J. Indian Soc. Coastal Agric. Res. 41(2): 128-133 (2023) https://doi.org/10.54894/JISCAR.41.2.2023.126544

Short Communication

Effect of Crop Residue and Fertilizer Management on Growth, Yield and Economics of Rice in the Coastal Region of Maharashtra

Received: 03.08.2022 Accepted: 16.11.2023

Rice is the most important crop in Maharashtra with a production of 3.03 million tonnes from an area of 1.47 million ha and with a productivity of 2.11 t ha^{-1} (DES, 2022). In the coastal Konkan region, rice production is estimated at 1.13 million tonnes with a yield of 2.81 t ha^{-1} (Palkar *et al.,* 2022). Farmers traditionally follow rice residue management practices in the Konkan region of Maharashtra. Residue decomposition is primarily influenced by environmental conditions in which decay takes place, the chemical quality of leaf litter/residue and the nature and abundance of decomposers. Residue management, if properly followed, can improve soil quality and provide a favourable environment for crop growth. The influence of organic matter on soil physical, chemical and soil fertility is well known (Saha and Ghosh, 2013). Residue decomposition is a major pathway for providing organic and inorganic nutrient elements for the nutrient cycling processes and controls nutrient return to the agro-ecosystem. The addition of residues in soil helps to inprove the soil carbon content with consequent inprovement of soil fertility that leads to an increase in the productivity of crops (Adams and Angradi, 1996). The recycling of crop residues has the advantage of converting the surplus farm waste into useful products for meeting the nutrient requirement of crops. Continuous cultivation of rice in the same field over the years without adding any nutrient source depletes the indigenous soil nutrient status. Residue incorporation in soil with the integration of fertilizers improves soil fertility and crop productivity (Meshram *et al.,* 2020). A large amount of rice residue is annually produced in rice-growing countries, and in India, an average of 500 million tonnes (Mt) of crop residue is generated every year (Meena *et al.,* 2022). The P_2O_5, N, K_2O and S contents are 2.3, 5.5, 25, and 1.2 kg t^{-1} of paddy straw, respectively, and straw includes 50-70% of micronutrients absorbed by rice, as well as 400 kg of carbon (Meena *et al.,* 2022). This shows that there is an enormous potential of these residues to act as a nutrient source through proper recycling in the crop production systems for restoring soil fertility. If residues are not recycled then it may cause mining of soil for major nutrients leading to net negative balances and multi-nutrient deficiencies in crops (Mandal *et al.,* 2004). This is one of the reasons for declining crop yields. Therefore, there is an urgent need to manage the crop residues for future sustainability and stabilization of agro-ecosystems. Thus, a study was undertaken to investigate the effect crop residue and fertilizer management on growth parameters, yield and economics of rice in the coastal belt of Maharashtra.

The experiment was conducted in the Agronomy Research Farm of Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra during the *kharif* season of 2019. The experimental soil was red lateritic in nature (*Alfisols*), kaolinitic belonging to the hyperthermic family of *Typic Haplustalf*. Dapoli is located in the Konkan region of coastal Maharashtra in the Western Plateau and Hills Region of ACZ-9 (Agro-climatic Zone) and is confined between Sahyadris hills in the east and Arabian Sea in the west. The region is characterized by a humid climate with an average annual rainfall of more than 3500 mm. The present experiment was laid out in a strip plot design (SPD) with crop residues and fertilizer dose as the two factors. The treatments consisted of four crop residue levels, namely, (C_1- Rice straw @ 5 t ha^{-1}, C_2- *Terminalia tomentosa* leaf residues @ 5 t ha^{-1}, C_3- Rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residues @ 2.5 t ha^{-1} and C_4- Control (Without residue), and three fertilizers levels *viz.*, F_1- 100% NPK, F_2- 75% NPK and F_3- 50% NPK. The twelve treatment combinations were replicated thrice. Residues of rice and *Terminalia* were collected and sun-dried. *Terminalia tomentosa* is a forest nutritious species and its residue contains 1.92% N, 0.32% P 0.97% K, 80 mg Zn kg^{-1}, 730 mg Fe kg^{-1}, 95 mg Mn kg^{-1} and 15 mg Cu kg^{-1}. The chopped residues were incorporated in the rice field 45 days prior to

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transplanting. Rice variety Ratnagiri-1 was raised during *kharif* (rainy) season using recommended practices. Rice crop was transplanted at 20 × 15 cm spacing. The 100% NPK recommended dose applied was 100:50:50 kg ha^{-1} for rice in the form of urea, single super phosphate (SSP) and muriate of potash (MOP). Plant height was measured from the base of the plant *i.e.*, from ground level up to the collar of the last fully opened leaf and thereafter up to the base of the panicles. The number of tillers per plant was recorded at each critical growth stages (*viz.*, tillering, flowering and at harvest) of rice. The grain yield was calculated by multiplying with the net plot size and converted to t ha^{-1}.

The economics of rice cultivation was worked out as per the following formulae.

Gross monetary returns (GMR) = Yield × Selling price

Net monetary returns (NMR) = GMR - Cost of cultivation

Benefit:cost ratio (B:C ratio) = Gross monetary returns (₹)/Cost of cultivation (₹)

The results obtained were statistically analyzed and interpreted as per the methods described by Panse and Sukhaatme (1985).

The maximum number of tillers (12.56, 14.97 and 9.94 plant^{-1}) were recorded with the incorporation of rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residue @ 2.5 t ha^{-1} over control and 50% and 75 % NPK alone (Table 1). It was followed by *Terminalia tomentosa* leaf residue @ 5 t ha^{-1} and rice straw @ 5 t ha^{-1} levels which were found to be at par with each other at the flowering and harvest stages of rice. Lower number of tillers (11.15, 13.57 and 9.46 plant^{-1}) were recorded in control (no residue) treatment during tillering, flowering and at harvest stage. Among the fertilizer levels, 100% NPK recorded maximum tiller numbers (12.49, 15.09 and 9.99 plant^{-1}) during tillering, flowering and at the harvest stages than 50% NPK and 75% NPK applied alone. The interaction effect of crop residue and fertilizer levels was observed to be statistically significant at the tillering and flowering stages of rice but it was found non-significant at harvest (Table 1). Organic residues along with balanced fertilization may have increased the number of tillers which also may be due to optimum environmental factors (Saravana Kumar *et al.,* 2017). Similarly, Almaz *et al.* (2017), recorded that the application of organic manures along with chemical fertilizers significantly increased the number of tillers per plant as compared to the control and sole application of fertilizers. According to them more number of tillers m^{-2} might be due to the increased availability of nitrogen, which plays a vital role in cell division. Organic sources offer more balanced nutrition. However, Namdeo *et al.* (2017) and Singh *et al.* (2018) reported that the maximum plant tillers were obtained with conjoint use of organic manures and inorganic fertilizers which could be attributed to the slow release of nitrogen and reduced leaching losses.

The height of rice plants (Table 1) at tillering and flowering was recorded as highest (18.08 and 44.88 cm plant^{-1}, respectively) in the treatment receiving rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residue @ 2.5 t ha^{-1}, whereas at harvest stage, the maximum height (85.34 cm plant^{-1}) was noted in the treatment with *Terminalia tomentosa* leaf residue @ 5 t ha^{-1}. The lowest height of 17.02, 40.83 and 78.48 cm plant^{-1} was respectively observed in control (no residue) at the tillering, flowering and harvest stage of rice. Among the fertilizer levels, application of 100% NPK recorded maximum height (18.02, 45.55 and 85.82 cm plant^{-1}) during tillering, flowering and harvest stages of rice as compared to application of 50% NPK alone. The interaction effect of crop residue and fertilizer was observed statistically non-significant at only the tillering stage but it was significant during both the flowering and harvest stages of rice (Table 1). The increase in plant height could be ascribed to the fact that balanced doses of nutrients along with organics resulted in higher availability of nutrients in the soil for plant nourishment. Further, organic sources which release nutrients slowly allowing continuous availability of nutrients enhanced cell division, elongation as well as various metabolic processes which ultimately resulted in increased plant height (Almaz *et al.,* 2017). The plant height of rice was significantly higher due to application of organic nutrient sources in combination with chemical fertilizer.

The maximum grain and straw yield (4.78 and 5.57 t ha^{-1}) of rice was recorded with the application of rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residue @ 2.5 t ha^{-1} over control (no residue) (Table 1). It was

Table 1. *Effect of crop residues and fertilizer on tillers, height and yield of rice*

Treatments	Number of tillers plant^{-1}			Plant height (cm)			Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
	Tillering	Flowering	Harvest	Tillering	Flowering	Harvest		
Crop residues levels								
C_1	12.16	14.71	9.81	17.83	44.11	83.78	4.65	5.35
C_2	12.39	14.92	9.92	17.96	44.71	85.34	4.74	5.57
C_3	12.56	14.97	9.94	18.08	44.88	85.13	4.78	5.51
C_4	11.15	13.57	9.46	17.02	40.83	78.48	2.77	3.10
SE (m) ±	0.21	0.17	0.15	0.65	0.13	0.26	0.11	0.20
CD at 5%	0.74	0.58	-	-	0.46	0.92	0.36	0.69
F test	S	S	NS	NS	S	S	S	S
Fertilizer levels								
F_1	12.49	15.09	9.99	18.02	45.55	85.82	4.47	5.17
F_2	12.09	14.61	9.75	17.79	43.36	82.95	4.28	4.88
F_3	11.61	13.92	9.62	17.35	41.99	80.78	3.94	4.59
SE (m) ±	0.162	0.115	0.124	0.524	0.317	0.108	0.07	0.07
CD at 5%	0.636	0.450	-	-	1.246	0.423	0.27	0.28
F test	S	S	NS	NS	S	S	S	S
Interaction C × F								
SE (m) ±	0.588	0.555	0.337	1.562	0.827	0.733	0.36	0.44
CD at 5%	1.813	1.709	-	-	2.548	2.257	1.12	1.36

S - Significant; NS - Non significant

found to be at par with C_1- rice straw @ 5 t ha^{-1} and C_2- *Terminalia tomentosa* leaf residue @ 5 t ha^{-1}. The lowest rice grain and straw yields (2.77 and 3.10 t ha^{-1}) was recorded in control (no residue). In the case of fertilizer levels, the application of 100% NPK significantly resulted in higher grain yield and straw (4.47 t ha^{-1} and 5.17 t ha^{-1}, respectively) of rice than 50% NPK and 75% NPK. The interaction effect of crop residue along with fertilizer was found to significantly influence the grain and straw of rice (Table 1). It may be due to organics being beneficial in reducing the fixation of added or mineralized nutrients and it played a complementary role in boosting the crop grain and straw yield. The soil fertility and productivity of the plots receiving both inorganic and organic sources of nutrients were better as compared to control and when chemical fertilizers were applied alone (Mandal *et al.,* 2004; Saha *et al.,* 2010; Sharma and Sharma*,* 2001). Similar results were also reported by Almaz *et al.* (2017) and Pasha and Reddy (2018) who observed that integrated nutrient management with the application of 100% NPK along with crop residue recorded maximum grain and straw yields than control. Namdeo *et al.* (2017), Saravana Kumar *et al.,* (2017), Singh *et al.* (2018) and Singh *et al.* (2019) stated that all the yield attributes were higher with the substitution of crop residue/manure in combination with 50-75% RDF due to slow release and continuous supply of balance quantity of nutrients throughout the crop growth stages. This enabled the rice plants to assimilate sufficient photosynthetic products leading to increased dry matter production which increased grain and straw yields. Therefore, sustained efforts are needed to improve and maintain the most important natural resource base, the soil. Judicious integration of mineral fertilizers, organic and crop residues will help improve crop yields and at the same time maintain the soil health. (Meena *et al.,* 2018; Shukla *et al.,* 2020).

Significantly higher gross monetary returns (GMR), net monetary returns (NMR) of ₹97603.11/- and ₹12808.89/- ha^{-1}, respectively and B:C ratio (1.15) were recorded with application of rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residue @ 2.5 t ha^{-1}, whereas lowest gross monetary returns (GMR) (₹56191.78/- ha^{-1}), net monetary returns (NMR) (₹ 19440.67 /- ha^{-1}) and B:C ratio (0.74) were observed in control (no residue). Among the inorganic applications, 100% NPK resulted in highest gross monetary returns and net monetary returns in rice crop (₹91637.42/- and ₹7837.42/- ha^{-1}) and B:C ratio (1.09) than other applications. The lowest gross monetary returns and net monetary returns (₹80646.08/- and - ₹192.08 /- ha^{-1}) and B:C ratio (0.99) were recorded with the application of 50% NPK alone. The interaction effect of crop residue and fertilizer was observed to significantly effect the gross monetary returns, net monetary returns and B:C ratio of rice (Table 2).

Application of crop residues along with fertilizer management had a beneficial effect on getting optimum returns from rice which may be due to reduced cost and higher yields obtained that ultimately improved the benefit:cost ratio. Similar results were observed by Davari *et al.* (2012), Meena *et al.* (2012), Singh and Kushwaha (2013) and Uddin and Fatema (2016). They suggested that the application of crop residue management is must for achieving maximum crop yields and optimum returns.

Recycling of crop residue in the field can be helpful for soil and crop health development, ultimately increasing the production of crops. Therefore adoption of residue recycling will be more beneficial for the farmers in future. From our investigation, it can be concluded that the application of rice straw @ 2.5 t ha^{-1} + *Terminalia tomentosa* leaf residue @ 2.5 t ha^{-1} along with 100% NPK is most useful for improving growth, yield and economics of rice in *Alfisol*. The balanced

Table 2. *Economics of rice under crop residues and fertilizer management practices*

Treatments	GMR (₹ ha^{-1})	NMR (₹ ha^{-1})	B : C ratio
Crop residues levels			
C_1	95095.44	11284.00	1.14
C_2	97238.89	11940.33	1.14
C_3	97603.11	12808.89	1.15
C_4	56191.78	-19440.67	0.74
SE (m) ±	1494.61	1245.50	0.01
CD at 5%	5172.02	4309.99	0.05
F test	S	S	S
Fertilizer levels			
F_1	91637.42	7837.42	1.09
F_2	87313.42	4799.08	1.05
F_3	80646.08	-192.08	0.99
SE (m) ±	1167.90	973.14	0.02
CD at 5%	4585.73	3821.00	0.06
F test	S	S	S
Interaction C × F			
SE (m) ±	6240.98	5200.83	0.07
CD at 5%	19230.37	16025.35	0.21
F test	S	S	S

S - Significant

application of NPK along with crop residues could be more suitable for getting the optimum productivity and growth of rice in the coastal region of Maharashtra.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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