages. Among the treatments, T₈ (incorporation straw with application of 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry) recorded the highest actinomycetes density of 58, 67, 62 cfu g⁻¹ soil x 10³ at tillering, flowering and at harvest stages, respectively. It was followed by straw

incorporation with 25 kg additional N ha⁻¹ as basal and cow dung slurry (T₆), which recorded 57, 65, 59 cfu g⁻¹ soil x 10³ at tillering, flowering and harvest stages, respectively. The lowest actinomycetes population was associated with T₉ (34, 49, 34 cfu g⁻¹ soil x 10³) at respective stages.

Effect of paddy straw incorporation on C: N ratio (Table 4)

C:N ratio of soil was estimated during rice growth stages such as tillering, flowering and harvest. Irrespective of treatments, C:N ratio tends to decline with time. The C:N ratio was ranged from 26.7 to 48.6 at tillering and progressively it declined as 14.4 to 19.1 at harvest stages. Incorporation of straw with additives cause wide variation in C:N ratio between the treatments. Rice straw incorporation with application of 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry (T₈) recorded significantly the lowest C:N ratio of 26.7, 20.3 and 14.4 at tillering, flowering and harvest stage, respectively. Next to this, straw incorporation with 25 kg additional N ha⁻¹ as basal and cow dung slurry (5%) (T₆) recorded the C:N ratio of 29.8, 22.3 and 15.8 at tillering, flowering and harvesting stages. Incorporation of rice straw alone without additives (T₁) showed wider C:N ratio of 48.6, 35.5 and 19.1 at tillering, flowering and harvesting stages, respectively.

Rice residue is a good source of nutrients, if it is properly managed. This observation is strengthened by the nutrient composition of rice residue 0.5 to 0.8 per cent N, 0.16 to 0.27 per cent P, 1.4 to 2.0 per cent K, 0.05 to 0.10 per cent S and 4 to 7 per cent silica (Si) (Dobermann and Fairhurst, 2002). However, the nutrient potential of the rice residue is hampered by a wide C: N ratio. In the present study, the C: N ratio of the rice residue was 53.3, which was too wide for effective N

mineralization. If rice planting was done immediately after incorporation of residue without addition of any microbial inoculants led to very slow decomposition process and affected the growth of succeeding rice (Udayasoorian *et al.*, 1997). The decomposition of rice residue was a slow process (Hitoichi Shiga, 1997; Choudhury *et al.*, 2002) due to wide C: N ratio and it had high amount of silica, cellulose, lignin etc. (Parr *et al.*, 1992; Bakker, 2013). This led to prolonged accumulation of organic acids and other toxic substances which affected the growth and development of standing crop (Kumari *et al.*, 2008). The growth characters, yield attributes and yield of succeeding rice were very much reduced, when paddy straw was incorporated without additives and planting done immediately. The *in-situ* incorporation of crop residue with high C: N ratio in soil typically resulted in microbial N immobilization and temporary decreases in plant available N (Singh *et al.*, 2005). Incorporation of stubbles alone without any straw management significantly reduced the crop yield. Vasisht (1991) reported that due to slow decomposition of rice residues, the source size and sink capacity of the succeeding rice crop was affected and ultimately the grain and straw yields were reduced. Son *et al.*, (2013) reported that the direct incorporation of straw reduced the availability of important mineral nutrients in growing plants through immobilization of organic forms and produce photo-toxic substances.

Effect of paddy straw incorporation on microbial population (Fig. 1, 2 and 3)

The result of the present investigation indicated that the treatment T₈ (straw incorporation with + 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry) recorded higher bacteria, fungi and actinomycetes population at flowering and it

declined at harvest stage (Fig. 1, 2 and 3). The no residue plots (T9) recorded the lowest microbial population in soil.

Krishnakumar *et al.*, (2005) revealed that organic material significantly increased the bacterial population. Soil microbial biomass has been used as an index of soil fertility which depends on nutrient fluxes. Similarly maximum bacterial population observed in (T8) straw incorporation with 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry may be due to the residual effect of rice crop at flowering stage which was found parallel to the present result. At harvest, the decreasing bacterial population was due to decrease in organic carbon (Watts *et al.*, 2010). The findings of Gaiind and Nain (2011) concluded that drastic decrease in microbial biomass may be attributed to low availability of substrate at crop maturity stage. Sannathimmappa *et al.*, (2015) also concluded that the activity of phosphate solubilizing microorganisms in the soil was significantly

increased due to incorporation of paddy straw treated with combination of cow dung slurry at 5% + *T. harizianum* at 5 kg ha⁻¹ + *P. sajarcaju* at 5 kg ha⁻¹.

Effect of paddy straw incorporation on C: N ratio (Fig. 4)

Wide variation in C: N ratio of soil due to residue management was observed at different stages, which persisted until harvest. In the present study, rice straw incorporation with application of 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry (T8) recorded the lowest C: N ratio at all stages of crop growth. According to Singh *et al.*, (2005), when planting was done immediately after straw incorporation with no additives, the C: N ratio of the soil was very wide (48.6). This probably resulted in immobilization of N and affected the crop growth. The different residue management practices helped to bring down the initial C: N ratio by varying degree.

Table.1 Effect of paddy straw incorporation on population of Bacteria (cfu g⁻¹ x 10⁶) in soil at various stages of rice

Treatments	Bacteria (cfu g ⁻¹ x 10 ⁶)		
	Tillering	Flowering	Harvest
T ₁ :	43	61	51
T ₂ :	51	66	59
T ₃ :	45	63	52
T ₄ :	47	64	54
T ₅ :	55	71	64
T ₆ :	57	74	66
T ₇ :	49	65	56
T ₈ :	58	76	68
T ₉ :	41	58	49
SEd	1.20	1.93	1.90
CD (P=0.05)	2.60	4.13	4.07

Table.2 Effect of paddy straw incorporation on microbial population of fungi (cfu g⁻¹ x 10⁴) in soil at various stages of rice crop

Treatments	Fungi (cfu g ⁻¹ x 10 ⁴)		
	Tillering	Flowering	Harvest
T ₁ :	29	46	35
T ₂ :	39	63	50
T ₃ :	31	49	43
T ₄ :	34	53	46
T ₅ :	47	65	54
T ₆ :	49	68	57
T ₇ :	36	60	48
T ₈ :	51	70	59
T ₉ :	26	43	32
SEd	0.84	1.56	1.47
CD (P=0.05)	1.80	3.35	3.16

[**Treatments:** T₁- Incorporation of rice straw alone, T₂- T₁ + 25 kg additional N ha⁻¹ as basal, T₃- T₁ + bio-mineralizer, T₄- T₁ + Cow dung slurry, T₅- T₁ + 25 kg additional N ha⁻¹ as basal + bio-mineralizer, T₆- T₁+ 25 kg additional N ha⁻¹ as basal + cow dung slurry, T₇- T₁ + bio-mineralizer + cow dung slurry, T₈- T₁ + 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry, T₉- control (no residue)].

Table.3 Effect of paddy straw incorporation on microbial population of actinomycetes (cfu g⁻¹ x 10³) in soil at various stages of rice crop

Treatments	Actinomycetes (cfu g ⁻¹ x 10 ³)		
	Tillering	Flowering	Harvest
T ₁ :	37	51	39
T ₂ :	50	58	52
T ₃ :	41	53	43
T ₄ :	45	55	46
T ₅ :	56	62	56
T ₆ :	57	65	59
T ₇ :	47	56	49
T ₈ :	58	67	62
T ₉ :	34	49	34
SEd	0.52	1.60	1.54
CD (P=0.05)	1.15	3.43	3.31

Table.4 Effect of paddy straw incorporation on C: N ratio at various stages of rice crop

Treatments		C:N ratio		
		Tillering	Flowering	Harvest
T₁	:	48.6	35.5	19.1
T₂	:	31.4	24.1	16.7
T₃	:	43.3	32.6	17.7
T₄	:	41.2	28.7	17.5
T₅	:	30.7	22.8	16.4
T₆	:	29.8	22.3	15.8
T₇	:	33.0	24.3	17.1
T₈	:	26.7	20.3	14.4
T₉	:	14.3	12.9	12.7
SEd		1.08	0.80	0.52
CD (P=0.05)		2.33	1.73	1.13

[**Treatments:** **T₁**- Incorporation of rice straw alone, **T₂**- **T₁** + 25 kg additional N ha⁻¹ as basal, **T₃**- **T₁** + bio-mineralizer, **T₄**- **T₁** + Cow dung slurry, **T₅**- **T₁** + 25 kg additional N ha⁻¹ as basal + bio mineralizer, **T₆**- **T₁**+ 25 kg additional N ha⁻¹ as basal + cow dung slurry, **T₇**- **T₁** + bio-mineralizer + cow dung slurry, **T₈**- **T₁** + 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry, **T₉**- control (no residue)].

Fig.1 Effect of paddy straw incorporation on population of Bacteria (cfu g⁻¹ x 10⁶) in soil at various stages of rice crop.

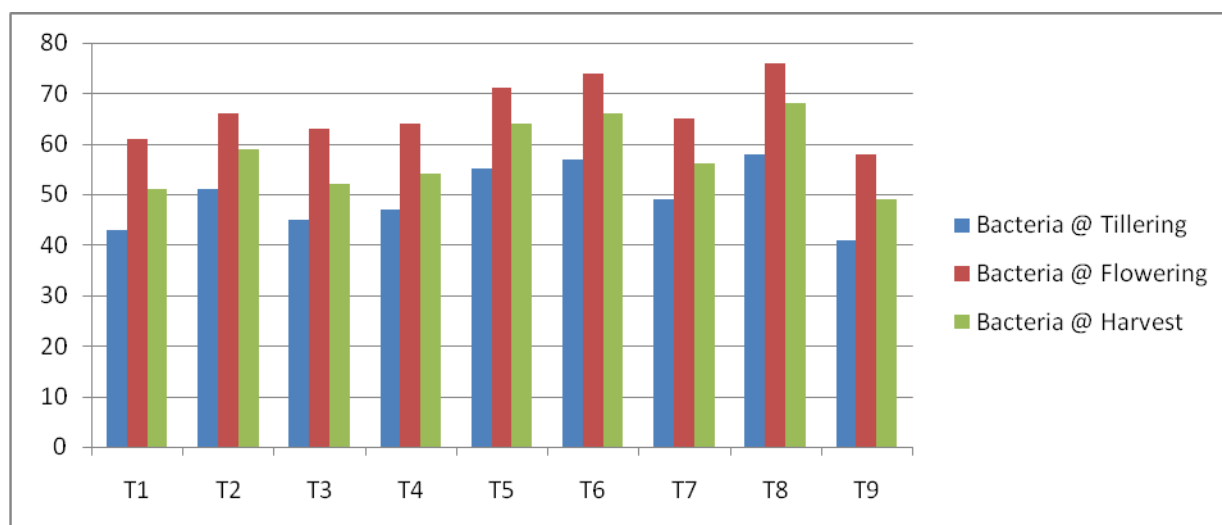
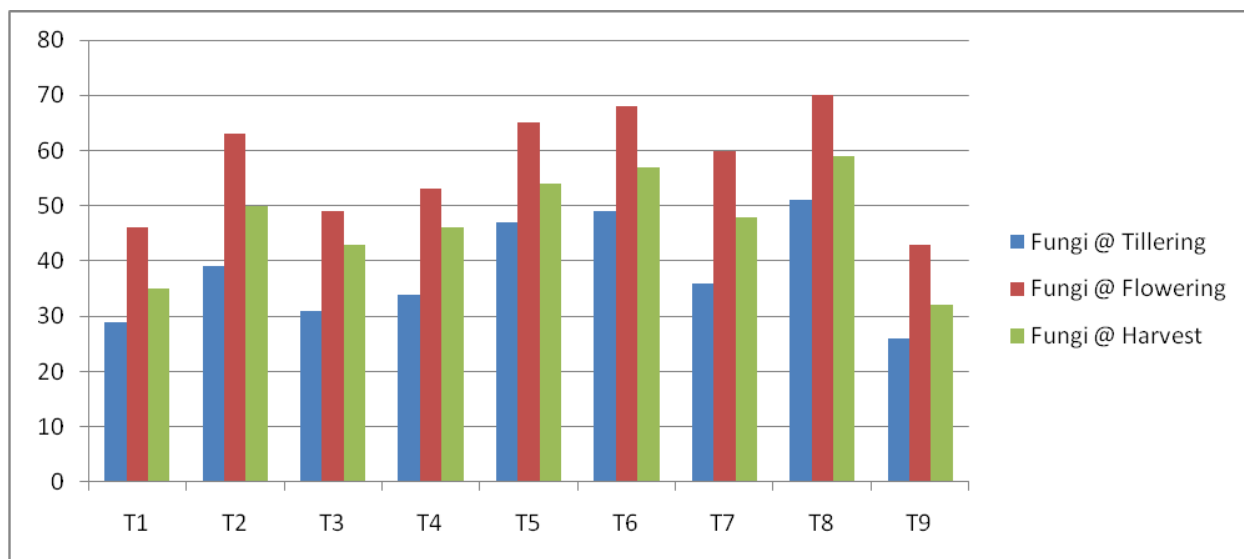


Fig.2 Effect of paddy straw incorporation on population of Fungi (cfu g⁻¹ x 10⁴) in soil at various stages of rice crop



[**Treatments:** **T₁**- Incorporation of rice straw alone, **T₂**- T₁ + 25 kg additional N ha⁻¹ as basal, **T₃**- T₁ + bio-mineralizer, **T₄**- T₁ + Cow dung slurry, **T₅**- T₁ + 25 kg additional N ha⁻¹ as basal + bio mineralizer, **T₆**- T₁+ 25 kg additional N ha⁻¹ as basal + cow dung slurry, **T₇**- T₁ + bio-mineralizer + cow dung slurry, **T₈**- T₁ + 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry, **T₉**- control (no residue)].

Fig.3 Effect of paddy straw incorporation on population of Actinomycetes (cfu g⁻¹ x 10⁶) in soil at various stages of rice crop

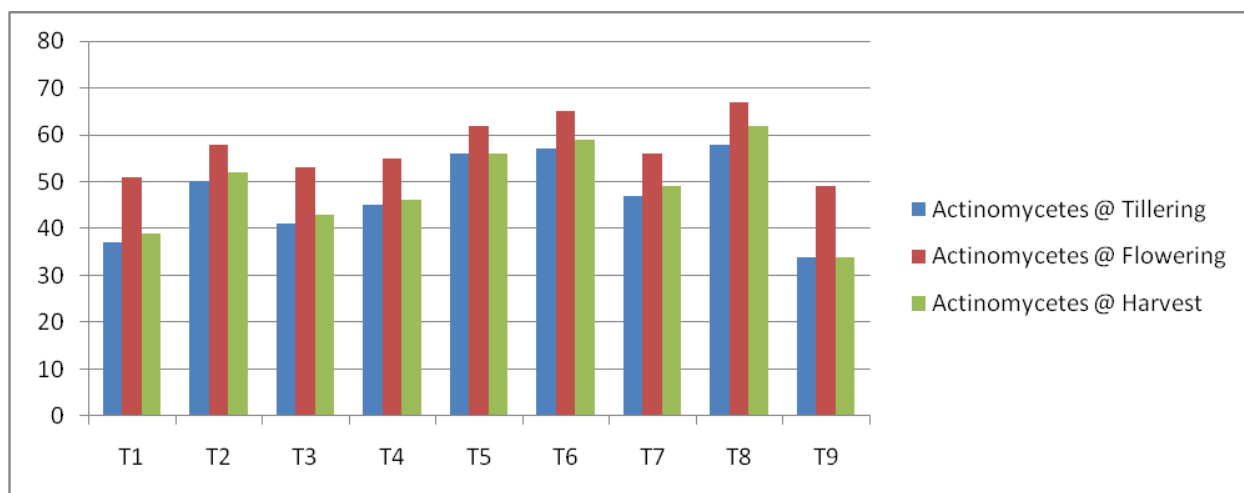
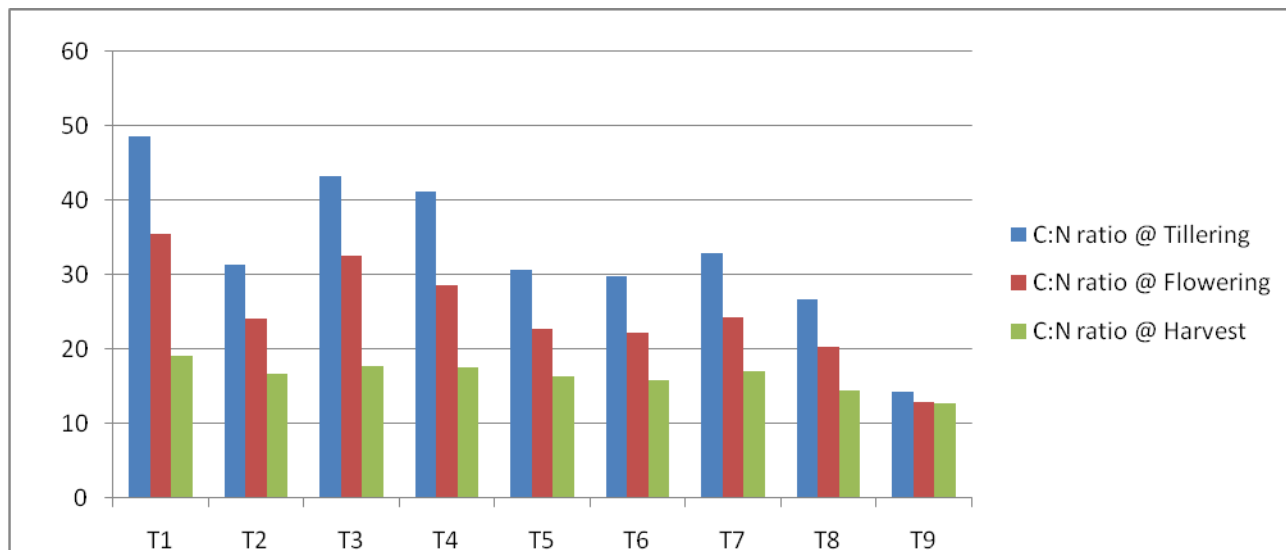


Fig.4 Effect of paddy straw incorporation on C: N ratio in soil at various stages of rice crop



[**Treatments:** **T₁**- Incorporation of rice straw alone, **T₂**- T₁ + 25 kg additional N ha⁻¹ as basal, **T₃**- T₁ + bio-mineralizer, **T₄**- T₁ + Cow dung slurry, **T₅**- T₁ + 25 kg additional N ha⁻¹ as basal + bio mineralizer, **T₆**- T₁ + 25 kg additional N ha⁻¹ as basal + cow dung slurry, **T₇**- T₁ + bio-mineralizer + cow dung slurry, **T₈**- T₁ + 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry, **T₉**- control (no residue)].

Among the residue management practices, the straw incorporation with 25 kg additional N ha⁻¹ as basal, bio-mineralizer and cow dung slurry decreased the C: N ratio. Gaur *et al.*, (1987) reported similar effectiveness of inoculation with a suitable microorganism to speed up the biodegradation process and reduction in C: N ratio. The effective biodegradation of residues were confirmed with microbial inoculants (Vijayakumar, 1997; Esther *et al.*, 2013) to bring down the C: N ratio to a narrow level (Sharma *et al.*, 2014).

With passage of time, C: N ratio got reduced under all the treatments, wide variation was noticed between various treatments at initial stage, become narrower as the age of the crop progressed. This was because of microbial development during the time gap which increased the degradation process and released the available nutrients present in the

added chopped straw to bring down the C: N ratio. This was in agreement with the findings of Azmal *et al.*, (1997). Among the treatments, straw incorporation with 25 kg additional N ha⁻¹ as basal + bio-mineralizer (2 kg t⁻¹) + cow dung slurry (5%) recorded the lowest C: N ratio at all stages of crop growth. Because rice residue 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) and Bijay-Singh *et al.*, (2008).

In conclusion, from the detailed discussion, application of 25 kg additional N ha⁻¹ as basal in residue incorporation is essential to narrow down the soil C: N ratio and increased soil

microbial population. This encourages the soil nutrient availability to succeeding rice crop and subsequently maximum yield. In addition to this, application of Cow dung slurry and Bio-mineralizer leads to further strong increase in residue decomposition rate (narrow C: N ratio) and soil microbial population, which favors maximum yield of succeeding rice crop. Hence, the straw incorporation with 25 kg additional N ha⁻¹ as basal + bio-mineralizer + cow dung slurry is the best option to increase the soil microbial population and quick decomposition of residue in succeeding rice field.

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