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Research Article

Influence of residue management on yield and yield components of zero till maize

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ABSTRACT

Crop residue burning in open fields contributes to global warming by greatly polluting the air and emitting greenhouse gases. In order to seek an alternative, the current study was initiated to explore the perspective of lignocellulolytic microbes to expedite in situ decomposition of crop residues. The objective of this experiment was to study the effects of residue management and fertilizers on the yield and yield components of maize. The experiment was conducted at a college farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad during rabi 2020-21 and 2021-21, respectively and was laid out in strip plot design with twenty-four treatments having three replications. A higher number of cobs plant^{-1}, cob length, cob girth, number of kernel rows cob^{-1} number of kernels cob^{-1}, test weight, grain, and biological yields were recorded with incorporation of residues treated with SSP and consortia in combination with 75 % RDF application. However, these parameters were minimal for residue burning and removal treatments with 125% RDF application. The plots in which residues were not incorporated also performed poorly and resulted in the lowest values of these parameters. It is concluded that the application of microbial consortia at the rate of 10% of residue weight in incorporated plots along with the application of SSP resulted in higher yield and yield components of maize.

Keywords- *Residue burning, microbial consortia, yield parameters, yield*

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INTRODUCTION

Agriculture plays a crucial role in the Indian economy where 143 million hectares (M ha) of land is put under intensive agriculture producing approximately 285 million tonnes (Mt) of food grains. It has been assessed that ten major crops (rice, wheat, sorghum, pearl millet, barley, finger millet, sugar cane, potato tubers, pulses, and oilseeds) of India produce approximately 683 million tons (Mt) of crop residues (CR) both on-farm and off-farm [1]. Out of the total CR produced approximately 140 Mt CR are subjected to open field burning. CR from rice accounted for 40% of the total residues burnt followed by wheat residue (22%) and sugarcane trash (20%) [5].

Rice-wheat systems of Indo-Gangetic Plains (IGP) are the main contributor to India's total cereal production, accounting for 23% and 40% of India's total rice and wheat area, respectively [7]. Henceforth, it is quite predictable that IGP is the key contributor to rice and wheat residues. Moreover, scarcity of labor, the high cost involved in incorporating/removing residues from fields and composting, lack of requisite machinery to incorporate crop residues in soil have compelled the farmers to adopt burning. Burning of paddy straw could cause an intact loss of about 79.38, 183.71 and 108.86 kg ha^{-1} N, P, and K, respectively [6, 8]. Hence, its uninterrupted removal and burning could lead to net losses of nutrients which eventually will cause greater nutrient input costs in the short run and a decline in soil health and productivity in the long run scenario. Here arises the significance of alternative as well as sustainable ways of crop residues management. The technique of *ex-situ* decomposition of crop residues or composting dates back to several decades, however, is still holds its importance in sustainable crop residue recycling. Nevertheless, the *in situ* or in-field decomposition of crop residue using microbial inoculums is rarely studied. However, the greater challenge is not only achieving the complete decomposition but also enhancing the rate of *in situ* decomposition to make the field available to the farmers for the next crop. Although there are few studies on the application of lignocellulolytic microbes for *in situ* residue decomposition [2, 3], still there is a need for further extensive studies to examine the efficacy of the microbial inoculants in abating the nuisance of crop residue burning. Henceforth, the present study was undertaken to evaluate the effect of paddy residue management practices on the growth and yield of zero tillage maize grown after rice.

MATERIAL AND METHODS

A field experiment was conducted in field no: C-12 of Agricultural College farm, Rajendranagar, Hyderabad which is geographically situated at 17^{0}32'22''N latitude and 78^{0}41'11''E longitude with an altitude of 550 m above the mean sea level. The experimental soil was neutral in reaction (7.8), low in organic carbon (0.38 %) and available nitrogen (145 kg ha^{-1}), and medium in available phosphorous (38 kg ha^{-1}) and available potassium (277 kg ha^{-1}). There were eight residue management methods *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 and three fertilizer doses *viz.*, F_1: 75% RDF, F_2: 100% RDF and F_3: 125 % RDF. All these were tested in strip plot design, and replicated thrice. Deccan Hybrid Makka (DHM-117) was used for the study during the *rabi* seasons of the year 2020 and 2021, released from All India Coordinated Research Project on Maize, (Indian Institute for Maize Research), Hyderabad, Telangana State in 2009. Maize seeds were sown under zero tillage situation during *rabi* season in the same experimental site where *kharif* rice was grown in the previous season.The yield attributes like the number of cobs plant^{-1}, length of the cob, girth of the cob, no of kernel rows cob^{-1}, number of kernels cob$^{-1,}$ and test weight in maize were recorded at harvest. The tagged plants were used for recording yield attributes. From selected five plants, the cob length was measured from base to tip of the cob and computed as the average cob length in centimeters. The girth was measured at the point of maximum girth using a thread and measured with a scale. The mean girth of the cob was computed and expressed in cms. A number of kernel rows in each cob were counted manually. A grain sample was taken from each net plot, the sample was weighed and the seeds in the sample were counted. The 100-grain weight was computed and is expressed in grams.The harvested produce from each plot was tied in bundles separately, sun-dried and dry weight was recorded in kilograms with the help of electronic balance. The weight of cleaned grains obtained from each plot after shelling/threshing was recorded. The net plot grain and stover yield of five plants which were marked for recording post-harvest observations were added and the total yield was expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

Number of Cobs Plant^{-1}: It is revealed from the data in Table 1 that the higher number of cobs per plant was significantly affected by the interaction of different residue management practices and fertility levels. Among the combinations, consortium + incorporation + SSP with 125 % RDF (R_8F_3) gave a maximum number of cobs per plant which was on par with consortium + incorporation + SSP with 100% RDF (R_8F_2) and consortium + incorporation + SSP with 75% RDF (R_8F_1) combinations. The reason for having a statistically higher number of cobs per plant with R_8 treatment might have been due to the concurrent availability of moisture and nutrients in synchrony with their need which resulted in better partitioning of photosynthates and increased the number of cobs plant^{-1} during both the years of experiment than other treatments. In 2020-21, removal with 75% RDF (R_3F_1) had a lower number of cobs plant^{-1} and was on par with *in-situ* burning (R_1F_1), retention (R_2F_1), retention + consortium (R6F_1), and incorporation (R4F_1), but it was significantly higher in 2021-22. Poor availability of nutrients and moisture as a result of the loss of organic matter caused by burning and removal may be the cause of variation in the number of cobs plant^{-1} in relation to residue management practices ［4］.

Length of the Cob: With the application of 125% RDF in conjunction with consortium + incorporation + SSP, much longer cobs were seen, and it was comparable to 100% RDF and 75% RDF (Table 2). Lower cob length was seen in removal with 75% RDF which was comparable to *in-situ* burning with 75% RDF, retention with 75% RDF, and consortium + retention with 75% RDF. Similar findings were made earlier by ［3］, who reported that wheat treated with several fungal isolates had longer spikes than the untreated control.

The girth of the Cob: When compared to other residue management techniques, the incorporation of residues treated with consortium and SSP along with 125 % RDF considerably increased the cob girth of maize and was found to be on par with 100% RDF and 75% RDF as shown in Table 3. It could be because the microbial consortium plays a significant role in the degradation, produces favorable soil moisture, reduces soil temperature, and enhances the absorption and utilization of available nutrients, all of which contribute to an overall improvement in crop growth. This reflects the relationship between the source and the sink, which in turn increased the yield characteristics of maize in both years.

Number of Kernel Rows Cob^{-1}: During the two years of study, the data pertaining to the number of kernel rows cob^{-1} of maize showed that it was unaffected by residue management practices and fertility levels as well as their interaction as shown in Table 4.

Number of Kernels Cob^{-1}: As shown in Table 5, consortium + incorporation + SSP with 125% RDF produced a higher number of kernels cob^{-1} than R_8F_2 (consortium + incorporation + SSP with 100 percent RDF) and R_8F_1 (consortium + incorporation + SSP with 75 percent RDF). However, this result was comparable to R_8F_2 and R_8F_1. In 2020-21, R_3F_1 (removal with 75 percent RDF) was found to be on par with R_1F_1 (*in-situ* burning with 75 percent RDF), R_2F_1 (retention with 75 percent RDF), R_6F_1 (retention + consortium with 75 percent RDF), and R_4F_1 (incorporation with 75 percent RDF), while R_4F_1 (incorporation with 75 percent RDF) was found to be superior to R_3F_1, R_1F_1, R_2F_1 and R_6F_1 during second year of experiment *i.e.,*2021-22.

Test Weight: Non-significant effect of fertility levels and residue management interaction was recorded with the test weight in maize (Table 4).

Grain Yield:A critical look at the data indicates that the grain yield of maize was influenced significantly due to the different residue management practices and fertility levels. Maize kernel yield was significantly higher with consortium + incorporation + SSP in combination with 125% RDF (R_8F_3) than with the other residue management practices examined. The kernel yield of maize mainly depends on the partitioning ability of photosynthates from source to sink *i.e.*, developing cobs and kernels which leads to increased yield. All the yield-promoting characters were significantly higher with consortium + incorporation + SSP due to better partitioning of photosynthates to developing cobs. Consortium + incorporation with 125 % RDF (R_7F_3) was the next best treatment in terms of higher maize yield, and it distinguished itself significantly from the other treatments, namely, incorporation (R_4F_3) and incorporation + SSP(R_5F_3). The absence of consortium limited the availability of nutrients as well as the activity of microbes in sole incorporation plots, hence the decomposition rate was slow. So an additional dose of nutrients (125 % RDF) limited the immobilization and improved the yield in R_4 and R_5 plots. According to ［9］, the mere incorporation of residues into the soil has a negative impact on the available nutrients in the soil due to the immobilization of nutrients by the presence of residues with a wide C/N ratio, resulting in lower yields in rice and wheat. The grain yields under 125% RDF + removal, 125% RDF + *in-situ* burning and 125% RDF + retention, 125% RDF + retention + consortium were found to be statistically on par with each other, and 125% RDF + residue incorporation was also found at par during first year of study while it was significantly superior over R_3 R_1 R_2 and R_6 during second year *i.e., rabi* 2021-22.

Straw yield : It is apparent from the data that residue management practices and fertility levels had recorded a significant impact on straw yield. The highest straw yield was achieved when consortium, incorporation, and SSP (R_8) were used in conjunction with 125% RDF (F_3). During both *rabi* 2020-21 and 2021-22, the straw yields under 125% RDF + removal (R_3F_3), 125% RDF + *in-situ* burning (R_1F_3), 125% RDF + retention (R_2F_3), and 125% RDF + retention + consortium (R_6F_3) were found to be statistically equivalent to one another. When fertilizers are combined with residues and microbial consortium, the physical properties of the soil will be improved, micronutrients will be replenished, soil moisture will be retained and fertilizer efficiency will increase for high yield.

Conclusion: This experiment has shown that the incorporation of crop residues after the application of microbial consortia and SSP in conjunction with 125% RDF significantly increased yield and yield components of maize.

Table 1: No. of cobs plant^{-1} of zero till maize as influenced by paddy residue management and fertilizer levels during rabi, 2020-21 and 2021-22

Treatment	No of cobs plant $^{-1}$ (2020-21)				No of cobs plant $^{-1}$ (2021-22)			
	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
R_1-*In-situ* burning	0.17	0.90	1.67	0.91	0.34	1.10	1.78	1.07
R_2- Retention	0.17	1.01	1.62	0.93	0.36	1.07	1.86	1.10
R_3- Removal	0.15	0.95	1.59	0.90	0.34	1.11	1.70	1.05
R_4- Incorporation	0.19	0.85	2.00	1.01	0.40	1.23	2.06	1.23
R_5-Incorporation + SSP	0.95	1.30	1.36	1.20	0.71	1.60	1.70	1.34
R_6-Retention + consortium	0.18	1.02	1.73	0.98	0.16	1.25	1.98	1.13
R_7-Consortium + incorporation	1.30	1.38	1.44	1.37	1.44	1.46	1.49	1.46
R_8-Consortium + incorporation + SSP	1.43	1.56	1.54	1.51	1.52	1.57	1.61	1.57
Mean	0.57	1.12	1.62		0.66	1.30	1.77	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	0.04		0.13		0.03		0.09	
Fertility levels	0.07		0.30		0.10		0.42	
R at levels of F	0.11		0.32		0.11		0.34	
F at levels of R	0.35		1.04		0.39		1.14	

Table 2: Cob length (cm)of zero till maize as influenced by paddy residuemanagement and fertilizer levels during rabi, 2020-21 and 2021-22

Treatment	Cob length (2020 -21)				Cob length (2021-22)			
	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
R_1- *In-situ* burning	10.1	12.5	15.9	12.8	10.7	14.1	16.5	13.8
R_2- Retention	11.0	13.3	14.7	13.0	11.4	13.9	16.5	13.9

R_3- Removal	9.8	13.1	14.9	12.6	9.9	14.6	16.2	13.6
R_4- Incorporation	11.7	13.8	15.3	13.6	13.5	15.3	17.5	15.4
R_5-Incorporation + SSP	12.2	15.8	16.6	14.9	14.0	17.4	18.1	16.5
R_6-Retention + consortium	10.0	13.3	16.3	13.2	12.1	13.8	16.5	14.1
R_7-Consortium + incorporation	15.6	16.3	16.6	16.2	16.8	17.3	17.8	17.3
R_8-Consortium + incorporation + SSP	17.2	17.4	17.9	17.5	17.7	18.1	18.5	18.1
Mean	12.2	14.4	16.0		13.3	15.6	17.2	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	0.3		1.1		0.2		0.6	
Fertilizer levels	0.4		1.4		0.3		1.2	
R at levels of F	0.4		1.1		0.4		1.0	
F at levels of R	1.1		3.3		1.1		3.3	

Table 3: Cob girth (cm) of zero till maize as influenced by paddy residue management and fertilizer levels during rabi, 2020 and 2021

Treatment	**Cob girth (2020 -21)**				**Cob girth (2021-22)**			
	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**
R_1-*In-situ* burning	7.9	9.7	11.6	9.7	8.4	10.5	12.3	10.4
R_2- Retention	8.0	9.9	11.7	9.9	8.7	10.6	12.3	10.5
R_3- Removal	7.6	9.4	11.3	9.4	8.1	10.3	11.9	10.1
R_4- Incorporation	9.0	10.2	12.4	10.5	10.0	12.8	14.2	12.3
R_5-Incorporation + SSP	9.8	12.9	13.1	11.9	10.6	14.4	15.2	13.4
R_6-Retention + consortium	7.2	10.0	13.4	10.2	7.2	10.7	15.1	11.0
R_7-Consortium + incorporation	12.7	13.6	13.7	13.3	14.0	14.5	14.9	14.5
R_8-Consortium + incorporation + SSP	14.3	14.8	15.0	14.7	15.1	15.5	16.1	15.6
Mean	9.6	11.3	12.8		10.3	12.4	14.0	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	0.4		1.1		0.3		0.9	
Fertilizer levels	0.1		0.5		0.3		1.2	
R at levels of F	0.3		1.0		0.4		1.2	
F at levels of R	0.8		2.5		1.2		3.6	

Table 4: Kernel rows cob^{-1} and 100 kernel weight (g) of zero till maize as influenced by paddy residue management and fertilizer levels

Treatments	Kernel rows cob^{-1}		100 kernel weight (g)	
	2020-21	2021-22	2020-21	2021-22
Horizontal plots: Paddy residue management options (R)				
R_1- *In-situ* burning	14.1	14.7	22.3	24.6
R_2- Retention	14.5	14.9	23.3	25.5
R_3- Removal	13.8	14.5	22.2	24.2
R_4- Incorporation	14.8	15.4	24.5	26.7
R_5-Incorporation + SSP	15.0	15.6	24.7	27.1
R_6-Retention + consortium	14.6	15.2	24.0	26.2
R_7-Consortium +incorporation	15.4	16.0	24.9	27.3
R_8-Consortium + incorporation + SSP	15.8	16.3	25.6	27.5
SE(m)±	0.4	0.6	0.7	0.7
CD (*P=0.05*)	NS	NS	NS	NS
Vertical plots: Fertilizer levels (F)				
F_1- 75 % RDF	13.8	14.4	23.3	25.4
F_2- 100 % RDF	14.8	15.3	23.8	26.1
F_3- 125 % RDF	15.6	16.2	24.7	27.0
SE(m)±	0.4	0.3	0.3	0.3
CD (*P=0.05*)	NS	NS	NS	NS
Interaction				
R at levels of F				
SE(m)±	0.5	0.5	0.8	0.8
CD (*P=0.05*)	NS	NS	NS	NS
F at levels of R				
SE(m)±	1.4	1.1	2.0	2.0
CD (*P=0.05*)	NS	NS	NS	NS

Table 5: No of kernels cob^{-1} of zero till maize as influenced by paddy residuemanagement and fertilizer levels during rabi, 2020-21 and 2021-22

Treatment	No of kernels cob^{-1} (2020 -21)				No of kernels cob^{-1} (2021-22)			
	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
R_1- *In-situ* burning	145	282	327	251	188	284	362	278
R_2- Retention	148	241	379	256	192	289	362	281
R_3- Removal	144	255	348	249	169	281	378	276
R_4- Incorporation	149	264	399	271	245	301	425	324
R_5-Incorporation + SSP	186	368	394	316	244	402	428	358

R_6-Retention + consortium	145	225	416	262	194	293	382	290
R_7-Consortium + incorporation	348	357	369	358	381	390	399	390
R_8-Consortium + incorporation + SSP	376	397	401	391	411	423	438	424
Mean	205	299	379		253	333	397	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	8		26		9		28	
Fertilizer levels	9		38		5		20	
R at levels of F	10		31		9		26	
F at levels of R	32		93		23		66	

Table 6: Yield (Kg ha^{-1}) of maize as influenced by residue management and fertilizer levels during 2020-21.

Treatment	**Grain yield (Kg ha^{-1})**				**Straw yield (Kg ha^{-1})**			
	Fertilizer levels							
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**
R_1- *In-situ* burning	4412	5161	5991	5188	5030	6232	7052	6105
R_2- Retention	4488	5438	5869	5265	4295	6245	7941	6160
R_3- Removal	4039	5255	6220	5171	5284	6180	6666	6043
R_4- Incorporation	4564	5418	6239	5407	4649	6553	8061	6421
R_5-Incorporation + SSP	5381	5923	6088	5797	5611	7492	7956	7020
R_6-Retention + consortium	4724	5355	5941	5340	5537	6254	7268	6353
R_7-Consortium + incorporation	6132	6211	6273	6205	7508	7581	7702	7597
R_8-Consortium + incorporation + SSP	6487	6529	6787	6601	7932	8164	8357	8151
Mean	5028	5661	6176		5731	6838	7625	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	125.2		379.8		159.1		482.7	
Fertilizer levels	127.7		501.6		184.0		722.5	
R at levels of F	139.9		405.3		217.9		631.2	
F at levels of R	413.9		1199.1		666.9		1932.1	

Table 7: Yield (Kg ha^{-1}) of maize as influenced by residue management and fertilizer levels during 2021-22.

Treatment	Grain yield (Kg ha^{-1})				Straw yield (Kg ha^{-1})			
	Fertilizer levels							
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
R_1- *In-situ* burning	4828	5210	5807	5282	5170	6396	7219	6262
R_2- Retention	4909	5359	5723	5330	4816	6417	7797	6343
R_3- Removal	4520	5403	5801	5241	4352	6221	8041	6205
R_4- Incorporation	5383	5771	6292	5815	6206	6873	7887	6989
R_5-Incorporation + SSP	5867	6291	6489	6216	6970	7750	7814	7511
R_6-Retention + consortium	4976	5377	5854	5402	5060	6490	7839	6463
R_7-Consortium + incorporation	6518	6631	6693	6614	7915	8055	8143	8038
R_8-Consortium + incorporation + SSP	6929	6971	7096	6999	8269	8568	8828	8555
Mean	5491	5877	6219		6095	7096	7946	
For comparison the mean of	SE(m)±		CD (*P=0.05*)		SE(m)±		CD (*P=0.05*)	
Residue management	125.1		379.7		169.2		513.3	
Fertilizer levels	82.8		325.2		167.4		657.3	
R at levels of F	100.1		290.0		218.2		632.3	
F at levels of R	238.7		691.7		647.4		1875.4	

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