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Growth, Productivity and Profitability of Direct Seeded Rice as Influenced by Maize Crop Residue Management Practices and Fertility Levels in Rice-Maize Sequence

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Abstract: The present investigation was carried out during *kharif* seasons of 2020-21 and 2021-22 on a sandy clay loam soil at the Agricultural College Farm, Bapatla to study the growth, productivity and economics of direct seeded rice as influenced by maize crop residue management practices and fertility levels in rice-maize sequence. The experiment was laid out in split-plot design with four maize residue management techniques (M_1: Exportation of maize stover, M_2: *In-situ* burning of maize stover (farmers practice), M_3: Mulching maize stover with rotary mulcher and M_4: Incorporation of maize stover with rotovator) as main plot treatments and three fertility levels (100% RDF, 75% RDF and 50% RDF) as sub plot treatments. The incorporation of maize stover with rotovator indicated significant effect on growth, yield attributes and economics of rice compared to exportation of maize stover during both the years of experiment. Among the fertilizer levels, application of 100% RDF significantly improved the growth, yield attributes and economics of rice compared to 50% RDF treatment. Combined use of incorporation of maize stover with rotovator along with application of 100% RDF resulted significantly higher number of filled grains panicle^{-1} (169.5), grain yield (6195 kg ha^{-1}).

Keywords: Maize crop residue, Fertilizer levels, Plant height, tillers, Grain yield and direct seeded rice

One of the potential alternatives to rice-pulse systems is the rice (*Oryza sativa* L.), maize (*Zea mays* L.) system. Currently rice-maize (RM) is one of the most important cropping systems of the country due to the rising demand from the poultry sector and the tightening of the global export-import market. Overall, in India, rice and maize production is 125, 30 million metric tons from the area 45.50, 9.70 million ha with the productivity of 4.12, 3.09 metric t ha^{-1}, respectively (USDA 2021). Rice-maize systems are predominantly practiced in the southern and northeastern parts of India, with over 500,000 hectares of planted area. Andhra Pradesh has the largest rice-maize acreage in southern India and this system is rapidly expanding through resource saving techniques, mostly under zero cultivation. High-yielding Rice-Maize system extracts more nutrients, particularly N, P, or K, than rice-rice systems or rice-wheat (Yadvinder Singh 2005). Timsina et al (2010) found that in rice-maize crop systems, a very little crop residue is returned to the soil and other organic inputs are low, resulting in soil organic loss. India generates 516 mt of total crop residue annually, whereof, maize contributes 110 mt, respectively (Sahu et al 2021). Management of stover after maize harvests poses an enormous challenge to all maize farmers around the globe.

The maize stover is most often harvested in dried condition and packaged in large heaps to use as fodder in later date or in lean seasons. Now a days, the use of maize stalk as animals fodder gradually decreasing and instances of on field burning of stover increasing due to non-availability of agriculture labor for timely harvesting, increase in transportation costs, lack of sufficient time to take up next season crops. Instead of resorting to such practices, if managed to slash, shred and spread in the field evenly using machinery, this help in protecting soil and land resources from erosion. Fertilizer application is one of the most expensive costs for cereal crops growers and yet much of the N, P and K used to supplement crop needs are lost to the environment due to the low nutrient use efficiency of cereal crops. Over or under nitrogen, phosphorus and potassium fertilizer application can lead to a reduction in crop yield, in addition to creating conditions which favor nutrient losses to the environment, poor soil quality and plant nutrition. Therefore, there is a need for improved nutrient management strategies, in particular N, P and K under different scenarios like removed, burning, surface retention or incorporated residue management to properly replace nutrients, ensuring adequate plant nutrition and at least sustained grain yield. The present investigation was therefore undertaken to study the growth, productivity and profitability of direct seeded rice as influenced by maize crop residue management practices and fertility levels in rice-maize sequence.

MATERIAL AND METHODS

The experiment was conducted with four maize residue management practices M_1: Exportation of maize stover, M_2: *In-situ* burning of maize stover (farmers practice), M_3: Mulching maize stover with rotary mulcher and M_4: Incorporation of maize stover with rotovator) as main plot treatments and three fertility levels (100% RDF, 75% RDF and 50% RDF) as sub plot treatments which was replicated thrice. The experiment was carried out on sandy clay loam soils of Agricultural College Farm, Bapatla during *kharif* seasons of 2020-21 and 2021-22. The experimental soil was slightly alkaline in reaction; E.C was non-saline in nature and below the critical point, low in organic carbon, low in available nitrogen, medium in available phosphorus and high in available potassium. The average maximum and minimum temperatures were 32.0^{0}C and 24.4^{0}C during *kharif* 2020-21 and 32.0^{0}C and 23.8^{0}C during *kharif,* 2021-22, respectively. The total rainfall of 847.2 mm and 1219 mm received during *kharif* seasons of 2020-21 and 2021-22, respectively. The test variety used for sowing was BPT-5204 and crop was sown at 20 cm and 15 cm inter and intra row distance, respectively and adopted all the standard package of practices. The nutrients, namely urea, single super phosphate, and muriate of potash, were applied according to the respective treatments. Nitrogen was divided into three equal split doses, which were applied during three specific stages: sowing, active tillering, and panicle initiation. Entire quantity of phosphorus and half dose of potassium were applied at the time of sowing. Remaining dose of potassium was applied at PI stage of the crop. After harvest of maize cobs, residues of the maize crop were retained. Maize residues were added as per treatment in the four main plots. In residue removal plots, the residues were completely removed after harvest of the crop. Ninety five days were allowed for decomposition of crop residues during both the years of experimentation. The data on growth attributes, yield attributes, yield and economics were recorded as per standard procedures.

Measurement of growth parameters, yield attributes, yield and economics: For determining drymatter accumulation (DMA), samples from 50 cm row length were taken by cutting the plant from ground level and sun-dried for 2–3 hours and later oven-dried at 65^{0}C till the constant weight was achieved. The dry-weights were recorded. A quadrate of 50 cm × 50 cm^2 size was placed at two random spots in each plot and effective tillers were counted and expressed as no./m^2. Randomly five panicles from each plot were taken and from them number of filled grains/panicle and 1000-grain weight were determined. Grain and straw yield were computed by harvesting crop from the net plots leaving border area of 50 cm from each side. Harvested produce was sundried, bundled and brought to thrashing floor and threshed separately. Economics of each treatment were calculated considering the current market price of each input and output during both the years of experimentation. Gross returns were computed based on market price of rice grain and straw prevailing during study years. Net return was obtained by subtracting cost of cultivation from the gross return. However, B: C ratio was calculated dividing gross returns by cost of cultivation.

Statistical analysis: All the experimental data were statistically analyzed using OPSTAT software.

RESULTS AND DISCUSSION

Growth parameters: There was significant positive impact of crop residue incorporation as well as fertilizer levels on plant height of rice over control treatment. Plant height of rice under different maize crop residue management practices was observed between 85.4 and 112.7 cm (Table 1). Significant higher plant height of rice was with incorporation of maize stover with rotovator (M_4). Increase in plant height in residue incorporated plot may be attributable to greater nutrient availability during crop growth stages, which may have increased nitrogen absorption by the roots for the synthesis of protoplasm necessary for rapid cell division, increasing plant height. The present findings are in similarity with the earlier findings by Khatri et al (2020). The plant height of rice was significantly increased from 50% RDF to 100% RDF. Increased nitrogen levels may have resulted in higher nitrogen consumption, which facilitated the conversion of synthesized carbohydrates into amino acids and protein, resulting in a considerable change in plant height. This in turn promoted cell division and cell elongation, which facilitated the plant's ability to grow more quickly. This is in accordance with Vijayalakshmi et al (2020).

Number of tillers and drymatter production at harvest were influenced significantly by different maize crop residue management practices. The higher number of tillers and drymatter production were recorded in incorporation of maize stover with rotovator treatment (M_4) which was statistically at par with mulching of maize stover with rotary mulcher (M_3) and significantly higher than the other treatments. This might be because nutrients are more readily available and easier to absorb at different crop growth stages due to faster mineralization and release of nutrients, which may have in turn improved cell division and photosynthate synthesis at the corresponding point of growth and development. Due to the actions of beneficial microbes and the enlarged organic pool in the soil, there was improved nutrient availability for a longer period of time during crop growth. The present results are in close confirmation with the earlier reports of Chaudhary et al (2020).

There was a progressive increase in number of tillers m^{-2} and drymatter production at harvest of rice with increase in levels of fertilizers. Among the graded levels of fertilizer application, the maximum number of tillers m^{-2} and drymatter production of rice was recorded with application of 100% RDF (S_1), and found to be significantly superior to rest of the fertilizer levels. It was followed by 75% RDF (S_2) and 50% RDF (S_3). This might be due to greater reserves of photosynthates present in the stems of the plants receiving higher fertilizer levels which were translocated to the panicle and resulted in significant difference with the dry weight of panicle in plants with lower nitrogen applications (Duary and Pramanik 2019).

The senescence of leaves generally caused the mean CGR and RGR to decline with increasing crop age. At 30-60 DAS over both experiment years, various maize crop residue management techniques had a substantial impact on CGR and RGR The higher values of mean CGR and RGR were noticed with incorporation of maize stover with rotovator (M_4) followed by the treatments M_3 and M_2 which were comparable with each other. The lowest mean CGR and RGR recorded under exportation of maize stover (M_1) treatment. This could be attributed to more number of taller plants, tillers and higher drymatter production per unit area and LAI. These findings are in accordance with Kumar et al (2016) and Vijayaprabhakar et al (2020).

With respect to fertilizer levels, at 30-60 DAS, mean crop growth rate increased with increase of fertilizer level. However, there was a non–significant effect on relative growth rate at 30-60 DAS. The highest mean crop growth rate of rice was observed with application of 100% RDF (S_1), which was significantly superior to all the other levels of fertilizers where the treatment S_1 was on par with treatment S_2. The lower mean crop growth rate with application of the lowest fertilizer level @ 50% RDF (S_3). During tillering to flowering, the high LAI at higher fertilizer levels produced high CGR, which further increased DMA during the reproductive stage, resulting in high crop productivity. However, lower nitrogen concentrations result in less effective radiation usage, which in turn results in decreased biomass accumulation. The findings of present investigation are in agreement with those of Mondal et al (2013).

Yield attributes of rice: Among the various maize crop residue management practices influence significant effect on yield attributing characters of rice crop except 1000 grain weight (Table 2). A significant increase in the more of panicles m^{-2} and number of filled grains panicle^{-1} respectively was found under incorporation of maize stover (M_4) which was statistically similar with mulching of maize stover with rotary mulcher (M_3). The lower number of panicles m^{-2} and number of filled grains panicle^{-1} observed with exportation of maize stover (M_1) treatment which showed statistically inferiority to

Table 1. Growth parameters of direct seeded rice as influenced by maize crop residue management practices and fertilizer levels (Pooled mean of 2 years)

Treatments	Plant height (cm) at harvest	Number of tillers m^{-2} at harvest	Dry matter accumulation (kg ha^{-1}) at harvest	Leaf area index at 60 DAS	Mean crop growth rate (g day^{-1}) at 30-60 DAS	Relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS
Maize crop residue management practices						
M_1	85.4	352	11205	2.42	4.15	0.040
M_2	94.5	388	12349	2.66	5.01	0.048
M_3	103.3	424	13193	2.96	5.14	0.042
M_4	112.7	460	13830	3.07	5.76	0.049
CD (p = 0.05)	7.0	30	1155	0.31	0.36	0.003
CV (%)	6.1	6.4	7.9	9.69	6.23	5.79
Fertilizer levels						
S_1	108.0	438	13663	2.96	5.68	0.046
S_2	97.8	407	12658	2.80	5.05	0.045
S_3	91.0	372	11612	2.58	4.32	0.043
CD (p = 0.05)	5.6	22	893	0.18	0.31	NS
CV (%)	6.5	6.2	8.2	7.45	7.08	6.29
Interaction						
M x S	NS	NS	NS	NS	NS	NS
S x M	NS	NS	NS	NS	NS	NS

the rest of the treatments. It might be attributed to a steady supply of sufficient nitrogen and its solubilization, which may have aided in more rapid cell division and expansion (Khatri et al 2020). Among the various fertilizer levels influence significant effect on yield attributing characters of crop except 1000 grain weight during the two years of experiment. However, number of panicles m^{-2} and number of filled grains $panicle^{-1}$ registered significantly more with application of 100% RDF (S_1) over 75% RDF (S_2). This might be due to increase in more number of tillers m^{-2} coupled with higher nutrient uptake. These findings are in corroboration with those reported by Meena et al (2015) and Reddy et al (2017). During both years of the experiment, the interaction effect between maize crop residue management practices and fertilizer levels on the number of filled grains $panicle^{-1}$ was shown to be significant (Table 3). Incorporation of maize stover with rotovator (M_4) along with application of 100% RDF (S_1) gave the higher number of filled grains $panicle^{-1}$ (169.5) than other treatment combinations during both the years respectively. This might be due to integration of crop residue

Table 2. Yield attributes, yield and harvest index of direct seeded rice as influenced by maize crop residue management practices and fertilizer levels (Pooled mean of 2 years)

Treatments	No. of panicles m^{-2}	Number of filled grains $panicle^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Maize crop residue management practices						
M_1	325	122.5	14.5	4860	5873	45.02
M_2	355	132.6	14.9	5292	6398	45.18
M_3	380	139.7	15.1	5757	6879	45.59
M_4	395	156.2	15.5	5980	7034	46.02
CD (p = 0.05)	28	18.8	NS	374	472	NS
CV (%)	6.6	11.8	6.2	5.9	6.2	5.9
Fertilizer levels						
S_1	387	153.0	15.3	5923	6896	46.32
S_2	364	138.6	15.1	5603	6628	45.82
S_3	341	121.5	14.6	4891	6114	44.22
CD (p = 0.05)	17	6.4	NS	258	440	NS
CV (%)	5.5	5.4	5.2	5.4	7.8	5.8
Interaction						
M x S	NS	S	NS	S	NS	NS
S x M	NS	S	NS	S	NS	NS

Table 3. Interaction between maize crop residue management practices and fertilizer levels on number of filled grains $panicle^{-1}$ of direct seeded rice (Pooled mean of 2 years)

Treatments	Fertilizer levels			
Maize crop residue management practices	S_1	S_2	S_3	Mean
M_1	142.8	130.2	94.5	122.5
M_2	146.0	131.3	120.3	132.6
M_3	153.8	140.5	124.8	139.7
M_4	169.5	152.5	146.5	156.2
Mean	153.0	138.6	121.5	
		CD	CV	
Main plot		18.8	11.8	
Sub plot		6.4	5.4	
Interaction				
M X S		12.9		
S X M		21.5		

incorporation and chemical fertilizers increased the more number of filled grain panicle^{-1}. The present findings are also supported by Govind, (2016) in rice-rice cropping system.

Yield of rice: Grain yield and straw yield of rice were influenced significantly by different maize crop residue management practices except harvest index during both the years of experiment (Table 2). The maximum grain and straw yield of rice was with incorporation of maize stover with rotovator (M_4) over exportation of maize stover and was at par with mulching of maize stover with rotary mulcher (M_3). The superiority of incorporation of maize stover with rotovator, in terms of yield can be attributed to higher number of panicles m^{-2}, filled grains per panicle^{-1} and also improved growth parameters (LAI and drymatter production) as compared to other treatments. This may be due to the fact that crop residues are rich in C and N, and the cumulative release rates of crop residues were rapid within 90 days of incorporation, respectively (Wu et al 2011). Crop residues that are mixed with soil particles decompose faster than residues that are left on the soil surface. Through microbial degradation, incorporated maize stalks are transformed into different easily mineralizable form of soil organic matter. Plants absorb mineralized plant nutrients from soil solution both directly and indirectly. Incorporating crop residues recycles nutrients and increases soil organic matter. These results are consistent with the findings of Davari et al (2012). During both years of the experiment, significant influence of varied fertilizer levels was observed on rice grain and straw yield, except for harvest index. Application of 100% RDF gave significantly higher grain yield and straw yield of rice compared to 50% NPK and 75% NPK. Higher grain yield might be due to higher availability of nutrients as evidenced from N, P and K content in grain and straw at harvest subscribes to the view that increased availability of growth inputs involved in the formation and development of yield components. The interaction effect of maize crop residue management practices and fertilizer levels on rice grain yield was significant (Table 4). Incorporation of maize stover with rotovator (M_4) along with application of 100% RDF (S_1) gave the higher grain yield (6185 kg ha^{-1}) than other treatment. This may be due to integration of stover, along with nitrogen, phosphorus, and potassium fertilizers, into the soil resulted in a notable enhancement in rice grain yield due to the improved nutrient reserves in the soil (Khatri et al 2020). This is due to the slow release and continuous supply of balanced amounts of nutrients during the different growth stages, allowing rice to absorb sufficient photosynthetic products and thus, increases the dry matter and source capacity, resulting in higher grain and straw yield.

Economics: The results pertaining to GRs, NRs and B: C of rice with different maize crop residue management practices and fertilizer levels indicated that there was significant difference among treatments (Table 5, Fig. 1). The significantly increase in the GRs, NRs and B: C by the incorporation of maize stover with rotovator (M_4) was statistically comparable with mulching of maize stover (M_3) and both of them were significantly superior to the remaining treatments. The treatment exportation of maize stover (M_1) recorded the least gross return, net return and B: C ratio was significantly inferior compared to other treatments during two successive years of study. Among the fertilizer levels, higher GRs, NRs and B:C ratio with application of 100% RDF (S_1) was ascribed to more monetary return owing to higher yield than the other treatments.

Table 4. Interaction between maize crop residue management practices and fertilizer levels on grain yield (kg ha^{-1}) of direct seeded rice (Pooled mean of 2 years)

Treatments	Fertilizer levels			
Maize crop residue management practices	S_1	S_2	S_3	Mean
M_1	5484	5264	3831	4860
M_2	5965	5304	4607	5292
M_3	6058	5842	5373	5757
M_4	6185	6002	5752	5980
Mean	5923	5603	4891	
		CD	CV	
Main plot		374	5.9	
Sub plot		258	5.4	
Interaction				
M X S		516		
S X M		562		

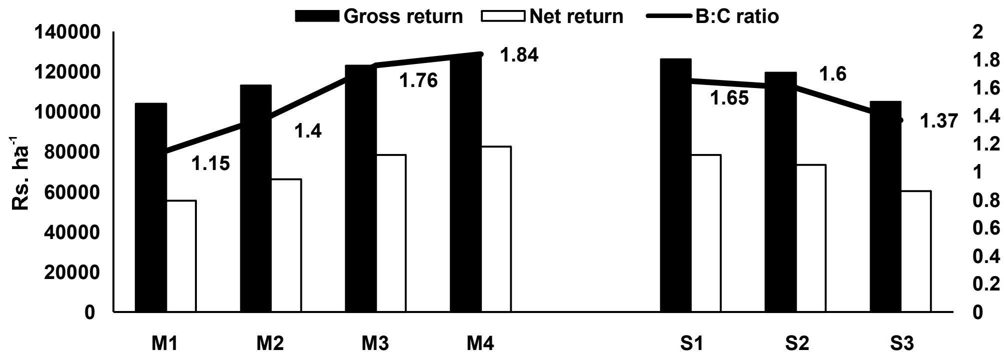

Fig. 1. Gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B: C ratio of direct seeded rice as influenced by maize crop residue management practices and fertility levels

Table 5. Gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B: C ratio of direct seeded rice as influenced by maize crop residue management practices and fertility levels (Pooled mean of 2 years)

Treatments	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
Maize crop residue management practices			
M_1	103977	55666	1.15
M_2	113266	66254	1.40
M_3	123061	78550	1.76
M_4	127611	82675	1.84
CD (p = 0.05)	8460	8460	0.19
CV (%)	6.3	10.4	10.6
Fertilizer levels			
S_1	126288	78475	1.65
S_2	119646	73454	1.60
S_3	105002	60430	1.37
CD (p = 0.05)	4582	4582	0.10
CV (%)	4.5	7.5	7.5
Interaction			
M x S	NS	NS	NS
S x M	NS	NS	NS

CONCLUSION

Incorporation of maize stover with rotovator along with application of 100% RDF were found to be more effective and sustainable approach to enhance the growth, yield attributes, yield and profitability of direct seeded rice in rice-maize sequence.

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