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Effect of Paddy Straw Incorporation on Growth and Yield of Rice under Wetland Ecosystem

C. Guruanand [a], M. Raju [b*], K. Boomiraj [a], P. Boominathan [c], G. Prabu Kumar [d] and S. Mohan Kumar [a]

[a] Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore – 641003, India.
[b] Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore – 641003, India.
[c] Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore – 641003, India.
[d] Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore – 641003, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors CG and MR carried out verification of output, and wrote the protocol and the first draft of the manuscript. Authors GPK and PB generated the outputs. Authors MR, KB and SMK defined the methodology of the research and verification part. All authors read and approved the final manuscript.

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ABSTRACT

Burning the paddy straw had variety of effects both on and off the farm. It entails nutrient and economic productivity loss in addition to impact on air quality, animal and human health. Soil incorporation is a cost-effective method of disposing the paddy straw. Effects of enhanced paddy straw incorporation in the field to investigate the growth and yield parameters during the summer season at TNAU, Coimbatore. The treatments comprise Continuous flooding (Conventional) (M_1), AWDI (field water tube): Irrigation at soil moisture depletion by 10 cm (M_2), AWDI (field water tube): Irrigation at soil moisture depletion by 15 cm (M_3) as main plots. The subplot treatments

**Corresponding author: E-mail: rajumarimuthu1976@gmail.com, guruanand09@gmail.com;*

consist of Rice raw straw incorporation + 75% RDF (S_1), Rice raw straw incorporation with Pusa Decomposer Capsules + 75% RDF (S_2), Rice raw straw incorporation with TNAU Bio mineralizer + 75% RDF (S_3), Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4), 75% RDF (S_5), 100% RDF (S_6). Incorporation of rice straw, Pusa decomposer, TNAU Bio-mineralizer along with 75% RDF recorded better results in all growth stages and yield.

Keywords: Rice straw; amendments; incorporation; decomposer; biomineralizer.

1. INTRODUCTION

Rice, a vital staple food supporting over half of the global population, and have major role in human sustenance. Its cultivation in diverse terrains and climates has made it the backbone of numerous societies and economies worldwide. As of the latest available data rice production remains a pivotal agricultural activity, with the Food and Agriculture Organization (FAO) reporting a staggering 515 million metric tons of rice production (FAO, 2020) [1]. Nearly 46.38 million hectares of land produces more than 130.29 million tonnes of rice which is higher than any other food crops cultivated here [2].

India is one of the leading agricultural countries, experiences higher agricultural output, leading to a considerable amount of crop residue after harvest. A significant proportion of this residue is disposed through burning in the fields, resulting in severe environmental pollution, threats to human health, emission of greenhouse gases contributing to global warming and depletion of vital soil microbial diversity and essential plant nutrients, including nitrogen, phosphorus, potassium, and sulfur [3]. To improve crop productivity, the utilization of crop leftovers has become important.

Current sustainable agricultural practices focus on the adoption of organic sources, rather than artificial fertilizers, to boost soil productivity [4]. The recycling of organic waste plays a pivotal role in agriculture by increasing organic matter in the soil. However, the incorporation of dried rice straw presents challenges, such as hindrance to seedbed preparation and impediments to germination of subsequent crops [5], along with the unavailability of essential nutrients, particularly nitrogen to plants. To overcome these issues, incorporation of dried rice straw emerges as the safest approach for environment.

Composting rice straw, as opposed to burning or direct soil application, offers numerous benefits. It reduces air pollution caused by residue burning, minimizes the loss of organic matter and enhances nutrient availability for plant absorption. Comparative studies conducted by Goyal et al. [6] and Wassmann et al. [7] demonstrated that employing composted rice straw significantly improves soil fertility and crop yield. According to Phuong et al. [8] highlighted that the addition of organic matter, such as composted straw, enhances the soil's nutrient retention capacity, making nutrients more readily available to plants. AWD irrigation was found to reduce the total seasonal methane (CH_4) emission by 22.3% to 56.2% when compared with continuous flooding while maintaining rice yield [9].

The incorporation of composted rice straw holds great promise for sustainable agricultural production. It not only improves soil fertility and crop productivity but also mitigates greenhouse gas emission from rice ecosystem [10]. The significance of composting rice straw as a sustainable approach to manage crop residues. Embracing composting practices not only increases soil health and agricultural productivity but also aligns with global efforts toward environmentally conscious agriculture

2. MATERIALS AND mETHODS

2.1 Site Description

The field experiment was conducted wetland rice ecosystem at Wetland Farm, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India (Fig. 1) during the summer season / Sornavari (Chittirai pattam) (April to August). The Coordinate of the experimental site is 11º00’11.5N 76º55’37.1E with 411m above the mean sea level and it comes under the Western Agro Climatic Zone of Tamil Nadu. The average Maximum and Minimum Temperature of 37ºC and 30.1ºC were recorded during 16th and 27th Standard weeks respectively. The total rainfall received during the period is 287.5 mm in 23 rainy days.

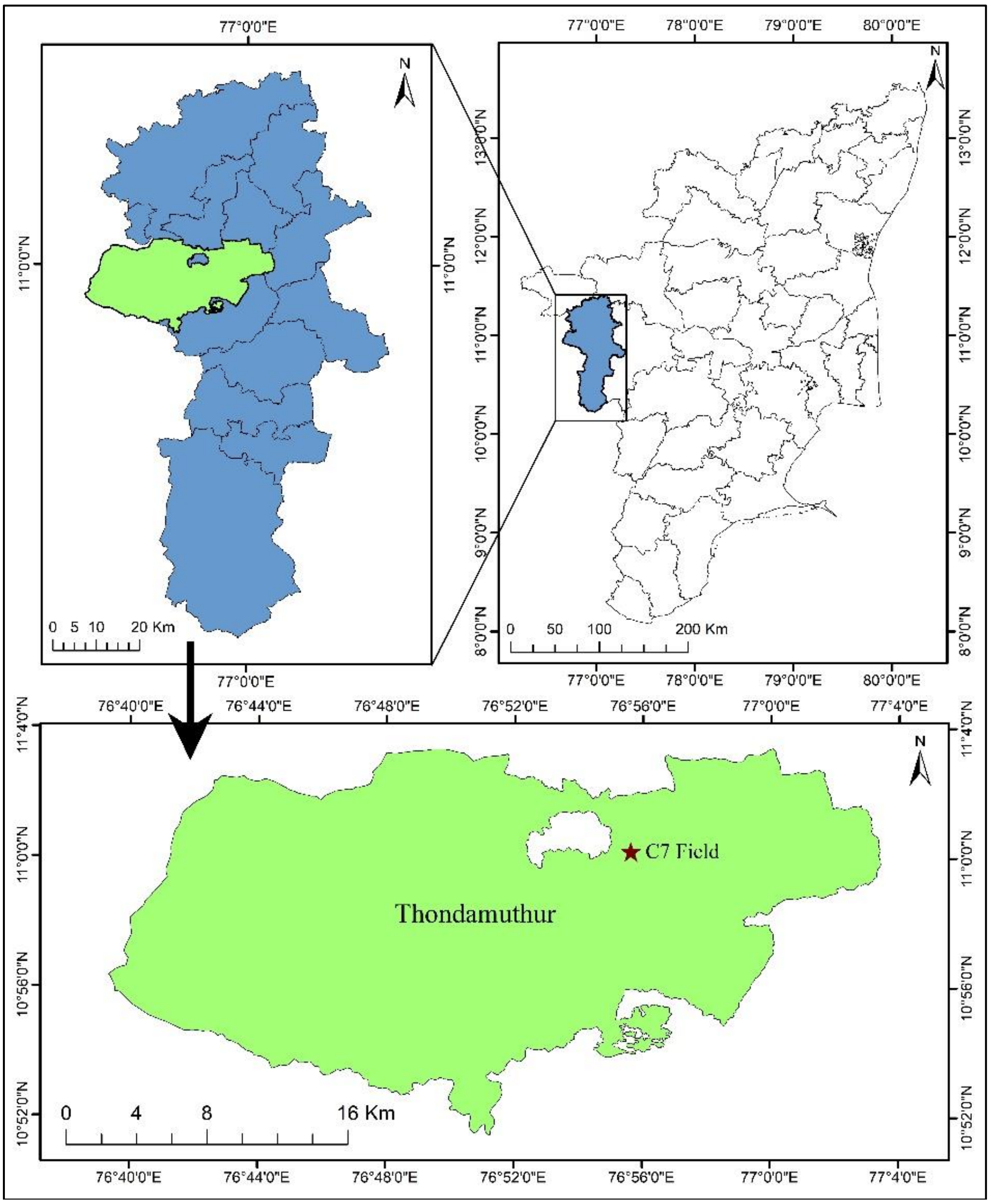

Fig. 1. Location of experimental field

2.2 Experimental Description

The variety chosen for the experiment is ADT 53 which was released during 2019 by Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India. It is a short duration variety (110 - 115 Days).

The Soil type of the experimental site is Clay loam with EC and pH of 0.67 ds/m and 8.2 respectively. Before forming the field layout, the initial soil was subjected to Physiochemical analysis. The experiment was conducted in strip plot design comprises of three Main Plots for water management and six sub plots for mitigation measures which is followed in three replications. In main plot, Continuous flooding (Conventional) (M_1), AWDI (field water tube): Irrigation at soil moisture depletion by 10 cm (M_2), AWDI (field water tube): Irrigation at soil moisture depletion by 15 cm (M_3). In subplot, Rice raw straw incorporation + 75% RDF (S_1), Rice raw straw incorporation with Pusa Decomposer Capsules + 75% RDF (S_2), Rice raw straw incorporation with TNAU Bio mineralizer + 75% RDF (S_3), Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4), 75% RDF (S_5), 100% RDF (S_6) was studied.

2.3 Preparation of Pusa Decomposer and TNAU Bio Mineralizer

Pusa decomposer capsules got from the Division of Microbiology, Indian Agricultural Research Institute (IARI), Pusa, New Delhi, India. 150 grammes of old jaggery was boiled in 5 litres of water to make culture, and the filth that floated on the surface of the boiling water was sieved out of the mixture. After being cooled to room temperature, the jaggery solution was combined with roughly 50 g of chickpea (*Cicer arietinum* L.) flour. Four Pusa decomposer capsules were cut open, thrown into the well-blended chickpea flour, and well mixed with a wooden stick. After that, the mixture was put onto a plastic tray, covered with a thin towel and kept in a warm location for one week.

TNAU biomineralizer @ 2 kg/tonne for rice straw was used and water was added @ 20 litres per 2 kg biomineralizer.

2.4 Statistical Analysis

Analysis of Variance (ANOVA) was performed on the data using R programming and statistical software. As recommended by Gutierrez et al. [11] the significant differences between mean values were assessed using Least Significant Difference (LSD) at a 5% probability level. Critical differences were examined at the 5% level of significance in cases where treatment differences were found to be statistically significant (F test). NS means the treatments were not statistically significant.

3. RESULTS AND DISCUSSION

3.1 Effect of Rice Straw Incorporation on Plant Height

Generally, growth and yield attributes were significantly influenced by different methods of planting systems and nutrient application. In this experiment the growth parameters were observed at three different stages of crop growth. The plant height was increased due to the positive effect of rice straw incorporation along with Pusa decomposer and TNAU biomineralizer + 75% RDF. According to Singh et al. [12] the application of Pusa decomposer along with RDF will increase the decomposition duration of rice straw and also increases the yield of the crop. The plant height was recorded at 30, 60 and 90 DAT which ranges between 32.8 - 40.3 cm, 59.5 – 63.7 cm and 96.7 – 106.2 cm respectively. Higher plant height was recorded in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) at all the stages of crop having the value of 40.3, 63.7 and 106.2 cm during 30,60 and 90 DAT respectively. All the values are significant at all stages according to value P (Table 1).

3.2 Effect of Rice Straw Incorporation on Number of Tillers hill^{-1}

The maximum number of tillers per hill was recorded on Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) having 15,21 and 25 tillers hill^{-1} on 30,60 and 90 DAT respectively. The range varies from 14 to 16 tillers hill^{-1} on 30 DAT, 18 to 21 tillers hill^{-1} is recorded during 60 DAT and nearly 23 to 25 tillers hill^{-1} in 90 DAT (Table 2). According to Thavanesan and Seran [13] the incorporation of rice straw increases crop growth and yield.

3.3 Effect of Rice Straw Incorporation on Soil Available Nutrients

The levels of soil nutrients like N, P and K were assessed during tillering, panicle development and maturity. After the straw is absorbed, the nutrients are returned to the soil, aiding in the long-term retention of soil nutrient reserves. Soil moisture determines a major role in increasing the rate of decomposition and yield [14]. Rice straw act as a main source for K for most of the rice growing farmers. When compared to the application of ash to the field, rice straw incorporation increases the soil pH, organic carbon and nutrient content. Large quantity of rice straw is required to attain adequate amount of N to the crop. As a result, the initial soil was analysed. The soil pH and EC are 8.2 and 0.67 dS m^{-1} respectively. After incorporation the level of pH and EC increases to 8.33 and 0.76 dS m^{-1} respectively. The initial the available N, P and K are 232, 17.08 and 288 kg ha^{-1} respectively (Table 3). Then the soil samples were collected and analysed during the maturity, the level of available N, P and K are 260, 16.15 and 322 kg ha^{-1} respectively which is shown in Fig. 2. Approximately 11.81% rise in the available K was observed. The current results were akin to the findings of Chivenge et al. [15].

3.4 Effect of Rice Straw Incorporation on Leaf Area Index

LAI is calculated for three different stages of rice. At 30 DAT, LAI ranges from 0.70 to 0.80, for 60 DAT ranges from 2.11 to 2.47 and for 90 DAT ranges from 3.16 to 4.32 (Table 4). LAI usually depends upon plant density, leaf size and shape, leaf angle distribution, growth stage and nutrient availability. As a result, the maximum LAI is recorded in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) having 0.80, 2.47, 4.32 respectively at 30, 60 and 90 DAT. Similar results were also observed by Paiman and Fakultas Pertanian [21].

3.5 Yield Attributes

Yield Attributes like Grain yield (Kg ha^{-1}), Straw yield (Kg ha^{-1}), Harvest Index (HI), Number of panicles m^{-2} and Panicle length (cm) were observed at harvest.

3.5.1 Number of panicles m^{-2} and panicle length

At harvest stage more numbers of panicles m^{-2} are observed in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) having 270 panicles followed by Rice raw straw incorporation with Pusa Decomposer Capsules + 75% RDF (S_2) having nearly 266 panicle m^{-2}. In this experiment, 75% RDF (S_5) recorded less no. of panicles (238/m^2).

The panicle length was measured at the harvest stage and it ranges between 24.5 to 27.3 cm. The highest panicle length is observed in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) having nearly 27.3 cm where the both number of panicle m^{-2} and panicle length are greater in above (Table 5). Rice straw incorporation has implications for nutrient cycling and soil fertility in paddy fields, particularly under cool temperature conditions. It highlights the importance of N management to promote efficient straw decomposition and nutrient release, which can benefit subsequent rice crops. The above finding is supported by Takakai et al. [22].

Table 1. Effect of rice straw incorporation on plant height (cm)

Treatment	30 DAT				60 DAT				90 DAT			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	36.2	40.3	35.3	37.3	59.0	64.3	60.7	61.3	101.7	99.2	100.0	100.3
S_2	36.0	41.0	36.3	37.8	61.3	65.2	60.3	62.3	101.3	106.3	98.0	101.9
S_3	37.7	40.3	37.0	38.3	62.3	62.3	63.0	62.5	95.7	110.0	99.7	101.8
S_4	40.3	42.3	38.4	40.3	63.5	65.2	62.3	63.7	102.0	111.0	105.7	106.2
S_5	32.3	35.0	31.0	32.8	57.7	58.6	62.3	59.5	96.3	95.7	98.0	96.7
S_6	36.3	37.3	35.3	36.3	61.2	62.7	59.5	61.1	99.0	98.0	101.7	99.6
Mean	36.5	39.4	35.6	37.1	60.8	63.1	61.4	61.7	99.3	103.4	100.5	101.1
Interaction	M	S	M×S		M	S	M×S		M	S	M×S	
SEd	0.22	0.36	0.66		0.45	0.69	1.06		0.67	1.29	2.08	
CD (0.05)	0.61	0.81	1.38		1.24	1.53	2.21		1.85	2.87	4.34	

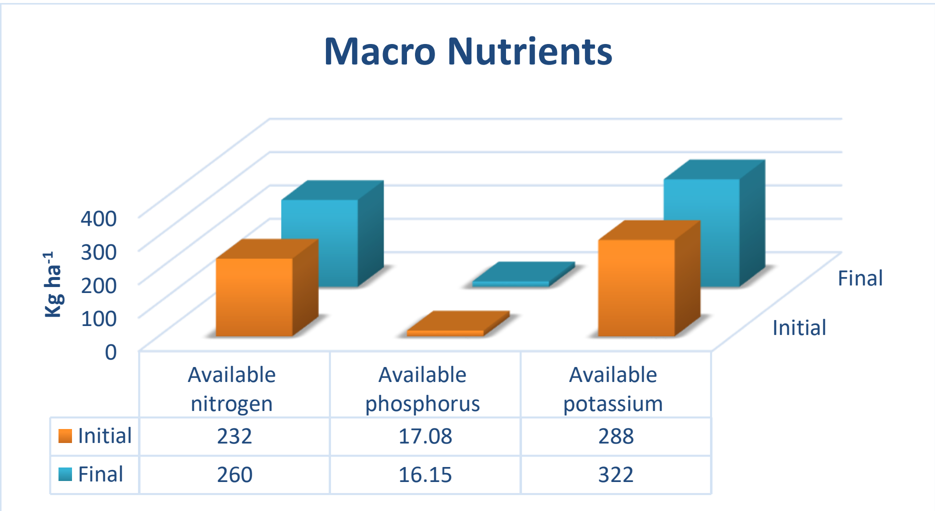

Fig. 2. Effect of rice straw incorporation on soil available nutrients

Table 2. Effect of rice straw incorporation on number of tillers hill^{-1}

Treatment	30 DAT				60 DAT				90 DAT			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	14	15	15	15	18	17	20	18	22	22	24	23
S_2	14	14	15	14	19	20	18	19	24	24	23	24
S_3	15	17	14	15	21	18	21	20	25	22	22	23
S_4	17	15	16	16	20	21	21	21	26	23	26	25
S_5	14	14	14	14	19	19	20	19	23	22	23	23
S_6	17	14	15	15	18	18	19	18	22	25	24	24
Mean	15	15	15	15	19	19	20	19	24	23	24	23
Interaction	M	S	M×S		M	S	M×S		M	S	M×S	
SEd	0.1	0.19	0.3		0.24	0.28	0.38		0.12	0.3	0.49	
CD (0.05)	0.26	0.43	0.63		0.67	0.61	0.8		0.33	0.67	1.01	

Table 3. Initial and final value of N, P, K, OC and soil pH in experimental site

Properties	Initial values	Final values	Methodology	Reference
Available Nitrogen (kg ha^{-1})	232	103.3	Alkaline Permanganate method	Subbiah and Asija, [16]
Available Phosphorus (kg ha^{-1})	17.08	5.13	Olsen's extractant method	Olsen et al. [17]
Available potassium (kg ha^{-1})	288	418.03	Neutral normal ammonium acetate method	Stanford and English 1949 [18]
Organic Carbon (%)	0.6	0.72	Chromic acid wet digestion method	Walkley and Black 1934 [19]
Soil pH	8.2	8.33	pH meter	Jackson [20]

Table 4. Effect of rice straw incorporation on plant leaf area index

Treatments	30 DAT				60 DAT				90 DAT			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	0.62	0.77	0.75	0.71	2.15	2.3	2.28	2.24	3.46	3.81	3.45	3.57
S_2	0.79	0.77	0.55	0.70	1.83	2.31	2.19	2.11	3.60	3.65	3.85	3.70
S_3	0.70	0.66	0.81	0.72	2.50	2.38	2.41	2.43	3.44	4.56	4.12	4.04
S_4	0.87	0.83	0.72	0.80	2.56	2.52	2.31	2.47	3.89	4.43	4.64	4.32
S_5	0.87	0.65	0.76	0.76	1.92	2.67	1.95	2.18	2.61	3.05	3.81	3.16
S_6	0.78	0.87	0.68	0.78	2.37	2.33	2.17	2.29	3.70	3.76	3.59	3.68
Mean	0.77	0.76	0.71	0.75	2.22	2.42	2.22	2.29	3.45	3.88	3.91	3.75
Interaction	M	S	M×S		M	S	M×S		M	S	M×S	
SEd	0.01	0.01	0.02		0.01	0.03	0.05		0.02	0.05	0.08	
CD (0.05)	0.02	0.02	0.04		0.03	0.07	0.09		0.05	0.12	0.16	

Table 5. Effect of rice straw incorporation on No. of panicles /m^2 and panicle length

Treatment	No. of panicles/m²				Panicle Length (cm)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	255	263	262	260	25.70	26.40	26.07	26.1
S_2	260	271	266	266	25.43	27.30	26.43	26.4
S_3	246	263	255	255	25.37	27.20	26.30	26.3
S_4	257	290	264	270	26.17	28.53	27.30	27.3
S_5	234	242	239	238	24.07	25.40	24.17	24.5
S_6	240	257	242	246	24.67	26.43	25.23	25.4
Mean	249	264	255	256	25.2	26.9	25.9	26.0
Interaction	M	S	M×S		M	S	M×S	
SEd	0.52	0.89	1.97		0.03	0.06	0.11	
CD (0.05)	1.45	1.98	4.1		0.08	0.14	0.24	

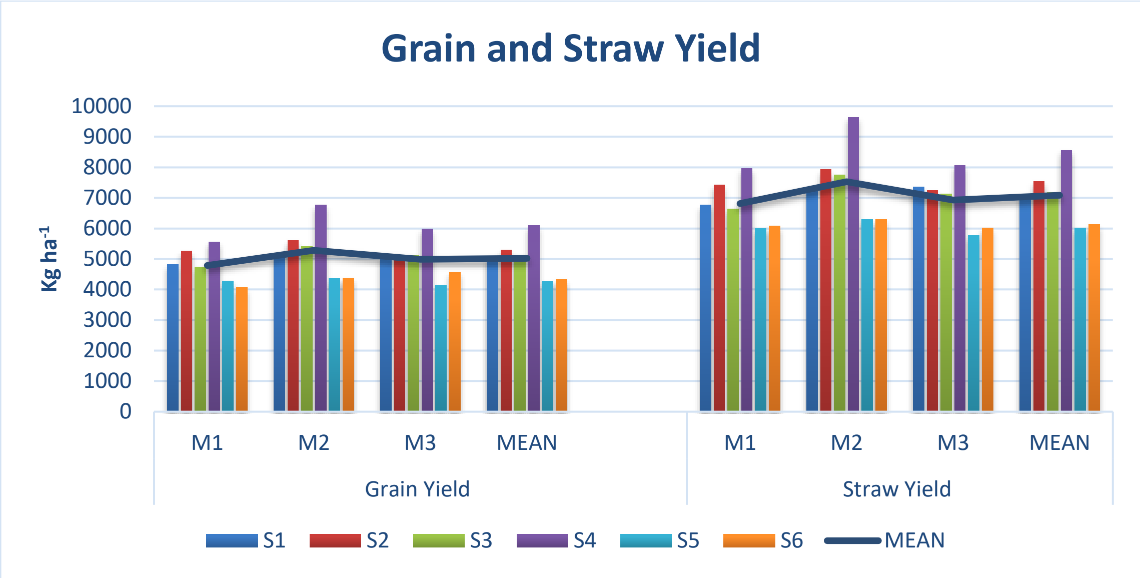

Fig. 3. Grain yield, straw yield and harvest index

3.5.2 Grain yield, straw yield and harvest index

At harvest, yield parameters like Grain yield and Straw yield were recorded and harvest index is calculated. The Grain yield ranges between 4263 to 6101 kg ha^{-1} and the straw yield ranges between 6020 to 8562 kg ha^{-1}. The maximum Grain Yield and straw yield was observed in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) having about 6101 and 8562 kg ha^{-1} respectively followed by Rice raw straw incorporation with Pusa Decomposer Capsules + 75% RDF (S_2) treatment having nearly 5295 kg ha^{-1} of grain yield and 7530 kg ha^{-1} of straw yield. The least amount of yield is recorded in 75% RDF (S_5) having about 4263 kg ha^{-1} of grain yield and 6020 kg ha^{-1} of straw yield. With this recorded values harvest index is calculated. It ranges between 0.413 to 0.417 which is shown in Fig. 3. All the above values are significant. Organic fertilizer formed from decomposed rice straw has a high nutritional potential, which promotes crop productivity, increases soil fertility and moisture content which improve crop development and grain yield [23]. Rice output is determined by the quantity of photosynthate present in leaves and stems during the seed filling phase, which is largely dependent on the photosynthesis process that occurred after blooming. The use of rice straw compost increases the amount of photosynthates in the leaves. The current results were akin to the findings of Paiman [24] and Takakai et al. [25].

4. CONCLUSION

From the above study it could be concluded that higher growth parameters like plant height, number of tillers per hill and leaf area index were observed in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) when compared to other treatments.

The soil properties of experimental site have been improved due to rice straw incorporation which is favorable for better crop growth and increases the soil microbial activity.

As a result, grain yield (6101 kg ha^{-1}) and straw yield (8562 kg ha^{-1}) was higher in Rice raw straw incorporation with Pusa Decomposer Capsules + TNAU Bio mineralizer + 75% RDF (S_4) followed by Rice raw straw incorporation with Pusa Decomposer Capsules + 75% RDF (S_2).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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