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Impact of Rice Residue Management Practices and Fertilizer Levels on Nutrient Content and Biomass Production of *Kharif* Rice

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ABSTRACT: The demand for a more sustainable management of agro-ecosystems in the context of climate change is increasing for meeting the needs of ever growing global population. The crop residue management is one of the important aspects under debate, since it represents the unneglectable quantity of organic matter which can be kept in or removed from the agro-ecosystem. Scientific curiosity in crop residue burning grew due to the emission of air pollutants, long range transport of air pollutants and deteriorating air quality and air, soil and environment. Therefore, it is important to look for sustainable solutions and technologies that can reduce the environmental footprint and add value by increasing the revenues of rice production systems.

The field experiment was conducted during the *kharif* season of 2021-2022 at the Agricultural College Farm, Bapatla, ANGRAU, Lam, Guntur, Andhra Pradesh to study the "Impact of rice residue management technologies and fertilizer levels on nutrient content and biomass production". The experiment was laid out in split-plot design with the rice residue management practices, assigned to the main plots and fertilizer levels to sub plots. The main plot comprised four different rice residue management practices *viz.*, Straw burning (M_1), Straw incorporation (M_2), Straw incorporation + FYM @ 5.0 t ha^{-1} (M_3) and Straw incorporation + DI (decomposing inoculum) + FYM @ 5 t ha^{-1} (M_4). Three fertilizer levels were applied to rice *viz.*, 75% RDF (S_1), 100% RDF (S_2) and 125% RDF (S_3), as sub plot treatments. Macronutrients content and total biomass production at harvest was significantly higher in the straw incorporation was done along with decomposing inoculum (DI) and FYM @ 5t ha^{-1} treatment. While, significantly lower nutrient content and total biomass production were obtained whenstraw was burnt. Among the fertilizer levels, the application of 125% RDF was significantly superior with highest nutrient content and total biomass production and lowest was observed in 75% RDF.

Keywords: Rice residue management, Straw burning, straw incorporation, Decomposing Inoculum, fertilizer levels, nutrient content and total biomass.

INTRODUCTION

Rice (*Oryza sativa* L.) is a major cereal and staple food for more than 70 per cent of the people living in the Asia. More than 90 per cent of rice is produced and consumed in Asia itself. The yield of rice needs to be increased by more than 1.2% annually to meet the rising food demand due to global rise in population and economic development and its demand in 2025 will be 765 million tonnes in the world (Normile, 2008).

Intensification of rice cropping systems has been associated with the use of high yielding and short duration varieties with shorter turnaround time between crops in multi cropping systems. On an average 15 million tonnes of rice straw is being generated in Andhra Pradesh every year, of which a large proportion is set on fire by farmers. Burning of rice straw has become a serious problem in Andhra Pradesh (The Hindu, dated 6th September 2020). Burning of 1 tonne of straw releases 2 kg of SO_2, 3 kg of particulate matter, 60 kg CO, 1460 kg of CO_2 and 199 kg of ash which strongly leads to environmental pollution and human health implications besides deterioration of soil health (NPMCR, 2014).

Manual collection of the straw in the field is unprofitable because of the high labor cost. Incorporation in the soil poses challenges in intensive systems with two to three cropping cycles per year due to the insufficient time for decomposition. As a result, open-field burning of straw has increased dramatically over the last decade, despite being banned in most rice growing countries because of pollution and the associated health issues. Therefore, it is important to look for sustainable solutions and technologies that can reduce the environmental footprint from rice production systems (Mandal *et al.,* 2004; Yadvinder-Singh *et al.,* 2004; Dobermann and Fairhurst 2002).

So, there is a need to adopt ways and means to manage this valuable resource. A large amount of rice residue is annually produced in the rice growing countries. There is enormous potential of recycling these easily available residues in the crop production systems. Rice crop giving a grain yield of 7 t ha^{-1} removes more than N 300, P 30 and K 300 kg ha^{-1} from the soil. If the residue is not returned this may cause mining of soil for major nutrients leading to net negative balance and multi-nutrient deficiencies in crops (Mandal *et al*., 2004). It is important to note that not all the possible options are economically viable.

Crop residue incorporation can improve soil organic carbon and soil nutrients content. It is beneficial for recycling of nutrients and C:N ratio needs to be corrected by applying extra amount of fertilizer at the time of residue incorporation (Singh *et al*., 2017). Since last two decades, people are taking interest to improve soil quality throughout the world. They recognized the fragility of natural resource for development of soil health. Among of them, residue management is the technology which is beneficial for soil and crop yield (Kumari *et al*., 2018). However, application of crop residue alone to sustain crop productivity is inadequate due to their wide C:N ratio which may lead to initial immobilization of nutrients depriving the crop proper nourishment.

Therefore, the present investigation was undertaken to evaluate the effect of incorporation of crop residues with supplemental inorganic fertilizers on nutrient content of rice crop and total biomass yield

MATERIAL AND METHODS

The field experiment was conducted during *kharif* season of 2021-22 at the Agricultural College Farm, Bapatla. The soil of the experimental site was a clay loam (sand 41.45%, silt 18.75% and clay 39.80%) with a bulk density of 1.31 g cc^{-3} having pH 7.66, EC 0.55 ds m^{-1}, low in organic carbon (0.43%), low in available nitrogen (272 kg ha^{-1}), medium in phosphorus (52.5 kg ha^{-1}) and high potassium content (325.2 kg ha^{-1}). Rice variety BPT-5204Samba Mahsuri was taken as the test variety with 140-150 days growth duration. The experiment was laid out in split-plot design with the rice residue management practices, assigned to the main plots and fertilizer levels assigned to sub plots. Rice straw obtained from the previous year was chopped and incorporated into the field in calculated amounts as per the treatment with the help of rotavator one month before sowing. FYM and decomposing inoculum was applied in calculated amounts as per the treatment combination for each plot separately and thoroughly incorporated into the soil with the help of spade as per treatments.

The main plot comprised four different rice residue management practices *viz.,* Straw burning (M_1), Straw incorporation (M_2), Straw incorporation + FYM @ 5.0 t ha^{-1} (M_3) and Straw incorporation + DI (decomposing inoculum) + FYM @ 5 t ha^{-1} (M_4). Three different fertilizer levels were applied to rice *viz.,* 75% RDF (S_1), 100% RDF (S_2) and 125% RDF (S_3) as sub plot treatments.

RESULTS AND DISCUSSION

Nutrient content

1. Nitrogen. Nitrogen content in direct seeded rice at harvest stage (grain and straw) was furnished in the Table 1. Perusal of data revealed that mean nitrogen content in plants varied significantly among the treatments at the harvest stage of crop growth on the application of crop residue management practices and fertilizer levels.

At harvest, significantly higher mean nitrogen content of grain and straw (1.59 and 0.80%) was recorded when straw incorporation was performed along with FYM @ 5 t ha^{-1} and incubating with decomposing inoculum (DI) which was statistically superior over other residue management practices. Rice crop taken up after straw burning resulted in a significantly lower mean nitrogen content of 1.23 and 0.62% respectively, in both grain and straw. Improved N nutrition could be due to the reason that decomposing culture adds the inoculum to the soil and FYM acts as substrate and starter for proliferation of decomposing microbes in the event when a residue having wide C:N ratio was incorporated into the soil.

Among the fertilizer levels, 125% RDF resulted in significantly higher mean N content of grain and in the straw over 75% RDF, while significantly on par with 100% RDF. Higher level of N fertilization might have improved the N supplementation by two ways one by release of N from the inorganic fertilizer and the second through resulting in mineralization of organic N bound to C from rice residue. The maximum N, P and K content in grain and fodder were recorded in 100% RDF over 75% RDF treatments (Mohammadi *et al.,* 2017).

The interaction effect of crop residue and fertilizer was found non-significant in influencing the mean nitrogen content in both grain and straw.

2. Phosphorus. Phosphorus content in direct seeded rice at harvest stage (grain and straw) was furnished in the Table 2. A perusal of data revealed that phosphorus content in plants at harvest differed significantly across the rice residue management practices and fertilizer levels.

Mean phosphorus content of grain was more when compared to the straw. Among all the rice residue management techniques, straw burning resulted in a significantly lower P content in both grain (0.38%) and straw (0.107%). However, when straw incorporation was performed along with FYM @ 5 t ha^{-1} and incubating with decomposing inoculum (DI), the P content rose to 0.47 and 0.152 per cent respectively in grain and straw. Straw incorporation along with FYM @ 5 t ha^{-1}either with or without decomposing inoculum were at a par in P content of straw (0.144 and 0.152%). FYM on one side acts as nutrient source for plant and the other side gives nourishment to decomposing microbes thus hastens up the decomposition rate of residues. Decomposing inoculum also helps in faster decomposition of rice residues and hence the nutrient release matches the crop demand. Adequate supply of phosphorus during initial establishment helps in better root growth and proliferation and hence results in better nutrition of crop.

Among the fertilizer levels, the 125% RDF resulted in significantly higher phosphorus content of 0.45 and 0.15 per cent in grain and straw respectively over 75% RDF with corresponding contents of 0.41 and was significantly on par with 100% RDF in the grain and in the straw the 125% RDF was found statistically superior and 75% and 100% RDF was on par. Similar results were observed in a two year field experiment by Zaki and Habashy (2011) with three doses of chemicals (100%, 50% and 25%) and revealed that the sole application of 100% RDF proved to be beneficial for N and P content. These results are in congruence with Mohammadi *et* al. (2017); Jyothibasu *et al.* (2017).

The interaction effect of rice residue and fertilizer was found non-significant in influencing the mean phosphorus content in both grain and straw.

3. Potassium. Potassium content in direct seeded rice at harvest stage (grain and straw) was furnished in the Table 3. Perusal of data revealed that potassium content in plants varied significantly among the treatments at the harvest stage of crop growth on the application of crop residue management practices and fertilizer levels.

At harvest stage, the rice residue management practices and fertilizer levels were significant in influencing the mean potassium content in both grain and straw. Straw incorporation performed along with FYM @ 5 t ha^{-1} and incubating with decomposing inoculum (DI) was statistically superior over other residue management practices in both grain and straw. Straw incorporation with or without FYM @ 5 t ha^{-1} proved to be significantly superior over straw burning with respect to mean potassium content in the grain and the incorporation of crop residue+ FYM with or without DI was significantly superior over straw burning. Straw burning and straw return were on par. Increase in the available K through inorganic fertilizers and mineralized potassium due to decomposition of crop residue (Nurhidayati *et al*., 2018). Jadhav (2018) noticed that the application of organic based ain residue @ 5 t ha^{-1} in soil increased potassium content and uptake of mustard in Alfisol.

Among the fertilizer levels, the 125% RDF resulted in significantly higher potassium content over 75% RDF and also was significantly on par with 100% RDF in case of K content in straw.

The interaction effect of rice residue and fertilizer was found non-significant in influencing the mean potassium content in both grain and straw.

Straw incorporation alone recorded comparatively lower uptake of N, P and K as compared to integration with FYM, inorganic fertilizers and decomposing. This might be ascribed to better initial establishment of the crop with the combined use of organic and inorganic fertilizers.

However, the straw has to decompose before the nutrients can become available for uptake and the rate of decomposition and supply of nutrients depends on soil type and season. Additionally, only a proportion of the nutrients become available in the season of application. For example, in a study on an alluvial soil in Vietnam, only about 67 to 69% of the rice straw had decomposed by the time the plant had reached physiological maturity (Thuan and Long 2010).

However, at a site in India the incorporation of rice straw 20 days before sowing wheat without N fertilization significantly decreased wheat yield but increased yield of rice that followed after wheat. The availability of nutrients is affected by the low quality of rice straw, with a high C:N ratio, resulting in slow decomposition and mineralization of nutrients, particularly short-term availability of N and to some extent P (Thuy *et al*., 2008).

Total drymatter production. The data pertaining to dry matter production were furnished in the table 4. In general, the drymatter production increases as the crop growth progresses.

At harvest, crop residues management practices and fertilizer levels had a significant influence on dry matter production. Straw incorporation + DI + FYM @ 5 t ha^{-1} was significantly superior over other residue management practices. Straw burn was significantly inferior in dry matter production compared to straw return. Fertilizer levels had a significant influence on the dry matter production at PI stage.

Additional fertilization might have pushed up the removal of nutrient and water from soil by the crop, which might have enhanced the photosynthesis and translocation of assimilate from source (leaves and stem) to sink *vis-à-vis* total biomass.

Among the fertilizer levels 125% RDF is significantly superior over 75% and 100% RDF. The higher doses of fertilizer might have improved nutrition of crop which has resulted in robust and healthy vegetative growth attributed to higher production of photosynthetic sources with increased chlorophyll content which trapped more solar radiation, enabling the plants to have increased photosynthetic efficiency. This might have enabled the highest leaf area, a greater number of tillers thereby providing an opportunity for plants to increase the photosynthetic rate and leading to production of significantly higher dry matter. These results are in congruence with Sandhu and Mahal (2014); Haque and Haque (2016); Tomar *et al.* (2018).

The interaction effect of crop residue and fertilizer was found non-significant at harvest stage of rice.

Table 1: Effect of rice residue management practices and fertilizer levels on nitrogen content (%) in grain and straw of rice.

CRM	Grain				Straw			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	1.17	1.21	1.32	**1.23**	0.58	0.61	0.66	**0.62**
M_2	1.28	1.33	1.40	**1.33**	0.65	0.63	0.69	**0.65**
M_3	1.36	1.42	1.55	**1.44**	0.65	0.66	0.80	**0.71**
M_4	1.45	1.59	1.74	**1.59**	0.70	0.82	0.89	**0.80**
Mean	**1.31**	**1.39**	**1.50**		**0.64**	**0.68**	**0.76**	
	SEm±	**CD (p=0.05)**	**CV%**		**SEm±**	**CD (p=0.05)**	**CV%**	
M	0.03	0.11	7.00		0.02	0.08	9.74	
S	0.05	0.15	11.96		0.02	0.05	8.03	
MxS	0.10	NS			0.03	NS		
SxM	0.09	NS			0.03	NS		

M_1: Straw burning — S_1: 75% RDF
M_2: Straw incorporation @ 5 t ha^{-1} — S_2: 100% RDF
M_3: Straw incorporation @ 5 t ha^{-1}+ FYM @ 5 t ha^{-1} — S_3: 125% RDF
M_4: Straw incorporation @ 5 t ha^{-1}+ DI + FYM @ 5 t ha^{-1}

Table 2: Effect of rice residue management practices and fertilizer levels on phosphorus content (%) in grain and straw of rice.

CRM	Grain				Straw			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	0.37	0.38	0.40	**0.38**	0.090	0.100	0.130	**0.107**
M_2	0.39	0.40	0.42	**0.40**	0.130	0.133	0.140	**0.134**
M_3	0.41	0.43	0.45	**0.43**	0.133	0.150	0.150	**0.144**
M_4	0.45	0.46	0.51	**0.47**	0.150	0.147	0.160	**0.152**
Mean	**0.41**	**0.42**	**0.45**		**0.13**	**0.13**	**0.15**	
	SEm±	**CD (p=0.05)**	**CV%**		**SEm±**	**CD (p=0.05)**	**CV%**	
M	0.01	0.04	8.68		0.00	0.01	8.56	
S	0.01	0.03	8.10		0.00	0.01	7.89	
M×S	0.02	NS			0.01	NS		
S×M	0.02	NS			0.01	NS		

M_1: Straw burning — S_1: 75% RDF
M_2: Straw incorporation @ 5 t ha^{-1} — S_2: 100% RDF
M_3: Straw incorporation @ 5 t ha^{-1}+ FYM @ 5 t ha^{-1} — S_3: 125% RDF
M_4: Straw incorporation @ 5 t ha^{-1}+ DI + FYM @ 5 t ha^{-1}

Table 3: Effect of rice residue management practices and fertilizer levels on potassium content (%) in grain and straw of rice.

CRM	Harvest							
	Grain				Straw			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	1.00	1.15	1.22	**1.12**	0.51	0.53	0.57	**0.54**
M_2	1.17	1.24	1.30	**1.23**	0.55	0.58	0.61	**0.58**
M_3	1.26	1.31	1.42	**1.33**	0.59	0.62	0.67	**0.63**
M_4	1.40	1.46	1.46	**1.44**	0.64	0.69	0.75	**0.69**
Mean	**1.21**	**1.29**	**1.35**		**0.57**	**0.61**	**0.65**	
	SEm±	**CD (p=0.05)**	**CV%**		**SEm±**	**CD (p=0.05)**	**CV%**	
M	0.02	0.05	7.73		0.03	0.10	7.30	
S	0.02	0.05	9.17		0.02	0.05	5.00	
MxS	0.03	NS			0.03	NS		
SxM	0.03	NS			0.03	NS		

M_1: Straw burning — S_1: 75% RDF
M_2: Straw incorporation @ 5 t ha^{-1} — S_2: 100% RDF
M_3: Straw incorporation @ 5 t ha^{-1}+ FYM @ 5 t ha^{-1} — S_3: 125% RDF
M_4: Straw incorporation @ 5 t ha^{-1}+ DI + FYM @ 5 t ha^{-1}

Table 4: Effect of rice residue management practices and fertilizer levels on total biomass production ($kg\ ha^{-1}$) at harvest stage of rice.

CRM	At Harvest			
	S_1	S_2	S_3	Mean
M_1	9386	9655	10929	**9990**
M_2	9787	11178	11395	**10787**
M_3	11330	11656	12973	**11987**
M_4	12340	13049	12227	**12999**
Mean	**10711**	**11384**	**12227**	
	SEm±	**CD (p=0.05)**	**CV%**	
M	192.89	667.51	5.06	
S	174.13	522.07	5.27	
MxS	348.26	NS		
SxM	343.60	NS		

M_1: Straw burning
M_2: Straw incorporation @ 5 t ha^{-1}
M_3: Straw incorporation @ 5 t ha^{-1}+ FYM @ 5 t ha^{-1}
M_4: Straw incorporation @ 5 t ha^{-1}+ DI + FYM @ 5 t ha^{-1}

S_1: 75% RDF
S_2: 100% RDF
S_3: 125% RDF

CONCLUSION

From the results of the present experiment conducted on *kharif* on direct seeded rice, the following broad conclusions can be drawn that the macronutrients content and total biomass production at harvest were significantly improved when Straw Incorporation + DI + FYM @ 5t ha^{-1} treatment. While, significantly lower nutrient contents and total biomass production were observed in Straw burning. Among the fertilizer levels, the application of 125% RDF treatment registered the highest nutrient content and total biomass production and lowest was observed in 75% RDF.

FUTURE SCOPE

This present investigation on the effect of rice residue management on nutrient content and biomass production, the performance of rice crop was improved and concluded from overall observation that maximum yield was found under treatment. Straw Incorporation + DI + FYM @ 5t ha^{-1} and can help to achieve the sustainable goals when compared to straw burning.

Although many alternative treatments methods have been developed and proven to be helpful for preventing the mismanagement of crop residues to some extent, the following practices are till recommended: i) social awareness needs to be strengthened regarding the detrimental effects of open burning of agricultural residue; ii) conservation agriculture techniques to maximize land cover need to be implemented and iii) methods of insitu decomposition of crop residue by using chemical, biological, and mechanical approaches should be developed.

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