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

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## 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 (Majumdharet *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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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 sp*p 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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