E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(4): 734-737
Received: 11-02-2024
Accepted: 18-03-2024

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Effect of tillage on yield attributes, yield and cropping system indices of pulse crops grown in mechanically harvested lowland rice

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i4j.631

Abstract
A field study was conducted during *rabi* season of 2022-23, at fields of Regional Agricultural Research Station (RARS), Warangal to study the "Effect of different tillage methods on growth parameters and economics of pulse crops grown in mechanically harvested lowland rice". The experiment was laid out in split plot design replicated thrice having three tillage practices (Zero tillage T_1; Reduced tillage T_2; Minimum tillage T_3) in main plots and four *rabi* pulse crops (Chickpea S_1; Greengram S_2; Blackgram S_3; Cowpea S_4) in sub-plots with total twelve treatment combinations. Study revealed that among tillage practices, reduced tillage (T_2) recorded significantly higher REY (9059 kg ha^{-1}), production efficiency (32.9 kg ha^{-1} day^{-1}) and profitability (Rs 292 ha^{-1} day^{-1}) whereas, among sub-plot pulse crops, greengram (S_2) recorded higher REY (9427 kg ha^{-1}), production efficiency (35.6 kg ha^{-1} day^{-1}) and profitability (Rs 318 $ha^{-1}day^{-1}$).

Keywords: Tillage, rice fallow, chickpea, greengram, blackgram, cowpea, pulses

1. Introduction
In India, around 30% of the area under rice production remains fallow in the subsequent winter *rabi* season (DAC, 2011) [4]. Large areas are left fallow during *rabi* season in India after harvest of rice crop in India. It is possible to plant another crop in rice fallow immediately after harvesting of rice crop due to enough soil moisture for supporting succeeding crop. In this perspective, there is an enormous opportunity to increase the total cropping area through strategic trapping of rice fallows (Kar and Kumar, 2009; Ghosh *et al.*, 2016) [12, 17]. Productivity and profitability from second crops in rice fallow can be improved with suitable crop management technique even by utilizing residual soil moisture (Pratibha *et al.*, 1997; Mahata *et al.*, 1992) [17, 15]. The soil structure was improved by growing of second crops after rice with tillage methods (Gangwar *et al.*, 2006) [6].
Pulses crops are best suited and fit into rice based cropping system because of shorter duration and their ability to grow under residual moisture and good candidates for efficient utilization of fallows. Pulses endowed with unique characteristics of biological N-fixation (BNF), deep rooted, and soil-fertility restoration property, pulses can be best fitted in rice fallows (Ali *et al.*, 2014) [2]. Pulses, being short-duration in nature and low-input requiring, offers a good opportunity to utilize residual soil moisture in rice fallow (Kar *et al.*, 2004; Kar and Kumar, 2009) [13, 12]. Therefore inclusion of pulses in rice fallow is one of the ways to increase production of pulses with low cost approach and increase income of the farmers.
Pulse crops like chickpea, blackgram, greengram and cowpea are suitable pulse crops for sustainable intensification of mechanically harvested lowland rice fallow during *rabi* season which benefit farmers economically and improve soil fertility due to nitrogen fixation.
Conventional method of land preparation consumes more energy, time and it is capital intensive. Whereas conservation tillage practices like minimum, reduced and zero tillage improve the energy efficiency, less soil disturbance and reduce the production cost (Hernanz *et al.*, 1995) [8].

Reduced tillage is the best tillage suitable in rice–based cropping systems with respect to system productivity, production efficiency, nutritional uptake and recovery efficiency of the added nutrients (Kar *et al.*, 2021) [14]. Keeping all these in view, experiment was undertaken to evaluate suitable tillage method for successful cultivation of pulse crops in rice fallows.

2. Materials and Methods

The experiment was carried out at at fields of Regional Agricultural Research Station (RARS), Warangal. The site is situated at an altitude of 351m and geographical bearing of 18°05'35.9"N latitude and 79°35'48.6"E longitude. According to Troll's climatic classification, it falls under Semi- Arid Tropical region (SAT). The experimental site is in Southern Telangana Agro-Climatic Zone. The experiment comprised 12 treatment combinations laid out in a split–plot design with three replications. There were three different tillage methods *viz.*, T_1: Zero tillage (Herbicide spray + seed dibbling) T_2: Reduced tillage (Twice cultivator and once rotavator) T_3: Minimum tillage (once cultivator and once rotavator) included as main-plot treatments and four pulse crops (S_1-: Bengalgram, S_2: Greengram, S_3: Blackgram and S_4: Cowpea) included as sub–plot treatments. This experiment was carried out in total of 36 plots and each plot having gross plot size 6.0 m x 4.0 m and net plot size 4.2 m x 3.6 m. Immediately after harvest rice the land was prepared as per the treatments and sowing was done. Recommended dosage fertilizers were applied as Urea, DAP and MOP and seeds were sown with prescribed seed rates according to crops. All crops were sown with spacing of 30 cm between rows and 10 cm between plants. To compare the performance of different pulse crops, economic yield of all the crops were converted into rice equivalent yield (REY) based on prevailed market price using the formula:

$$\text{REY} = \text{Rice yield (kg ha}^{-1}) + \frac{\text{Yield of crop (kg ha}^{-1}) \text{ x price of the crop (Rs kg}^{-1})}{\text{Price of the rice crop (Rs kg}^{-1})}$$

System profitability (Rs ha^{-1} day^{-1}) of the system was calculated by dividing the net returns of a crop by no. of days a crop occupied in field. The production efficiency (kg ha^{-1} day^{-1}) was calculated by dividing the total seed yield (Kg ha^{-1}) of a crop with total duration of crop of that particular crop.

Note: Observations on yield attributes and seed yield were compared on mean basis without statistical analysis as different crops having genetically distinct characteristics cannot be compared in sub plots, while influence of tillage and crops on rice equivalent yield (REY), production efficiency and profitability were analysed statistically and interpretation of the data was done as per the split plot design specified.

3. Results and Discussion

3.1 Yield attributes and yield

The data from Table.1 revealed that on mean comparative basis, reduced tillage (T_2) recorded higher number of pods per plant in chickpea, greengram, blackgram and cowpea (21.1, 27.7, 23.2 and 18.2 respectively). These findings were supported by studies of Aikins *et al.* (2010) [1] as intensity of tillage increased among treatments number of pods per plant also increased. However, number of seeds per pod and test weight of pulse crops was not influenced by tillage as they were nearly same among all tillage practices with minimal differences.

Seed yield of pulse crops was influenced by tillage practices as reduced tillage recorded higher seed yield in chickpea, greengram, blackgram and cowpea (1428, 1286, 1392 and 1093 kg ha^{-1} respectively). On mean comparative basis reduced tillage (T_2) recorded 20.4%, 25.7%, 27.3% and 17.7% higher seed yield than zero tillage (T_1) in chickpea, greengram, blackgram and cowpea respectively. The yield of rice fallow pulse crops was enhanced when tillage was applied after harvesting of rice, which might be due to improved soil physical conditions providing better growth conditions for the plants. Higher yield attributes (number of pods) under reduced tillage (T_2) resulted in higher seed yield. Similar results were documented by Kar and Kumar (2009) [12]. Among tillage practices, reduced tillage also recorded higher haulm yield and harvest index in chickpea (1812 kg ha^{-1} and 44.1%), greengram (2857 kg ha^{-1} and 29.8%), blackgram (3411 kg ha^{-1} and 29.0%) and cowpea (4026 kg ha^{-1} and 23.7%) respectively.

3.2 Cropping system indices

The data from Table 2 revealed that rice equivalent yield (REY), production efficiency and profitability were significantly influenced by tillage practices and cropping systems.

Significantly higher REY (9059 kg ha^{-1}) was recorded with reduced tillage (T_2), followed by minimum tillage (T_3), which had a REY of 8797 kg ha^{-1}, while zero tillage (T_1) recorded the lowest among tillage practices with a REY of 8385 kg ha^{-1}. Higher REY with reduced tillage (T_2) could be attributed to higher seed yield and yield attributes associated with this tillage practice. These results are in line with Deka *et al.* (2021). Among rice based cropping systems rice-greengram (9427 kg ha^{-1}) sequence recorded significantly higher REY compared to all other rice fallow crops and it was on par with rice-blackgram (9260 kg ha^{-1}) followed by rice-chickpea (8571 kg ha^{-1}) and the least REY was recorded with rice-cowpea (7730 kg ha^{-1}) sequence. Higher production potential of greengram coupled with the high selling price resulted in higher REY in rice-greengram system. The results are in conformity with Mallareddy *et al.* (2018) [16].

Among the main plot treatments, the highest production efficiency (kg ha^{-1} day^{-1}) was observed with reduced tillage (32.9), followed by minimum tillage (31.9) and the lowest with zero tillage (30.4). Among rice-based cropping system, significantly higher production efficiency was observed in greengram (35.6), followed by blackgram (34.3), chickpea (30.1) and cowpea (27.1). However, there was no interaction between main and subplots, as all the crops responded similarly to the tillage methods. In a similar study by Pratibha *et al.* (1997) [17], it was observed that, as the intensity of tillage increased among treatments, production efficiency also increased.

The experimental findings revealed that, among tillage practices higher system profitability was obtained with reduced tillage (Rs 292 ha^{-1}day^{-1}) followed by minimum tillage (Rs 280 ha^{-1}day^{-1}) and zero tillage (Rs 260 ha^{-1}day^{-1}). Among rice based cropping sequences, the rice-greengram (Rs 318 ha^{-1}day^{-1}) sequence generated the highest system profitability, followed by rice-blackgram (Rs 303 ha^{-1}day^{-1}) and rice-chickpea sequence (Rs 261 ha^{-1}day^{-1}) while, the lowest system profitability was generated by the rice-cowpea sequence (Rs 227 ha^{-1}day^{-1}). There was no interaction found between tillage and crops. Higher system profitability with rice-greengram sequence was due to high net returns generated by this system. These results are in line with the findings of Rao *et al.* (2022) [18], who noted that rice based cropping systems were more profitable with intensive tillage compared to zero tillage.

Table 1: Effect of tillage practices on yield attributes and yield of *rabi* pulse crops

Treatment	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test weight of 100 seed (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
Chickpea						
T_1	17.1	1.0	28.1	1186	1627	42.1
T_2	21.1	1.0	29.2	1428	1812	44.1
T_3	19.8	1.0	28.9	1331	1792	42.6
Greengram						
T_1	21.4	9.3	3.1	1023	2493	27.0
T_2	27.7	9.9	3.5	1286	2857	29.8
T_3	25.5	9.7	3.4	1175	2778	28.4
Blackgram						
T_1	18.1	7.0	4.4	1093	2905	25.7
T_2	23.2	7.8	4.4	1392	3411	29.0
T_3	20.6	7.5	4.6	1280	3378	27.5
Cowpea						
T_1	14.1	13.9	11.3	928	3705	21.1
T_2	18.2	14.4	12.6	1093	4026	23.7
T_3	16.8	14.3	11.6	1077	3962	21.3

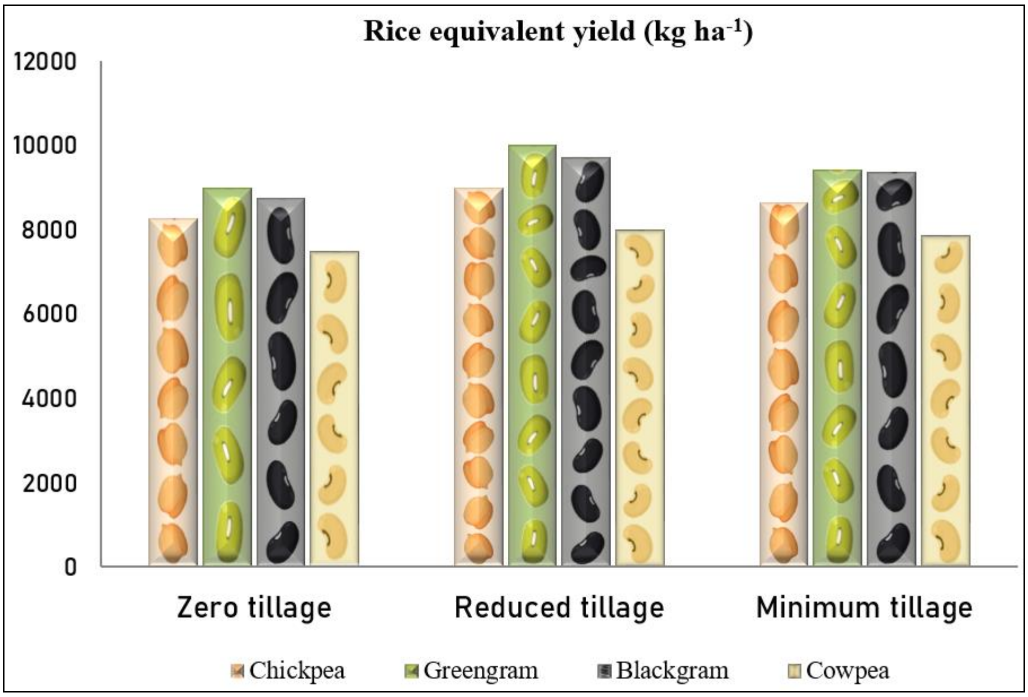

Fig 1: Rice equivalent yields (kg ha^{-1}) of *rabi* pulse crops under different tillage methods

Table 2: Rice equivalent yield (REY) of *rabi* pulse crops under different tillage methods

Treatment	REY (kg ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})	System profitability (Rs ha^{-1} day^{-1})
Main plots (Tillage practices)			
T_1: Zero tillage	8385	30.4	260
T_2: Reduced tillage	9059	32.9	292
T_3: Minimum tillage	8797	31.9	280
S.Em (±)	60.5	0.22	3.38
CD (p=0.05)	237.7	0.87	13.28
Sub plots (Rabi pulses)			
S_1: Chickpea	8571	30.1	261
S_2: Greengram	9427	35.6	318
S_3: Blackgram	9260	34.3	303
S_4: Cowpea	7730	27.1	227
S.Em (±)	77.4	0.29	4.33
CD (p=0.05)	230.1	0.85	12.85
Sub treatment at same level of main treatment			
S.Em (±)	134.1	0.50	7.49
CD (p=0.05)	NS	NS	NS
Main treatment at same level of sub treatment			
S.Em (±)	131.0	0.48	7.32
CD (p=0.05)	NS	NS	NS

4. Conclusion

Based on the research results of the present study it is clear that crops grown in reduced tillage performed very well and recorded maximum yield and yield attributes and cropping system indices. Reduced tillage has good potential to generate higher REY, profitability and production efficiency in mechanically harvested lowland rice over zero tillage. During *rabi* season rice fallows can be efficiently diversified with greengram due to their higher rice equivalent yield and profitability.

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