RESEARCH ARTICLE Legume Research- An International Journal, Volume 48 Issue 10: 1754-1759 (October 2025)

Residual Effects of Microbial Treated Paddy Residues Applied to Zero Till Maize on Growth and Yield of Summer Greengram

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10.18805/LR-5230

ABSTRACT

Background: Farmers' conventional tillage and residue removal practices in rice-maize-greengram systems in India are input-intensive, costly and soil degradative. A number of soil quality issues have emerged due to continuous cropping and burning of residues threatening the sustainability of rice based cropping systems for the last more than four decades. Nevertheless, the *in situ* or in-field decomposition of crop residue using microbial inoculum is rarely studied. This necessitated the use of microbial consortia developed by a combination of potent strains of fungi which can perform harmoniously for rapid decomposition of crop residues.

Methods: A field experiment was conducted during 2020-21 and 2021-22 with eight residue-management treatments and three fertility levels to zero till maize at college farm, Rajendranagar, PJTSAU using strip plot design and the residual effect on the succeeding greengram was studied.

Result: Greengram growth and yield were significantly higher under residual effect of incorporation of residues treated with microbial consortia consisting of *Trichoderma viridae, Aspergillus awamori* and *Phanerocheate* spp. along with 300:100:100 kg ha^{-1} of N, P_2O_5 and K_2O (125% RDF) and P supplied in the form of single super phosphate (SSP) under zero tillage during summer, 2021 and 2022. Growth parameters like plant height, leaf area index, dry matter production and yield attributes like number of pods plant^{-1}, pod length and number of seeds pod^{-1} in greengram were higher under residue incorporated plots compared to residue burning, removal and retention plots with 125% RDF.

Key words: Greengram, Incorporation, Microbial consortia, Plant growth, Yield attributes, Yield.

INTRODUCTION

Rice-maize (R-M) cropping systems, practiced widely in South Asia, have potential in climates ranging from tropical to sub-tropical and even warm temperate regions of Asia (Majumdhar *et al*., 2012). In these systems, rice is grown during the warm rainy season (July-October), followed by maize during the dry, cool *rabi* (winter) season (November-March/April). In India, these systems have replaced boro (winter) rice or wheat with a *rabi* maize crop because of high demand for maize from the expanding poultry and aquaculture industries (Kumari *et al*., 2010). In India, winter maize and wheat are grown, respectively, on approximately 0.35 and 0.43 M ha after rice and summer greengram is grown on approximately 0.14 M ha after winter maize or wheat. Greengram can potentially be grown on an additional 0.6 M ha under rice-maize-greengram (R-M-G) and rice-wheat-greengram (R-W-G) systems because of its shorter growth period (about 2 months), providing important benefits relative to nutrition security (Diary, 2018). While the R-W-G system has received considerable attention in the Indo-Gangetic Plains (IGP), the R-M-G system has received little or no attention.

For the rapid expansion of R-M-G system, sustainable and cost-effective technologies, with reduced labor requirement and rapid turnaround between crops, are needed. Potential technologies include reduced tillage or zero tillage and residue retention. In Telangana, farmers sow *rabi* crops after several passes of dry tillage after rice harvest and keep the land fallow for several days, which results in loss of soil moisture and delays planting. The shorter turnaround times between crops allow better use of residual soil moisture, better seedling emergence and a more uniform plant stand, faster and more efficient weeding and reduced labor requirements for cultural operations. Residue retention could play an important role in the R-M systems of India, where the residues of both crops are generally removed from the fields (Gathala *et al*., 2015).

Furthermore, agricultural waste products such as paddy straw and paddy husk are important sources of lignocellulosic biomass which is renewable and is one of the most abundant resources in the world. Biological

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How to cite this article: Rajitha, G., Padmaja, B., Reddy, M.M., Madhavi, A., Reddy, S.N., Triveni, S. and Yakadri, M. (2025). Residual Effects of Microbial Treated Paddy Residues Applied to Zero Till Maize on Growth and Yield of Summer Greengram. Legume Research. **48(10):** 1754-1759. doi: 10.18805/LR-5230.

Submitted: 10-08-2023 **Accepted:** 02-01-2024 **Online:** 14-03-2024

recycling of this biomass using microbial consortia is one of the upcoming technologies for agricultural wastes disposal in which biodegradation of lignocellullosic matter like paddy straw is carried out using efficient complex microbial consortia of lignolytic and cellulolytic microorganisms (Shukla *et al*., 2020). Using this microbial consortia, disposal of organic wastes will be reduced, decomposition rate of residues will be enhanced and quality of crop will be improved through recycling the nutrients present in the residues. It also reduces the dependence on non-renewable resources like fertilizers and minimizes the pollution.

Available studies on the effects of microbial consortia and residue-management options on yield and soil properties of various crops and cropping systems of the IGP show contradictory results. Thus, the current study was conducted on R-M-G system using fertilizers and residue management options to identify the most productive and profitable options for summer greengram sown after rice and maize.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted during *kharif*, *rabi* and summer seasons of 2020-21 and 2021-22 at the college farm of the Professor Jayashanker Telangana State Agricultural University, Hyderabad located at 17°32′22″N latitude and 78° 41′11″E longitude and 550 m above mean sea level. The experimental soil belongs to sandy clay loam with the following soil characteristics: pH-8.33, EC-0.37 dS m^{-1}, soil organic carbon-0.38%, available nitrogen-145 kg ha^{-1}, available phosphorous-38 kg ha^{-1}, available potassium-277 kg ha^{-1} and bulk density- 1.42 g cm^{-3} at the initiation of the experiment.

Treatment and experimental design

The experiment was laid out in strip plot design in twenty four treatment combinations with eight paddy residue management (R) practices for zero till maize after rice *viz*., R_1: Burning residue before sowing, R_2: Retention of residues, R_3: Removal of residues before sowing, R_4: Incorporation at 15 DAS, R_5: Incorporation at 15 DAS + SSP at equivalent to 'P' dose, R_6: Spraying consortia of decomposers @ 10% of residue weight + surface retention, R_7: Spraying consortia of decomposers @ 10% of residue weight + incorporation at 15 DAS, R_8: Spraying consortia of decomposers @ 10% of residue weight + incorporation at 15 DAS + SSP at equivalent to 'P' dose in horizontal plot and three fertility levels (F) *viz*., F_1: 180:60:60 kg N, P_2O_5 and K_2O ha^{-1} (75% RDF), F_2: 240:80:80 kg N, P_2O_5 and K_2O ha^{-1} (100% RDF) and F_3: 300:100:100 kg N, P_2O_5 and K_2O ha^{-1} (125% RDF) in vertical plot with three replications. The microbial consortia containing fungal strains of *Trichoderma viridae, Aspergillus awamori* and *Phanerochaeta spp* was used in the present study. The consortia was purchased from biofertilizer laboratory which was prepared by microbiologists. The microbiologists have grown the fungi separately and provided three bottles each containing one fungal species. On the day of application the three strains were mixed in a spray tanker and diluted with water. About 10 ml of consortia was sprayed for every 100 gms of residue weight with the help of a sprayer after chopping of residues to one inch size and retained between the maize rows after 15 DAS.

Rice (KNM-118 variety), maize (DHM-117 hybrid) and greengram (WGG-42 variety) were sown in planting geometry of 15 × 10 cm, 60 × 20 cm and 30 × 10 cm, respectively with seed rate of 25 kg ha^{-1} for rice, 20 kg ha^{-1} for maize and 20 kg ha^{-1} for greengram. Recommended dose of fertilizer for rice and maize (120:60:40 and 240:80:80 kg N, P_2O_5 and K_2O ha^{-1}, respectively) was given as per the treatments. Sun dried chopped residues of the rice crop of previous season were applied at 6.5 and 7.1 tonnes ha^{-1} during *rabi* 2020-21 and 2021-22 to maize as per the treatments. Greengram was sown on 9th March and 28th February after the harvest of maize during summer seasons of 2021 and 2022, respectively. Greengram was grown without any fertilizers or residue treatments. Thinning and gap filling were done 12 days after germination to maintain one healthy seedling per hill. Need based irrigations were applied.

Data collection

In order to record the growth and yield parameters in each net plot, five representative plants were randomly selected and tagged. All the successive observations were recorded on the selected plants during the crop growth period. Matured pods from the net plot area of 3.0 × 3.2 m^2 were picked manually and dried in the sun. The weight of cleaned grains obtained from each plot after threshing was recorded. The net plot seed and haulm yield of five plants which were marked for recording post-harvest observations were added and the total yield was expressed in kg ha^{-1}.

Regression analysis

Relationship of seed yield with growth paramaters and yield attributes was established by using regression analysis. While doing so, the parameters for which significantly high correlation was noticed were selected for regression studies. Plant seed yield (dependent variable) was assumed as a function of various growth parameters and yield attributes (independent variable) and the following straight line model was established by least square technique (Gomez and Gomez, 1984) as follows:

$$Y = a+bx$$

Where,
y = Seed yield (kg ha^{-1}).
a = Y-axis intercept.
b = Regression coefficient.
x = Independent variable.

RESULTS AND DISCUSSION

Plant growth

Data obtained from pooled analysis of 2021 and 2022 years showed that higher plant height, leaf area index (LAI) and dry matter production (DMP) of greengram was evident from incorporation of residues treated with microbial

consortia and SSP with 125% RDF (R_8F_3) which was statistically on par with microbial consortia + incorporation + SSP with 100% RDF (R_8F_2) and significantly superior over rest of the treatments (Table 1). On the other hand, significantly lower plant height, leaf area index and dry matter production was recorded with the treatment removal with 75% RDF (R_3F_1) which was comparable with that of *in-situ* burning with 75% RDF (R_1F_1), retention with 75% RDF (R_2F_1) and retention + consortia with 75% RDF (R_6F_1) treatments. The variation in plant growth among the treatments showed the importance of microbial consortium application to hasten up the decomposition of residues that increased the nutrient availability to sustain the plant growth and leaf area (Bargaz *et al*., 2018). The higher dry matter production was due to better root establishment resulting in better translocation and the movement of nutrient in soil solution and ultimately their greater absorption and utilization by the growing plants. Naiyar *et al*. (2016) and Dotaniya *et al.* (2013) also reported the similar findings.

Yield attributes

The number of pods plant, pod length and number of seeds pod^{-1} of greengram were discernibly influenced by the interaction of both residue management methods and fertility levels as obtained from pooled analysis of the data (Table 2). The combination of consortia + incorporation + SSP with 125% RDF or 100% RDFrecorded distinct and significantly higher yield attributes as compared to rest of the treatment combinations tested. On the other hand, the significantly lower number of pods plant, pod length and number of seeds pod^{-1} of greengram was recorded with the treatment combination of residue removal with 75% RDF but was found to be on par with *in-situ* burning with 75% RDF, retention with 75% RDF and retention + consortia with 75% RDF. The higher number ofpods plant^{-1}, pod length and number of seeds pod^{-1} with consortia + incorporation + SSP with 125% RDF could be marked out due to the faster decomposition of crop residues that released nutrients in tune with the crop growth and concurrent availability moisture content that resulted in better growth and development of greengram (Badiger *et al*., 2019).

Yield

Among all the tested combinations, R_8F_3 (consortia + incorporation + SSP with 125% RDF) recorded significantly higher seed yield and haulm yield (Table 3) which was comparable with R_8F_2 (consortia + incorporation + SSP with 100% RDF) and significantly superior over R_8F_1 (consortia + incorporation + SSP with 75% RDF) treatment combination. On the other hand, the significantly lower seed yield and haulm yield was recorded with the treatment combination of R_3F_1 (removal with 75% RDF) which was statistically comparable with that of R_1F_1 (*in-situ* burning with 75% RDF), R_2F_1 (retention with 75% RDF) and R_6F_1 (retention + consortia with 75% RDF). Paddy residues applied to maize crop released plant nutrients slowly to the greengram over time. Higher growth, greater absorption and better translocation of assimilates from source to sink could have resulted in increased yield as nutrients were available at more frequent intervals from residual sources in consortia + incorporation + SSP treatment. These results are also in consonance with the findings of Davari *et al.* (2012) in greengram grown after wheat crop.

Regression analysis

Regression between growth parameters and seed yield

The dependence of seed yield on plant height, leaf area index and dry matter production was evident from significant (P=0.01) and positive correlation between yield and plant height, leaf area index and dry matter production data (Table 4). Determination coefficient (R^2) was observed to be 0.90 for plant height at 15 and 30 DAS, 0.96 for LAI at 45 DAS and 0.97 for dry matter production at 30 DAS which

Table 1: Regression equation between seed yield vs growth parameters and yield attributes as influenced by residual effect of paddy residue management and fertility levels.

Parameter	DAS	Regression	
		Equation	R^2
Plant height (cm)	15	y = 144.28x-211.12	0.90
	30	y = 55.60x+25.13	0.90
	45	y = 55.70x+23.99	0.89
	Harvest	y = 13.61x+584.14	0.41
Leaf area index	15	y = 14074x-34.46	0.73
	30	y =531.2 x+17.55	0.94
	45	y = 504.89x+206.92	0.96
Dry matter (kg ha^{-1})	15	y = 6.65x-48.79	0.93
	30	y = 1.16x+30.07	0.97
	45	y = 0.52x+99.87	0.96
	Harvest	y = 0.21x+78.63	0.96
No of pods plant^{-1}	Harvest	y = 58.56x-122.17	0.96
Pod length (cm)	Harvest	y = 94.48x+59.38	0.98
No of seeds pod^{-1}	Harvest	y = 97.43x+5.74	0.92

Table 2: Residual effect of paddy residue management and fertilizer levels on plant height (cm), LAI and dry matter production (kg ha^{-1}) of greengram.

Treatment	Plant height (cm)				LAI				DMP (kg ha^{-1})			
	Fertilizer levels (F)											
Residue management (R)	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean
R_1- *In situ* burning	18.8	22.0	25.1	22.0	1.40	1.80	2.08	1.76	1911	2827	3917	2885
R_2- Retention	19.9	22.5	24.7	22.4	1.58	1.76	1.99	1.78	2038	2957	3754	2916
R_3- Removal	18.7	21.6	25	21.8	1.40	1.71	2.12	1.74	2170	2838	3413	2807
R_4- Incorporation	19.8	23.6	28.7	24.0	1.66	1.89	2.15	1.90	2588	3197	3757	3181
R_5- Incorporation + SSP	24.0	26.7	27.6	26.1	1.81	2.06	2.22	2.03	3164	3590	3676	3477
R_6- Retention + consortium	19.6	22.9	25.1	22.5	1.42	1.83	2.15	1.80	2175	2943	3750	2956
R_7- Consortium + incorporation	27.8	28.9	29.6	28.8	2.08	2.16	2.24	2.16	3572	3786	3938	3765
R_8- Consortium + incorporation + SSP	29.4	30.0	31.0	30.1	2.19	2.29	2.37	2.28	3915	4083	4299	4099
Mean	22.3	24.8	27.1		1.69	1.94	2.17		2692	3278	3813	
For comparison the mean of	SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)	
Residue management	0.3		0.9		0.02		0.07		62		189	
Fertilizer levels	0.2		0.9		0.01		0.05		22		88	
R at levels of F	0.3		1.0		0.03		0.09		90		262	
F at levels of R	0.9		2.8		0.08		0.24		253		732	

Table 3: Residual effect of paddy residue management and fertilizer levels on no. of pods plant^{-1}, pod length (cm) and no.ofseeds pod^{-1} of greengram.

Treatment	No. of pods plant^{-1}				Pod length (cm)				No. of seeds pod^{-1}			
	Fertilizer levels (F)											
Residue management (R)	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean
R_1- *In situ* burning	11.2	14.0	15.7	13.6	6.0	7.7	9.0	7.6	5.7	6.7	8.6	7.0
R_2- Retention	12.0	13.7	15.5	13.7	6.1	7.9	9.3	7.8	5.7	6.9	8.5	7.0
R_3- Removal	10.4	13.8	16.1	13.4	5.7	7.5	9.2	7.5	5.8	7.2	7.6	6.9
R_4- Incorporation	11.9	14.6	17.4	14.6	6.6	8.1	10.0	8.2	5.8	7.6	9.3	7.6
R_5- Incorporation + SSP	14.3	16.6	17.2	16.0	8.2	9.2	9.8	9.1	6.7	8.7	9.3	8.2
R_6- Retention + consortium	11.9	14.0	16.1	14.0	5.9	7.8	9.6	7.8	5.5	7.2	8.7	7.1
R_7- Consortium + incorporation	17.0	17.4	17.8	17.4	9.5	9.8	10.0	9.8	8.5	9.0	9.4	9.0
R_8- Consortium + incorporation + SSP	18.4	18.7	19.1	18.7	10.2	10.4	10.7	10.4	9.3	9.8	10.3	9.8
Mean	13.4	15.4	16.9		7.3	8.6	9.7		6.6	7.9	9.0	
For comparison the mean of	SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)	
Residue management	0.4		1.1		0.2		0.5		0.1		0.4	
Fertilizer levels	0.3		1.0		0.1		0.4		0.1		0.4	
R at levels of F	0.3		1.0		0.2		0.5		0.1		0.4	
F at levels of R	0.9		2.6		0.5		1.4		0.4		1.1	

Table 4: Residual effect of paddy residue management and fertilizer levels on yield (kg ha^{-1}) and harvest indexof greengram.

Treatment	Seed yield (kg ha^{-1})				Haulm yield (kg ha^{-1})				Harvest Index			
	Fertilizer levels (F)											
Residue management (R)	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean	F_1- 75% RDF	F_2- 100% RDF	F_3- 125% RDF	Mean
R_1- *In situ* burning	508	693	843	681	1686	1948	2200	1945	26.20	27.75	27.48	27.14
R_2- Retention	532	688	859	693	1786	1985	2220	1997	26.31	27.61	27.62	27.18
R_3- Removal	491	667	851	670	1650	1917	2184	1917	26.77	27.79	26.90	27.15
R_4- Incorporation	574	760	893	742	1847	2089	2308	2081	26.43	27.78	27.97	27.39
R_5- Incorporation + SSP	744	829	855	809	1972	2307	2390	2223	27.59	28.37	27.23	27.73
R_6- Retention + consortium	543	743	848	711	1841	1989	2192	2007	26.56	28.10	27.75	27.47
R_7- Consortium + incorporation	841	888	915	881	2295	2371	2438	2368	28.21	28.25	28.18	28.21
R_8- Consortium + incorporation + SSP	911	949	1006	955	2431	2508	2583	2507	31.91	26.75	27.08	28.58
Mean	643	777	884		1939	2139	2314		27.50	27.80	27.53	
For comparison the mean of	SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)		SE(m)±		CD (P=0.05)	
Residue management	17		52		35		107		0.22		NS	
Fertilizer levels	14		55		18		72		0.25		NS	
R at levels of F	17		49		26		76		0.47		NS	
F at levels of R	47		135		55		159		1.43		NS	

showed a linear increase in the growth parameters with the corresponding increase in yield.

Regression between yield attributes and seed yield

The dependence of seed yield on number of pods per plant, pod length and number of seeds per pod was evident from significant (P=0.01) and positive correlation between yield and number of pods per plant, pod length and number of seeds per pod (Table 4). Determination coefficient (R^2) was observed to be 0.96 for number of pods per plant, 0.98 for pod length and 0.92 for number of seeds per pod at harvest which showed a linear increase in the yield attributes with the corresponding increase in yield.

CONCLUSION

In conclusion, paddy residue management and fertility levels to zero till maize had a significant impact on succeeding greengram growth, yield attributes and yield. Microbial consortia + SSP + incorporation along with 100% RDF resulted in increased plant height, leaf area index, dry matter production, number of pods plant, pod length and number of seeds pod^{-1}, seed yield and haulm yield. Therefore, crop residue incorporation at 6.5-7.0 t ha^{-1} and application of microbial consortia in combination with fertilizers have a positive residual impact on increasing summer greengram growth and productivity under zero till rice-maize-greengram cropping system.

Conflict of interest

All authors declare that they have no conflicts of interest.

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