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Field Validation on Incorporation of Rice Husk Biochar and Paddy Straw Compost on Crop Attributes and Soil Properties in Rice Ecosystem

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Authors' contributions

This work was carried out in collaboration among all authors. Author KBK prepared the manuscript and analyzed the data. Author MR designed the methodology and guided to complete the research program in an organized way. Authors KSB and CU worked on the verification part of the thesis research and helped in the preparation of this manuscript. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: To study the effect of rice husk biochar and rice straw compost on Rabi season rice cultivation.
Study Design: The randomized block design was used. The treatments of different doses of soil amendments like rice husk biochar, rice straw compost and recommended fertilizer doses are applied.
Place and Duration of Study: The experimental trial was conducted during the Rabi season (January - April) of 2022 at Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India.

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Methodology: The study consisted of 11 sets of RBD design treatments replicated thrice. The rice variety of ADT57 Short duration variety was used for this study. The observation has been recorded during the crop growing period at regular intervals.

Results: The study results revealed that application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) treatment showed the highest plant growth parameters like plant height (27.88, 74.22 and 108.89 cm), number of tillers m^{-2} (122, 620 and 642), leaf area index (2.62, 6.53 and 8.47), SPAD reading (47.22, 43.64 and 40.46), root length (18.86, 37.45 and 56.31 cm) and root volume (17.85, 26.01 and 37.77 ml) at 30, 60 and 90 DAT respectively and yield parameters like grain yield (5133 kg/ha), straw yield (7090 kg/ha), panicle length (25.28cm) and number of productive tillers m^{-2} (571.6) and was significantly on par with application of PSB @ 2kg/ha + Rice Husk Biochar (RHB) @ 5 t/ha + 75% RDF (T_6) and superior over the other all treatments. Plant growth parameters of application of PSB @ 2kg/ha + Rice Husk Biochar (RHB) @ 5 t/ha + 75% RDF (T_6) recorded the plant height (27.41, 73.76 and 108.29 cm), number of tillers m^{-2} (118, 613 and 630), leaf area index (2.54, 6.42 and 8.38), SPAD reading (46.26, 43.10 and 40.20), root length (18.35, 37.05 and 55.40 cm) and root volume (17.42, 25.44 and 37.33 ml) at 30, 60 and 90 DAT respectively and yield parameters like grain yield (4953 kg/ha), straw yield (7077 kg/ha), panicle length (25.07 cm) and number of productive tillers m^{-2} (555). So, the application of PSB @ 2 kg/ha + RSC @ 5 t/ha + 75% RDF has recorded the best results than all other treatments. With respect to soil properties, application of Rice husk Biochar (RHB) @ 5t/ha + 75% RDF (T_4) has reduced the soil bulk density (from 1.52 to 1.47) and application of rice straw compost @ 5t/ha has increased the soil pH (from 6.58 to 7.14) as compared to other treatments whereas the nutrient status (nitrogen (from 212 to 266 kg ha^{-1}); phosphorus (from 45.41 to 61.59 kg ha^{-1}) and potassium (from 192 to 218.4 kg ha^{-1}) has increased by application of PSB @ 2kg/ha + RSC @ 5t/ha + 100% RDF (T_{11}) than other treatments.

Keywords: Rice husk biochar (RHB); rice straw compost (RSC); recommended Fertilizer dose (RDF); leaf area index (LAI); SPAD reading (Chlorophyll content) and number of tillers.

1. INTRODUCTION

Rice (*Oryza sativa L.*) is a staple food crop for the world population and has grown throughout the world. In India, the area of crop harvested is 45 million ha in 2020 and the annual production of rice is 178 million tonnes with average productivity of 3962.3 kg ha^{-1}. India ranks second in World wise rice production next to China. It shares 23.56% of global rice production [1]. According to the Food and Agriculture Organization (FAO), to meet demand by 2025, the world's population and agricultural production would need to be significantly increased [2]. In order to provide food for the growing population with the same land leads to intensive agricultural practices. So, the application of inorganic fertilizer is done for crop cultivation. These continuous practices lead to the deterioration of soil fertility status.

India is one of the countries which are more dominant in agriculture. More agricultural production also leads to more agricultural residual production. In order to get rid of the leftover straw and stubbles after harvest, a significant amount of crop is burned in the fields. Crop residue burning results in environmental pollution, human health risks, the production of greenhouse gases that contribute to global warming, and the loss of essential soil microbial diversity and plant nutrients like N, P, K, and S [3]. So, crop residues are sustainably used as a source to increase crop production. Among the various agro-wastes, Rice husk is a bulk agricultural waste that in more than 75 countries produces 116 million tonnes of rice husk per year [4]. The yearly rice husk production in India is typically over 120 million tons. Because of its low cellulose and other sugar content, rice husk is generally not suggested as cattle feed. So, rice husk is pyrolyzed into rice husk biochar by burning the rice husk. By burning it gets carbonized and gets in stable carbon forms and helps in Carbon sequestration.

Biochar is a very resistant material due to its condensed structure, the carbonaceous and porous material [5]. It is produced when biomass thermally decomposed at moderately high temperatures (200^oC-600^oC) in an atmosphere with low or no oxygen presence. It endows it with its beneficial soil amendment role in enhancing crop yield [6], improving soil properties [7], carbon sequestration, and reducing greenhouse gas emissions [8]. Recent studies show that co-

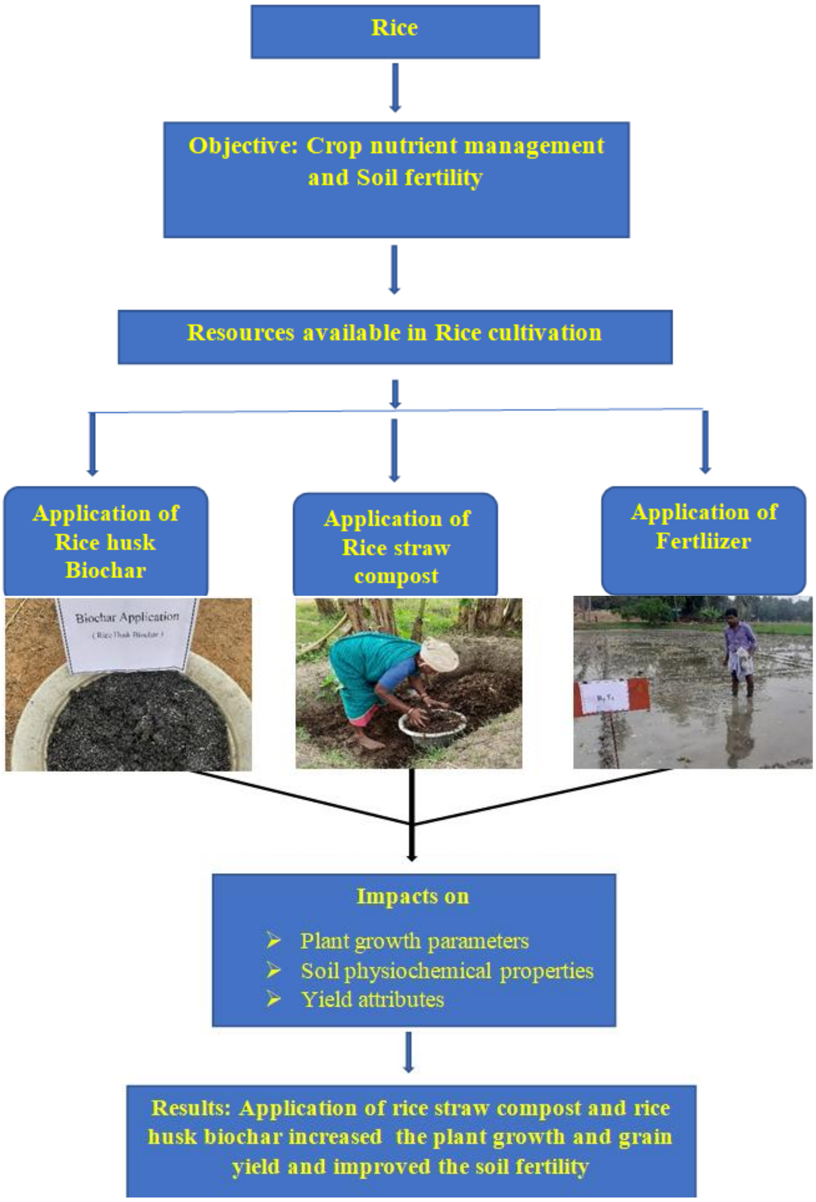

Chart 1. Flow chart of the research

applying biochar plus inorganic or organic fertilizer significantly improved soil characteristics and crop productivity.

In modern sustainable agriculture production focuses on employing organic sources to increase soil productivity rather than using artificial fertilizers. Recycling organic wastes in agriculture is necessary because it replenishes the soil health with organic materials. Fresh Rice straw incorporation is related to a number of issues, including the unavailability of nutrients to plants, particularly nitrogen, and residues that hamper seedbed preparation and contribute to lower germination of succeeding crops [9]. So, composting rice straw emerges as a safe solution for fresh straw incorporation. Composting straw is an alternative to burning and direct integration of fresh straw into the soil. It will reduce air pollution produced by residue burning as well as loss of plant nutrients and organic matter and make nutrients easily available for plant uptake. According to Khosa et al. [10] and Wassmann *et al*. [11], using composted rice straw instead of fresh rice straw has several advantages for soil fertility and crop productivity. Phoung *et al*. [12] stated that, by applying organic matter like straw compost to the soil, nutrient availability to plants is enhanced in a number of ways. It was reported that, compost-amended soil had considerably higher soil pH and EC, whereas biochar raised soil pH alone but not EC.

Several studies stated that the biochar and straw compost application has numerous beneficial effects on crop productivity and soil quality [13,14]. This research paper will provide useful information and raise awareness about the effects of Rice Husk Biochar and Paddy straw Compost derived from rice crop leftovers on Paddy productivity and soil properties.

2. MATERIALS AND METHODS

2.1 Experimental Site

An experiment on the influence of Rice husk biochar and rice straw compost on sustainable paddy production was conducted at Tamilnadu Rice Research Institute, Tamil Nadu, India during the *rabi* season (January - April). The coordinates of the experimental site are 10.9985° N, 79.4801° E with 19.4 m above from mean sea level. This location comes under the Cauvery delta zone of Tamilnadu. The geographical areas covered under Cauvery delta zone is Thanjavur, Tiruvarur, Nagapattinam, Pudukkottai, Cuddalore, Ariyalur, Karur and Tiruchirappalli districts. This zone is prone to paddy cultivation in all seasons as Rice – rice – rice fallow pulses. The soil type of the experimental site is alluvial in nature with pH and EC of 7.4 and 0.4 ds/m respectively. Before forming the experimental layout, the initial soil was collected and subjected to physiochemical analysis (Fig. 1). The total area of the experimental field is 0.45 acres (1850 m^2) and individual plots consist of a plot area of 20 m^2 (5m x 4 m).

2.2 The Meteorological Parameters

The climatic parameters observed during the cropping period showed maximum and minimum temperatures of 31.6^{0}C & 25^{0}C respectively. The amount of rainfall received during the cropping period is around 221mm for 16 days.

2.3 Field Experiment Details

ADT 57 paddy variety was chosen for the trial. This variety was recently released in 2022 from Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India. This variety comes under a short duration (115-120 days). The study consists of 11 treatments such as Control (No amendments) (T_1), Application of 75% Recommended Dose of fertilizer (RDF) (T_2), Application of 100% RDF (T_3), Application of Rice husk Biochar (RHB) @ 5t/ha + 75% RDF (T_4), Application of RHB @ 5t/ha + 100% RDF (T_5), Application of Phosphorus Solubilizing Bacteria (PSB) @ 2kg/ha + RHB @ 5t/ha + 75% RDF (T_6), Application of PSB @ 2kg/ha + RHB @ 5t/ha + 100% RDF (T_7), Application of Rice Straw Compost (RSC) @ 5t/ha + 75% RDF (T_8), Application of RSC @ 5t/ha + 100% RDF (T_9), Application of PSB @ 2kg/ha + RSC @ 5t/ha + 75% RDF (T_{10}), Application of PSB @ 2kg/ha + RSC @ 5t/ha + 100% RDF (T_{11}). This trial has been replicated thrice with the above set of treatments by adopting a Randomized block design. The 100% RDF of NPK at 120:40:40 Kg/Ha and 75% RDF of NPK at 90:30:30 kg/Ha. The spacing adopted is 25 X 25 cm.

2.4 Preparation of Rice Husk Biochar and Straw Compost

The waste rice husk that has been collected from the processing unit was heaped on a concert floor. The heaped rice husk gets burnt at 200^{0}C not to ash. At this temperature, slow pyrolysis of rice husk occurs, and the core part of the heap contains well-pyrolyzed biochar. The well-pyrolyzed biochar was applied to the field after overnight burning (12 hrs.) of rice husk and cooling of pyrolyzed Rice Husk.

The compost was prepared with paddy straw by PUSA-Decomposer mother culture. The culture was prepared by mixing the decomposer inoculum with jaggery solution mixed with gram flour. After the well mixing of the inoculum with jaggery solution left undisturbed for 10 days. Then the mother culture solution is diluted with water and used for spraying. The paddy straw was sprayed in the pit and the solution was sprayed likewise the solution was sprayed layer by layer. After 21 days the well-decomposed straw compost has been taken from the pit and applied to the field.

2.5 Biometric Observation and Yield Attributes

The biometric observation of Plant height (cm), the number of tillers per m^2, SPAD content, root length (cm), root volume, dry matter production (Kg m^{-2}) and Leaf Area Index (LAI) as per Palaniswamy and Gomez, [15] were recorded periodically at regular interval i.e., 30, 60 and 90 DAT. Similarly, yield attributes at the harvest stage were registered such as grain yield (kg/ha), straw yield (kg/ha), number of productive tillers m^{-2} and panicle length (cm). The collected data

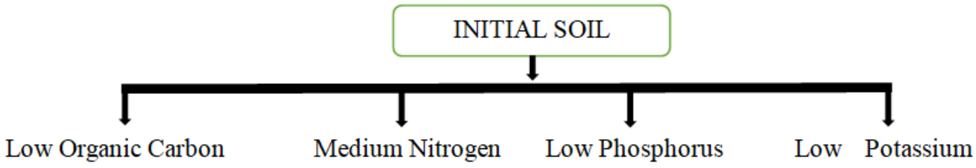

Fig. 1. The nutritional status of Initial soil Sample

from three replications were subjected to statistical analysis by using analysis of variance (ANOVA). The statistical analysis was done as per the procedure given by [16]. The critical difference at 5% probability level was calculated for the treatments with a significant difference.

3. RESULTS AND DISCUSSION

3.1 Influence of Treatments on Plant Height and Number of Tillers m^{-2} (Table 1)

The plant height and Number of tillers m^{-2} were significantly influenced by the treatments in all stages. The maximum plant height of 27.88 cm, 74.22 cm and 108.89 cm was recorded with application of PSB @ 2 kg/ha + Rice Straw Compost (RSC) @ 5 t/ha + 75% Recommended Fertilizer Dose (RDF) (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2 kg/ha + Rice Husk Biochar (RHB) @ 5 t/ha + 75% RDF (T_6) of 27.41cm, 73.76 cm and 108.29 cm at 30, 60 and 90 DAT respectively. The shortest plant height of 20.59 cm, 63.25 cm and 94.34 cm was recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively.

The maximum number of tillers m^{-2} 122, 620 and 642 was recorded with application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF (T_6) of 118, 613 and 630 at 30, 60 and 90 DAT respectively. The minimum number of tillers m^{-2} of 85, 413 and 438 were recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively. The Plant height response to rice husk biochar and rice straw compost has been shown in (Fig. 2).

From the above findings, rice straw compost and rice husk biochar application lead to an increase in the soil nutrient status by increasing the amount of available nutrients for plant uptake, but organic amendment rice straw compost has the property of slow releasing the nutrients, especially nitrogen (N) which leads to increase above-ground biomass because of supply of essential nutrient throughout the crop growing period. Then it also enriches the soil microbial activity and soil enzyme activities. The presence of phosphorus solubilizing bacteria helps in mobilizing the unavailable essential nutrient to available form for plant uptake. These findings are supported by Yasuda and Okada, [17] and Asadi et al. [18].

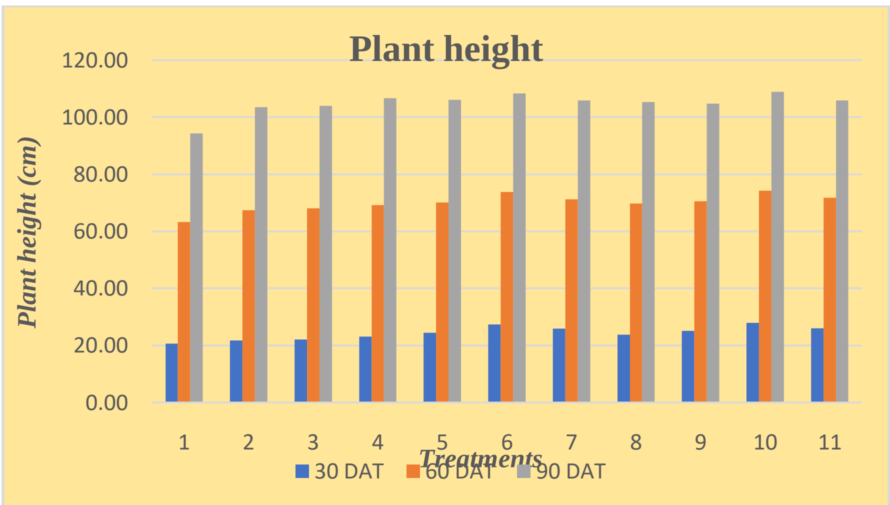

Fig. 2. Influence of Rice husk biochar and straw compost on Plant height

Table 1. Effect of RHB and RSC on Plant height and Number of tillers m^{-2}

Treatments	Plant Height (cm)			No. of tillers m^{-2} (Nos)		
	30 DAT	**60 DAT**	**90 DAT**	**30 DAT**	**60 DAT**	**90 DAT**
T_1 - Control (No amendments)	20.59	63.25	94.34	85	413	438
T_2 - 75% RDF	21.78	67.44	103.54	88	528	547
T_3 - 100% RDF	22.04	68.04	103.97	90	540	560
T_4 - RHB @ 5 t/ha + 75% RDF	23.05	69.16	106.67	93	542	562
T_5 - RHB @ 5 t/ha + 100% RDF	24.46	70.11	106.10	98	553	567
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**27.41**	**73.76**	**108.29**	**118**	**613**	**630**
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	25.90	71.24	105.83	106	573	590
T_8 - RSC @ 5 t/ha + 75% RDF	23.75	69.77	105.28	95	550	563
T_9 - RSC @ 5 t/ha + 100% RDF	25.16	70.56	104.79	102	555	572
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**27.88**	**74.22**	**108.89**	**122**	**620**	**642**
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	26.07	71.78	105.87	112	598	617
SE (D)	0.290	1.685	3.234	3.218	8.718	13.412
CD (P=0.05)	0.613	3.573	6.856	6.712	18.484	28.438

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar; RSC - Rice Straw Compost;
PSB - Phosphorus Solubilizing Bacteria

Table 2. Effect of RHB and RSC on leaf area index and SPAD reading

Treatments	Leaf Area Index (LAI)			SPAD (Chlorophyll Content)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1 - Control (No amendments)	1.615	5.49	7.10	39.80	35.80	32.24
T_2 - 75% RDF	1.940	5.90	7.46	41.28	38.10	35.63
T_3 - 100% RDF	2.061	5.96	7.60	41.76	38.60	36.08
T_4 - RHB @ 5 t/ha + 75% RDF	2.132	6.05	7.78	42.24	39.03	36.29
T_5 - RHB @ 5 t/ha + 100% RDF	2.294	6.19	7.95	43.06	40.95	38.57
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**2.541**	**6.42**	**8.38**	**46.26**	**43.10**	**40.20**
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	2.335	6.27	8.17	44.75	42.06	39.17
T_8 - RSC @ 5 t/ha + 75% RDF	2.261	6.13	7.84	42.60	39.74	36.82
T_9 - RSC @ 5 t/ha + 100% RDF	2.298	6.21	8.10	43.42	41.70	38.75
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**2.624**	**6.53**	**8.47**	**47.22**	**43.64**	**40.46**
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	2.426	6.37	8.29	44.96	42.98	39.50
SE (D)	0.033	0.115	0.244	2.499	1.657	0.875
CD (P=0.05)	0.069	0.245	0.517	5.298	3.513	1.853

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar; RSC - Rice Straw Compost;
PSB - Phosphorus Solubilizing Bacteria

3.2 Influence of Treatments on Leaf Area Index (LAI) and SPAD Reading (Table 2)

The Leaf Area Index (LAI) and SPAD reading were significantly influenced by the treatments in all stages. The maximum LAI of 2.62, 6.53 and 8.47 was recorded with application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2kg/ha + RHB @ 5 t/ha + 75% RDF (T_6) of 2.54, 6.42 and 8.38 at 30, 60 and 90 DAT respectively. The minimum LAI of 1.61, 5.49 and 7.10 was recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively.

The maximum SPAD reading of 47.22, 43.64 and 40.46 was recorded with application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2kg/ha + RHB @ 5 t/ha + 75% RDF (T_6) of 46.26, 43.10 and 40.20 at 30, 60 and 90 DAT respectively. The minimum SPAD reading of 39.30, 35.80 and 32.24 was recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively. The SPAD content of the crop decreases while growing to the maturity phase. The leaf Area Index (LAI) and SPAD to rice husk biochar and rice straw compost have been shown in (Fig. 3).

As the above findings state that the application of rice straw compost with the phosphorus solubilizing bacteria helps in more nutrient mobilization than all other treatments well as the same happens in rice husk biochar with phosphorus solubilizing bacteria in low amounts as with rice straw compost. So, the compost of rice straw contains more micronutrients and nitrogen availability. Nitrogen and micronutrients like zinc and magnesium play a major role in chlorophyll content. This was in accordance with the study results of Paiman *et al*. [19]'s study.

3.3 Influence of Treatments on Root Length and Root volume (Table 3)

The Root length and Root volume were significantly influenced by the treatments in all stages. The maximum Root length of 18.86 cm, 37.45 cm and 56.31 cm was recorded with application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2kg/ha + RHB @ 5 t/ha + 75% RDF (T_6) of 18.35 cm, 37.05 cm and 55.40 cm at 30, 60 and 90 DAT respectively. The minimum root length of 14.38 cm, 25.56 cm and 40.27 cm was recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively.

The maximum Root volume of 17.85 ml, 26.01 ml and 37.77 ml was recorded with application of PSB @ 2kg/ha + Rice Straw Compost @ 5 t/ha + 75% RDF (T_{10}) at 30, 60 and 90 DAT respectively which is on par with application of PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF (T_6) of 17.42 ml, 25.44 ml and 37.33 ml at 30, 60 and 90 DAT respectively. The minimum root volume of 11.59 ml, 18.47 ml and 25.91 ml was recorded with Control treatment (T_1) with no amendment at 30, 60 and 90 DAT respectively.

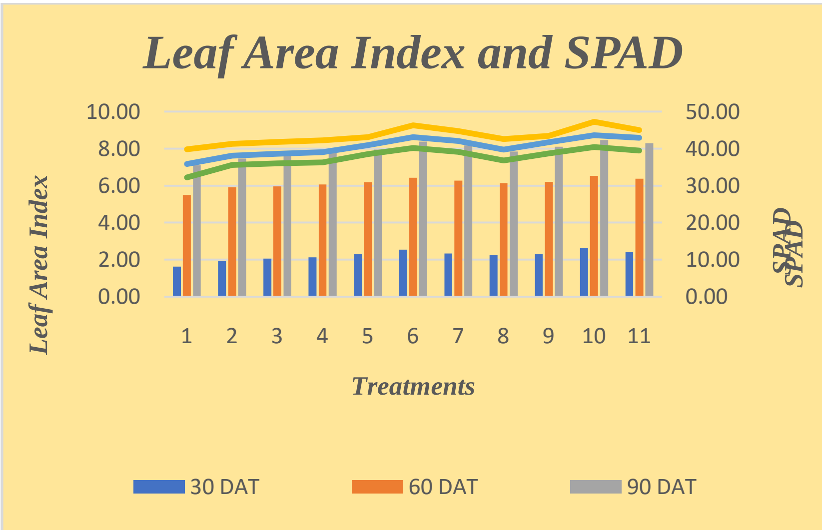

Fig. 3. Influence of Rice husk biochar and straw compost on LAI and SPAD

As the application of rice husk biochar and rice straw compost has played a role in soil's physical properties. The bulk density has been decreased with the application of rice husk biochar and rice straw compost has increased the root proliferation which enhances the root growth. Along with the soil BD and soil nutritional status also plays a role in root growth. So, the application of rice straw compost has increased the root length and root volume as same as the rice husk biochar. These findings were supported by Noguera *et al*. [20] and Steiner *et al*. [21].

3.4 Yield Attributes

Yield Attributes that were observed are Grain yield (Kg/ha^{-1}), Straw yield (Kg/ha^{-1}), Harvest Index (HI), Number of Productive tillers m^{-2} and Panicle length (cm) at the harvesting stage.

3.4.1 Grain yield, straw yield and harvest index (Table 4)

At the harvesting stage, the highest Grain yield (5133 Kg/ha^{-1}), Straw yield (7090 Kg/ha^{-1}) and Harvest index (0.42) were recorded in the application of PSB @ 2kg/ha + Rice Straw compost (RSC) @ 5 t/ha + 75% RDF (T_{10}) and on par with grain yield (4953 Kg/ha^{-1}), Straw yield (7077 Kg/ha^{-1}) and Harvest index (0.41) in the PSB @ 2 kg/ha + Rice Husk Biochar (RHB) @ 5 t/ha + 75% RDF (T_6). The Lowest Grain yield (3550 Kg/ha^{-1}), Straw yield (6062 Kg/ha^{-1}) and Harvest index (0.32) were observed in Control Treatment (T_1) with no amendments. The yield response of the crop to the application of rice husk biochar and rice straw compost has been shown in (Fig. 4). The organic fertilizer made from decomposed rice straw has very high nutrient potential which increases crop production and rice husk biochar can boost soil fertility and moisture content which also enhances crop growth as well as the grain production also. The amount of photosynthate present in leaves and stems during the process of filling seeds determines rice output, which is strongly dependent on the photosynthesis process that took place after flowering. The application of rice straw compost and rice husk biochar leads to an increase in the photosynthates present in the leaves. The above findings have been supported by Effendy et al. [22], Takakai et al. [23] & Khosa et al. [9].

3.4.2 Number of productive tillers m^{-2} and Panicle length (Table 5)

At harvesting stage, the highest Number of Productive Tillers m^{-2} (572) and longest Panicle (25.28 cm) were observed in application of PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF (T_{10}) and statistically at par with number of Productive Tillers m^{-2} (555) and panicle (25.07 cm) in the (T_6) PSB @ 2kg/ha + RHB @ 5 t/ha + 75% RDF (T_6). The lowest number of productive tillers m^{-2} (365) and shortest Panicle (21.69 cm) was observed in the control treatment (T_1) with no amendments. Application of rice straw compost which indirectly increases phosphate availability, the increase in harvest yield in the rice is due to the increase of phosphate nutrient availability, which has a determining role in the rice seed filling process. Rice husk biochar can increase soil fertility and fertilizer efficacy when combined with fertilizer due to its adsorptive power, retention of nutrients, and high silica content. Rice husk biochar's large amount of silica content improves plant structure, turgidity, and nutrient retention which also enhances the yield of the crop. The above findings have been supported by Goyal *et al*. [24], Takakai *et al*. [23] and Karam *et al*. [25].

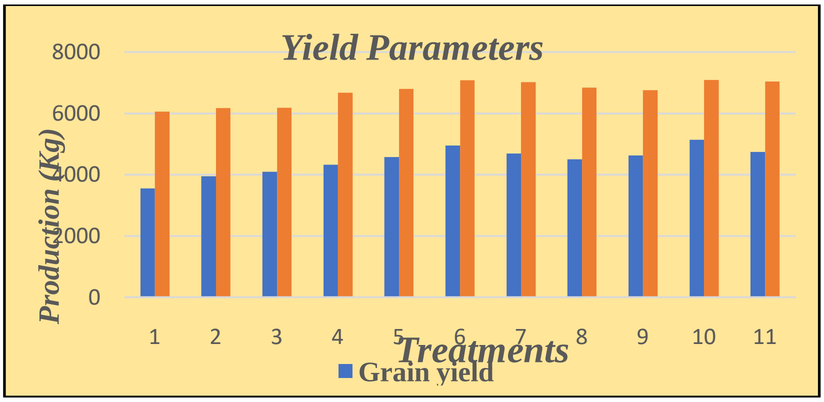

Fig. 4. The yield response to application of rice husk biochar and rice straw compost

Table 3. Effect of rice husk biochar and rice straw compost on root characters

Treatments	**Root Length (cm)**			**Root Volume (ml)**		
	30 DAT	**60 DAT**	**90 DAT**	**30 DAT**	**60 DAT**	**90 DAT**
T_1 - Control (No amendments)	14.38	25.56	40.27	11.59	18.47	25.91
T_2 - 75% RDF	15.22	27.36	42.58	13.03	19.17	27.56
T_3 - 100% RDF	15.53	27.04	42.56	14.02	20.28	30.00
T_4 - RHB @ 5 t/ha + 75% RDF	15.70	31.65	47.35	14.77	20.97	30.90
T_5 - RHB @ 5 t/ha + 100% RDF	16.77	32.96	49.73	16.02	21.89	34.35
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**18.35**	**37.05**	**55.40**	**17.42**	**25.44**	**37.33**
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	17.98	34.67	52.99	16.50	24.02	35.11
T_8 - RSC @ 5 t/ha + 75% RDF	16.03	33.99	50.35	15.77	21.53	32.90
T_9 - RSC @ 5 t/ha + 100% RDF	17.27	34.49	51.76	16.21	23.53	34.99
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**18.86**	**37.45**	**56.31**	**17.85**	**26.01**	**37.77**
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	18.03	35.22	53.58	16.83	24.90	35.85
SE (D)	0.340	1.921	3.555	0.239	1.819	3.462
CD (P=0.05)	0.721	4.072	7.537	0.498	3.586	7.340

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar; RSC - Rice Straw Compost;
PSB - Phosphorus Solubilizing Bacteria

Table 4. Effect of RHB and RSC on grain yield and straw yield of paddy

Treatments	**At Harvesting Stage**		
	Grain Yield (Kg/Ha)	**Straw Yield (Kg/Ha)**	**Harvest Index**
T_1 - Control (No amendments)	3550	6062	0.32
T_2 - 75% RDF	3947	6176	0.34
T_3 - 100% RDF	4093	6178	0.35
T_4 - RHB @ 5 t/ha + 75% RDF	4323	6669	0.36
T_5 - RHB @ 5 t/ha + 100% RDF	4573	6800	0.38
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**4953**	**7077**	**0.41**
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	4693	7021	0.39
T_8 - RSC @ 5 t/ha + 75% RDF	4503	6840	0.37
T_9 - RSC @ 5 t/ha + 100% RDF	4630	6761	0.38
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**5133**	**7090**	**0.42**
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	4743	7039	0.40
SE (D)	74.827	115.554	0.011
CD (P=0.05)	158.634	244.974	0.023

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar; RSC - Rice Straw Compost;
PSB - Phosphorus Solubilizing Bacteria

Table 5. Effect of RHB and RSC on Yield parameters of rice crop

Treatments	At Harvesting Stage	
	Panicle length (cm)	**No of productive Tillers/m^2 (No)**
T_1 - Control (No amendments)	21.69	365
T_2 - 75% RDF	22.84	460
T_3 - 100% RDF	22.90	473.3
T_4 - RHB @ 5 t/ha + 75% RDF	22.84	476.6
T_5 - RHB @ 5 t/ha + 100% RDF	23.94	485
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**25.07**	**555**
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	24.38	513.3
T_8 - RSC @ 5 t/ha + 75% RDF	23.64	480
T_9 - RSC @ 5 t/ha + 100% RDF	24.30	496.6
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	**25.28**	**571.6**
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	24.58	521.6
SE (D)	0.618	19.158
CD (P=0.05)	1.311	40.614

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar;RSC - Rice Straw Compost; PSB - Phosphorus Solubilizing Bacteria

3.5 Soil Analysis

The topsoil samples of 0 – 15 cm depth are collected from the initial soil before puddling and also from the treatment plots after harvest from the crop. The soil's physical properties, chemical properties and nutrient holding of soil samples are analyzed.

3.5.1 Soil properties (Table 6)

The sample collected at the harvesting stage has been analyzed for physiochemical properties like Bulk density (BD), pH and EC are analyzed. The lowest BD (1.47 mg/m^3) has been observed with the application of RHB @ 5 t/ha + 75% RDF (T_4). The highest pH (7.14) and highest EC (0.52 dS m^{-2}) has been observed with application of RSC @ 5 t/ha + 100% RDF (T_9). The highest BD (1.53) has been seen in treatment with the application of 100% RDF (T_3). The lowest pH (6.58) and lowest EC (0.45 dS m^{-2}) has been seen in the control treatment (T_1) with no amendments. The biochar itself has a lower density than the experimental soil and results in a "dilution" effect, its application directly decreased the BD of applied soil. The compost- amended soil had considerably higher soil pH and EC due to the high microbial and nutrient retention capacity. These findings are supported by Xiao et al. [26], Ghorbani et al. [27] and Phoung et al. [12].

3.5.2 Soil available nutrients (Table 6)

The highest OC of the soil (0.84) has been observed in the soil which is applied with PSB @ 2kg/ha + Rice Husk Biochar 5 t/ha + 100% RDF (T_7) and Rice Husk Biochar 5 t/ha + 100% RDF(T_5) and significant on par with the OC (0.83) in PSB @ 2 kg/ha + Rice Husk Biochar 5 t/ha + 75% RDF (T_6) and Rice Husk Biochar 5 t/ha + 100% RDF(T_4). The lowest OC (0.65) has been observed in the (T_1) control treatment with No amendment. More specifically, the relative fraction of passive C pools rose at application of rice husk biochar in addition to stabilizing soil C in the rice environment. Munda *et al*. [28] study support these findings.

The highest N (266 kg/ha), highest P (61.59 kg/ha), highest K (218.4 kg/ha) of the soil has been observed in treatment of (T_{10}) PSB @ 2kg/ha + RSC @ 5 t/ha + 75% RDF and significant on par with the (T_{11}) PSB @ 2 kg/ha + RSC @ 5 t/ha + 100% RDF. The lowest N (212 kg/ha), lowest P (45.41 kg/ha) and lowest K (192 kg/ha) has been observed in the (T_1) control with no amendment. The application of organic matter to the soil, phosphorus availability is enhanced in a number of ways. when compost is applied to the soil it raised labile phosphorus and enhances plant growth. The rice straw compost has good nutrient amounts and the retention capacity of nutrients are also high, these helps in increasing the soil available nutrients. These findings are supported by Phoung *et al*. [12].

Table 6. Effect of RHB and RSC on Soil available nutrients after harvest of crops (Post harvest stage)

Treatments	pH	EC (dS/m)	BD (mg/m^3)	Organic Carbon	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
T_1 - Control (No amendments)	6.58	0.45	1.52	0.65	212	45.41	192
T_2 - 75% RDF	6.72	0.47	1.52	0.66	247	49.85	207.9
T_3 - 100% RDF	6.75	0.48	1.53	0.66	251	51.22	210.4
T_4 - RHB @ 5 t/ha + 75% RDF	6.77	0.48	**1.47**	0.83	255	53.47	207.5
T_5 - RHB @ 5 t/ha + 100% RDF	6.79	0.48	1.48	**0.84**	257	54.71	210
T_6 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	6.75	0.49	1.46	0.83	255	58.82	208.1
T_7 - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	6.77	0.49	1.47	**0.84**	257	58.97	210.1
T_8 - RSC @ 5 t/ha + 75% RDF	7.12	0.51	1.51	0.69	264	55.48	215.5
T_9 - RSC @ 5 t/ha + 100% RDF	**7.14**	**0.52**	1.52	0.70	266	57.66	217.9
T_{10} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 75% RDF	7.10	0.51	1.49	0.69	264	60.73	215.9
T_{11} - PSB @ 2 kg/ha + RHB @ 5 t/ha + 100% RDF	7.12	0.52	1.50	0.71	**266**	**61.59**	**218.4**
SE (D)	NS	NS	NS	0.014	3.771	1.392	3.497
CD (P=0.05)	NS	NS	NS	0.031	7.996	2.951	7.414

RDF - Recommended Dose of Fertilizer; RHB - Rice Husk Biochar;RSC - Rice Straw Compost;
PSB - Phosphorus Solubilizing Bacteria

4. CONCLUSION

The results of this research conclude that the highest plant parameters like plant height, number of tillers m^{-2}, LAI, SPAD readings, root length and root volume and yield parameters like grain and straw yield, number of productive tillers m^{-2}, panicle length and Harvest Index were observed in (T_{10}) treatment with PSB @ 2kg/ha + Rice Straw Compost @ 5 t/ha + 75% RDF and numerically lower values are observed in (T_1) control treatment.

In soil properties, the high nutrient content has been observed in the soil sampled obtained from (T_{11}) PSB @ 2 kg/ha + Rice Straw Compost @ 5 t/ha + 100% RDF. So, the application of PSB @ 2 kg/ha + Rice Straw Compost @ 5 t/ha + 100% RDF helps in maintaining the soil with good health for plant growth and also helps in better paddy production with increased yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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