***Original Research Article***

# Studies on Machine and Operational Parameters Towards Development of Stubble Manager cum Crop Planter for Conservation Agriculture




## ABSTRACT

**Aims:** Optimization of machine parameters (type of flail blade and number of strip-till blades per flange) and operational parameters (rotor shaft speed and forward speed) for the development of stubble manager cum crop planter for conservation agriculture.
**Study design:** Split plot (3 factors); Type of flail blade/number of strip-till blades per flange as main plot and rotor shaft speed and forward speed as sub plots.
**Place and Duration of Study:** Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh, India. Duration of the study was from 2020 to 2022.
**Methodology:** Developed stubble manager cum crop planter as a solution for seeding of rice fallow pulse crops under combine harvested paddy field condition. This machine consists of two consists of stubble managing unit for mulching and strip tillage operations at a time and crop planting unit for placing pulse crop seed in furrow strips opened by stubble managing unit. The stubble managing unit was optimized for mulching parameters (shredding efficiency and paddy residue size reduction) and strip tillage parameters (furrow cross sectional area, furrow backfill and mass median diameter of soil clods) through field evaluation under combine harvested paddy field condition.
**Results:** Interactions between machine and operational parameters were not significant on shredding efficiency. Highest paddy residue size reduction (77.33 %) up to 10 cm was observed with Y-type flail blade at rotor shaft and forward speeds 1650 rpm and 2.5 km $h^{-1}$. Lowest furrow cross sectional area (20.93 $cm^2$) and highest furrow soil backfill (23.24 %) were obtained with two numbers of strip-till blades per flange at rotor shaft and forward speed 1350 rpm and 2.0 km $h^{-1}$ respectively. Interactions between machine and operational parameters were not significant on mass median diameter of soil clods.
**Conclusion:** Optimized parameters for the stubble managing unit of the proposed machine were Y-type flail blade, 2-numbers of strip-till blades per flange, rotor shaft speed 1500 rpm and forward speed 2.0 km $h^{-1}$.


*Keywords: Straw management, rice fallow pulse crop, mulching, strip tillage and conservation agriculture*

## 1. INTRODUCTION

Conservation agriculture (CA) is a method of managing agriculture ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment [1]. Minimum mechanical soil disturbance, organic soil cover and crop diversification are the three basic principles of CA [2]. Conservation tillage is any tillage system that leaves at least 30 % of the soil surface with crop residue after planting to reduce soil erosion [3]. Conservation tillage is the method of seedbed preparation that includes, leaving residue as mulch and an increase in surface roughness [4]. Conversion from conventional to conservation tillage, when this is done in line with the principles of CA, may improve soil structure, increase soil organic carbon, minimize soil erosion risks, conserve soil water, decrease fluctuations in soil temperature and enhance soil quality [1]. Retention of crop residue enhances soil biological activities as well as soil air and water movement. Developing techniques for effective utilization of vast crop residue is a major challenge. CA can be achieved through various conservation tillage practices viz., zero tillage (zero-till seed drill), or minimum tillage (strip-till seed drill or roto seed drill) both will result in minimal mechanical soil disturbance.

Mulching of crop residues on the field surface enhances soil water retention, suppresses weed growth, regulates the thermal regimes, and improves soil health, therefore, increasing crop productivity and saving of irrigation water [5]. Straw mulching and incorporation into the soil are the two best methods of managing paddy straw residues in the field without burning after harvesting of *Kharif* paddy crop. Both methods have tremendous effects on the soil's physical and chemical properties as well as increased yield over time. Mulched straw decomposes at a slower rate as compared to mixing into the soil. However, full incorporation has disadvantages of high costs and time consuming due to number of field operations involved: there is also immobilization of nitrogen by crop residues. Based upon the potential of these two available methods for in-situ paddy residue management (straw mulching and incorporation), and the benefits associated with adopting their practice, it was therefore necessary to introduce a machine that integrates both principles.

Blackgram (*Vigna mungo*) and greengram (*Vigna radiata*) are two important rice fallow pulse crops grow on residual soil moisture after harvesting of *Kharif* paddy crop in coastal districts of Andhra Pradesh, India. Andhra Pradesh state alone contributes about 1/5$^{th}$ of annual production of blackgram and greengram in India (4.104 million tonnes) [6]. The loose rice residues generated during combine harvesting may affect seeding operations for the subsequent rice fallow crops by using existing either zero-till or strip-till drill and it is an important problem faced by the farmers. Due to this reason, most of the farmers broadcast pulse crop seed 7-10 days before harvesting of *Kharif* paddy crop resulting poor seed to soil contact, low germination and non-uniform plant stand affecting yield of the crop. Thereby, a project on development of stubble manager cum crop planter was proposed as a solution for seeding of rice fallow pulse crops under combine harvested paddy field condition. As shown in the conceptual diagram Fig.1, stubble manager cum crop planter consists of two units viz., stubble managing unit and crop planting unit attached together by a frame. Stubble managing unit can do both mulching and strip tillage operations at a time and crop planting unit places pulse crop seed in furrow strips opened by stubble managing unit. The stubble managing unit was optimized for different machine and operational parameters for mulching and strip tillage operations through field evaluation under combine harvested paddy field condition.

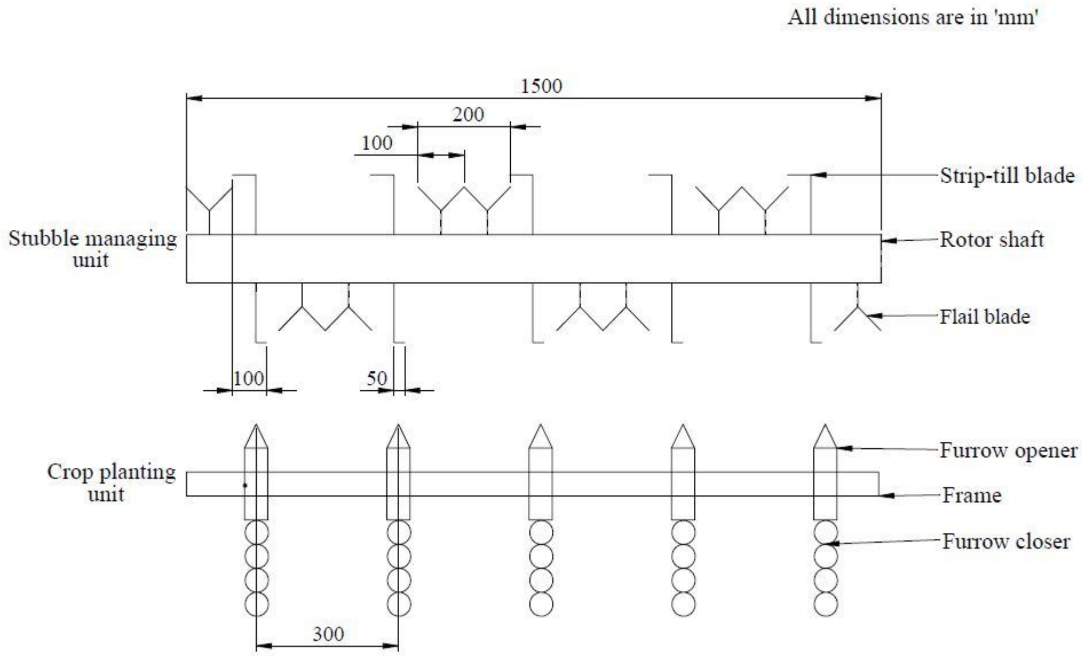


**Fig.1. Conceptual diagram of stubble manager cum crop planter (proposed machine)**

## 2. MATERIAL AND METHODS

### 2.1 Considerations for the Development of Stubble Managing Unit of the Proposed Machine

For the development of stubble managing unit of the proposed machine, existing tractor operated rotary mulcher (flail type straw chopper) was selected. Initially the rotary mulcher had flail blades around its rotor shaft for only mulching operation. Rotor shaft of the mulcher was modified so that it can hold strip-till blades for strip tillage operation in addition to flail blades as shown in Fig.4. A circular flange was used to fix strip-till blades on the rotor shaft of the mulcher. All the other components of the rotary mulcher were used as in the original condition. Therefore, proposed machine can do following operations in a single pass as shown in Fig.5.

(i) Shredding of paddy stubble/ loose straw and laying as a mulch on the surface of the soil.

(ii) Tilling narrow strips of soil at some depth and incorporation of paddy stubble/ loose straw in the tilled strip of soil.

As per recommendations from manufacturers and previous studies [7], the power requirement for paddy straw chopper was considered as 41 kW (55 HP). Therefore, power required for the proposed machine was considered as 41 kW (55 HP). The performance of flail type straw chopper was best at the rotary speed ranges between 750 to 1900 rpm [8]. Therefore, three rotor shaft speeds (1350, 1500 and 1650 rpm) and three forward speeds (2.0, 2.5 and 3.0 km $h^{-1}$) were selected for the optimization of performance of three types of flail blade (Y, H, and I) as shown in Fig. 2. L-type strip till blade configuration with 6 numbers per flange was optimized at low rotor shaft speed for the studies on development of the tractor operated strip-till drill [9]. Therefore, L-type strip-till blade (Fig. 3) was selected with varying no. of blades per flange (2, 4 and 6) for the studies on strip tillage. As both flail and strip-till blades were mounted the same rotor shaft of the stubble managing unit, same rotor and forward speeds selected for the flail blade were also used for the strip-till blade. The practice of strip-tillage aims to create narrow strips of seed bed furrows 50-200 mm wide by using rotary tiller [10] and [11]. Therefore, each strip-till blade set was arranged to open narrow strip of soil of 100 mm width and the soil between strip-till blades 200 mm width remains undisturbed and only 1/3rd of top soil was disturbed [12]. The undisturbed width of soil between strip-till blades was covered with shredded paddy stubble/straw (mulch) created by flail blade. The flail blade was operated above the ground level and the depth of operation of strip-till blade was selected as 30 mm to minimize soil disturbance, maintain soil cover with living or dead mulches. Therefore, the aim of conservation agriculture is not disturbed [13] and [12]. Detailed specifications of the flail and strip-till blades selected for the study and stubble managing unit are given in Table 1 and 2 respectively.

**(i) Inverted gamma blade - Y** **(ii) Hammer blade - H** **(iii) Straight blade - I**

**Fig. 2. Type of flail blades selected for the optimization**

**Fig. 3. L-type strip-till blade selected for the optimization**


**Fig. 4. Mounting of flail and strip-till blades on rotor shaft of stubble managing unit of the proposed machine**


**Fig. 5. Mulching cum strip tillage operation by stubble managing unit of the proposed machine**

**Table 1. Specifications of flail and strip-till blades selected for the optimization**

| S. No. | Parameter | Flail blade | | | Strip-till blade |
|---|---|---|---|---|---|
| | | Y-type | H-type | I-type | L-type |
| 1. | Height of blade, mm | 160 | 90 | 160 | 185 |
| 2. | Width of blade, mm | 130 | 130 | 100 | 40 |
| 3. | Breadth of blade, mm | 70 | 80 | 65 | 65 |
| 4. | Thickness of blade, mm | 6 | Variable | 6 | 6 |
| 5 | No. of components in the blade set | 3 | 1 | 5 | 2 |
| 8. | Effective cutting width of operation, mm | 200 | 200 | 200 | 90 |
| 9. | Weight of the blade set, kg | 1.495 | 1.469 | 2.119 | 1.284 |
| 10. | Material for the blade | Spring steel | Spring steel | Spring steel | Spring steel |

**Table 2. Specifications of the stubble managing unit of the proposed machine**

| S. No. | Particulars | Specifications |
|---|---|---|
| 1. | Working width | 1500 mm |
| 2. | Overall dimensions (length × width × height) | 2000 × 2000 × 1000 mm |
| 3. | Weight of the machine | 650 kg |
| 4. | Power requirement | 41 kW (55 HP) |
| 5. | Number of working elements for mulching | 10 |
| 6. | Type of flail blade | Y, I and H-type |
| 7. | No. of working elements for strip tillage | 10-30 (2-6 blades per flange) |
| 8. | Type of strip-till blade | L-type |
| 9. | No. of flanges | 5 |
| 10. | Flange diameter and thickness | 280 and 10 mm |
| 11. | Depth of operation of strip-till blade | 30 mm |
| 12. | Speed of rotor shaft | 1500 rpm |
| 13. | Rotor shaft diameter | 160 mm |
| 14. | Mode of power transmission to rotor | Belt and pulley |
| 15. | Centre distance between two strip-till blades | 300 mm |

## 2.2 Soil Parameters Measured During Experiments

Soil parameters viz., moisture content, bulk density and cone index were measured before evaluation of flail and strip-till blades of the stubble managing unit in the proposed machine. The results are shown in the Table 3. The average moisture content (db), bulk density and cone index of the soil were 24.94 %, 1.41 g $cm^{-3}$ and 22.80 kPa respectively. It was observed that, the coefficient of variation was less the 5 % for all the soil parameters. It showed that all the soil parameters are uniform across all the experimental plots.

**Table 3. Soil parameters in the experimental plot**

| S.No. | Parameter | Mean | SD | CV |
|---|---|---|---|---|
| 1 | Moisture content (db), % | 24.94 | 1.04 | 4.15 |
| 2 | Bulk density, g cm$^{-3}$ | 1.41 | 0.06 | 4.60 |
| 3 | Cone index, kPa | 22.80 | 0.83 | 3.65 |

## 2.3 Measurement of Effecting Parameters in the Optimization of Stubble Managing Unit of the Proposed Machine

For the optimization of performance of the stubble managing unit, parameters considered were shredding efficiency (%), paddy residue size reduction (%), furrow cross sectional area (cm$^2$), and furrow soil backfill (%). Detailed procedure for the measurement of these parameters is explained as below.

### 2.3.1 Shredding efficiency

The shredding efficiency is the percentage of amount of shredded paddy residue in the field after operation with respect to the paddy residue in the field before operation [14]. Here paddy residue means it includes both stubbles and loose straw. Average value of shredding efficiency per square meter was calculated at three random locations of the field as per the given formula below.

$$\eta_{se} = \frac{W_a}{W_b} \times 100$$

Where, $\eta_{se}$ = Shredding efficiency, %

$W_a$ = Weight of shredded paddy residue in the field after operation, g m$^{-2}$

$W_b$ = Weight of paddy residue in the field before operation, g

### 2.3.2 Paddy residue size reduction

Paddy residue after mulching operation was categorized into three different range of sizes viz., up to 10 cm, 10 to15 cm and above 15 cm [15]. Here paddy residue means it includes both stubbles and loose straw. To quantify paddy residue size reduction percentage, 100 nos. of shredded paddy residue pieces were collected in polythene bag from each plot at different locations. Tags were kept for each bag for identification. Then paddy residue pieces in each bag were differentiated for size by measuring straw length manually with the help of one meter measuring scale with an accuracy of 1 mm. Paddy residue size reduction percentage was calculated by using below formula.

$$\eta_{sr} = \frac{N_p}{N_T} \times 100$$

Where $\eta_{se}$ = Paddy residue size reduction, %

$N_p$ = Total no. of shredded paddy residue pieces in the selected size range

$N_T$ = Total no. of shredded paddy residue pieces selected

**2.3.3 Furrow cross sectional area**

Cross sectional area of furrow or tilled strip was calculated after strip-tillage operations. For this initially, a volume of randomly selected 25 cm long furrow sections were measured using the sand replacement method [16]. Well graded and air-dried coarse sand was used for these measurements. Average cross-sectional area of the tilled strip or furrow ($A_s$) was calculated by dividing volume of the selected section with the length of the section.

$$A_s = \frac{V_s}{L_s}$$

Where, $A_s$ = Cross sectional area of tilled strip or furrow

$V_s$ = Volume of soil required to fill 25 cm section of furrow

$L_s$ = Length of the furrow section i.e., 25 cm

**2.3.4 Furrow soil backfill**

Furrow backfill was measured as the volume of loosened soil retained within the furrow immediately after strip tillage operation [17]. All loose soil remaining in the furrow of 25 cm section was collected carefully by using a scoop and brush from three randomly selected locations of each plot. Then this soil was oven dried at 105$^0$C for 24 h and measures dried soil mass by using an electronic balance. A 100% backfill result by this method indicates the entire amount of soil originating from the furrow volume remained within the furrow boundaries during strip tillage. Percent furrow soil backfill was calculated by using below formula.

$$F_b = \frac{W_d}{V.\rho_s} \times 100$$

Where $W_d$ = Dry soil mass remaining in the furrow, g

$V$ = Volume of the tilled furrow section, $cm^3$

$\rho_s$ = Bulk density of the untilled soil, g $cm^{-3}$

#### 2.3.5 Mass median diameter of soil clods

Clod size distribution for soil after strip tillage operation was determined through sieve analysis as per the procedure by [18]. Sieve sizes of 4.75, 2, 1, 0.71, 0.5, 0.355, 0.25, 0.18, 0.15 mm and pan were used to conduct the experiment. The sieves were arranged in ascending order of sieve openings. The air-dried sample from the first treatment was kept on the top sieve and sieved manually for two minutes. The weight of the soil retained in each sieve was observed and tabulated. The same procedure was repeated for all the other treatments. From the sieve analysis, the cumulative percentage of soil passing through each sieve was determined. A curve was drawn between the cumulative percentage of soil passing through and the sieve size for each treatment. From the graph, the corresponding clod size at which 50 % of soil mass passing through gave the value of mass median diameter of soil clods.

### 2.4 Statistical Analysis

Data obtained was statistically analyzed by split plot 3-facorial design for the optimization of performance of the flail and strip-till blades of the stubble managing unit of the proposed machine. The experimental field was divided into three main plots in which three replications were allocated. Each of these main plots (type of flail blade/ no. of strip-till blades per flange) were split into three sub plots to assign three levels of rotor shaft speed and three levels of forward speed. Size of each plot was taken as 1.5 m × 20 m for conducting evaluation.

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of type of Flail Blade, Rotor shaft and Forwards Speeds on Mulching Parameters

The results and their analysis of effect of type of flail blade (F), rotor shaft speed (R) and forward speed (V) on the mulching parameters viz., shredding efficiency and paddy residue size reduction (up to 10 cm, 10-15 cm and above 15 cm) are given in Table 4 and 6 respectively.

**Table 4. Effect of types of flail blade, rotor shaft speed, and forward speed on mulching parameters**

| Treatment | Shredding efficiency, % | | | Paddy residue size reduction, % | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Up to 10 cm | | | 10-15 cm | | | Above 15 cm | | |
| | Y-blade | I-blade | H-blade | Y-blade | I-blade | H-blade | Y-blade | I-blade | H-blade | Y-blade | I-blade | H-blade |
| R1V1 | 79.69 | 60.12 | 68.02 | 71.33 | 47.33 | 58.00 | 12.00 | 39.00 | 21.67 | 16.67 | 13.67 | 20.33 |
| R1V2 | 77.92 | 58.06 | 67.07 | 68.00 | 44.33 | 55.67 | 14.67 | 41.00 | 19.00 | 17.33 | 14.67 | 25.33 |
| R1V3 | 76.79 | 57.11 | 66.30 | 63.33 | 40.67 | 53.33 | 17.00 | 42.67 | 17.67 | 19.67 | 16.67 | 29.00 |
| R2V1 | 83.94 | 63.19 | 72.65 | 76.00 | 51.33 | 61.33 | 11.33 | 37.33 | 23.33 | 12.67 | 11.33 | 15.33 |
| R2V2 | 82.52 | 61.11 | 71.07 | 73.00 | 48.33 | 56.67 | 13.67 | 40.00 | 20.33 | 13.33 | 11.67 | 23.00 |
| R2V3 | 81.60 | 59.04 | 69.44 | 69.33 | 44.00 | 56.00 | 15.00 | 43.33 | 19.00 | 15.67 | 12.67 | 25.00 |
| R3V1 | 86.35 | 65.14 | 74.46 | 77.33 | 53.67 | 63.00 | 11.00 | 35.33 | 26.00 | 11.67 | 11.00 | 11.00 |
| R3V2 | 84.52 | 64.09 | 73.03 | 74.00 | 49.67 | 60.67 | 13.67 | 38.67 | 25.67 | 13.00 | 11.67 | 13.67 |
| R3V3 | 83.14 | 62.79 | 71.53 | 70.67 | 44.67 | 57.33 | 15.33 | 41.00 | 23.67 | 14.00 | 14.33 | 19.00 |

Note: R1, R2 and R3 represent rotor shaft speed of 1350, 1500 and 1650 rpm respectively.
V1, V2 and V3 represent forward speed of 2.0, 2.5 and 3.0 km $h^{-1}$ respectively

**Table 5. Effect of no. of strip-till blades per flange, rotor shaft speed, and forward speeds on strip tillage parameters**

| Treatment | Furrow cross sectional area, $cm^2$ | | | Furrow soil backfill, % | | | Mass median diameter, mm | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2-blades | 4-blades | 6-blades | 2-blades | 4-blades | 6-blades | 2-blades | 4-blades | 6-blades |
| R1V1 | 20.93 | 22.27 | 23.07 | 23.24 | 19.90 | 14.85 | 0.283 | 0.283 | 0.284 |
| R1V2 | 21.20 | 22.67 | 23.33 | 22.66 | 18.79 | 13.06 | 0.282 | 0.286 | 0.278 |
| R1V3 | 21.33 | 22.80 | 23.73 | 22.54 | 18.15 | 12.61 | 0.282 | 0.285 | 0.280 |
| R2V1 | 21.47 | 23.33 | 24.13 | 22.55 | 17.65 | 12.45 | 0.278 | 0.280 | 0.285 |
| R2V2 | 21.60 | 23.73 | 24.40 | 22.29 | 17.11 | 12.21 | 0.278 | 0.276 | 0.283 |
| R2V3 | 22.13 | 24.00 | 24.53 | 21.81 | 16.35 | 11.57 | 0.278 | 0.284 | 0.282 |
| R3V1 | 22.53 | 24.13 | 24.93 | 20.59 | 14.92 | 10.78 | 0.283 | 0.285 | 0.285 |
| R3V2 | 23.07 | 24.13 | 25.07 | 20.12 | 14.12 | 10.35 | 0.282 | 0.283 | 0.277 |
| R3V3 | 23.33 | 24.40 | 25.20 | 19.77 | 13.11 | 9.94 | 0.279 | 0.274 | 0.277 |

Note: R1, R2 and R3 represent rotor shaft speed of 1350, 1500 and 1650 rpm respectively.
V1, V2 and V3 represent forward speed of 2.0, 2.5 and 3.0 km $h^{-1}$ respectively.

#### 3.1.1 Shredding efficiency

The results indicated that, all the individual parameters viz., F, R and V were having significant effect on the shredding efficiency at 1% level. Shredding efficiency was varied significantly with type of flail blade. Y-type flail blade had highest shredding efficiency followed by H-type and I-type flail blades. Similarly increase in rotor shaft speed increased shredding efficiency and increase in forward speed decreased shredding efficiency. Whereas all interactions between F & R, F & V, R & V, and F, R and V were not significant. It showed that, there was no significant change in shredding efficiency with increasing either rotor shaft speed or forward speed. Similar trend was observed for the studies on development of a machine for residue management of combine harvested paddy field [14]. Highest shredding efficiency was observed with Y-blade treatment R3V1 (86.35 %) followed by R2V1 (83.94 %) and least was observed in R1V1 (79.69 %).

**Table 6. Analysis of variance on effect of types of flail blade, rotor shaft speed, and forward speed on mulching parameters**

| Variables | Shredding efficiency, % | Paddy residue size reduction, % | | |
|---|---|---|---|---|
| | | Up to 10 cm | 10-15 cm | Above 15 cm |
| **Type of flail blade** | | | | |
| Y-blade | $81.83^{a}$ | $71.44^{a}$ | $13.74^{c}$ | $14.89^{b}$ |
| I-blade | $61.18^{c}$ | $47.11^{c}$ | $39.82^{a}$ | $13.07^{b}$ |
| H-blade | $70.40^{b}$ | $58.00^{b}$ | $21.82^{b}$ | $20.19^{a}$ |
| **Rotor shaft speed, rpm** | | | | |
| 1350 | 67.90 | $55.78^{b}$ | $24.96^{a}$ | $19.26^{a}$ |
| 1500 | 71.62 | $59.56^{a}$ | $24.82^{a}$ | $15.63^{b}$ |
| 1650 | 73.89 | $61.22^{a}$ | $25.59^{a}$ | $13.26^{c}$ |
| **Forward speed, km $h^{-1}$** | | | | |
| 2.0 | 72.62 | $62.15^{a}$ | $24.11^{b}$ | $13.74^{c}$ |
| 2.5 | 71.04 | $58.93^{b}$ | $25.19^{ab}$ | $15.96^{b}$ |
| 3.0 | 69.75 | $55.48^{c}$ | $26.07^{a}$ | $18.44^{a}$ |
| **Source of variation** | | | | |
| Type of flail blade (F) | 0.00** | 0.00** | 0.00** | 0.00** |
| Rotor shaft speed (R) | 0.00** | 0.00** | 0.01* | 0.00** |
| Forward speed (V) | 0.00** | 0.00** | 0.00** | 0.00** |
| Interaction F X R | 0.08 | 0.01* | 0.00** | 0.00** |
| Interaction F X V | 0.90 | 0.01* | 0.00** | 0.00** |
| Interaction R X V | 0.82 | 0.64 | 0.29 | 0.44 |
| Interaction F X R X V | 0.86 | 0.35 | 0.36 | 0.10 |

Note: ** <0.01 represents significant value at 1% level and * < 0.05 represents significant value at 5 % level. Superscripts with same letter were not significantly different.

### 3.1.2 Paddy residue size reduction

*3.1.2.1 Up to 10 cm*

The results indicated that, all the individual parameters viz., F, R and V were having significant effect at 1 % level. Highest mean percentage of paddy residue size reduction up to 10 cm was observed with Y-blade (81.83 %). Interactions between F & R and F & V were having significant effect at 5 % level on percentage of paddy residue size reduction up to 10 cm. Highest mean percentage of paddy residue size reduction up to 10 cm was observed with rotor shaft speed R3 (73.89 %) rpm followed by R2 (71.62 %) and both these were on par with each other. Highest mean percentage of paddy residue size reduction up to 10 cm was observed with forward speed V1 (62.15 %). Whereas interactions between R & V and F, R & V were not significant. Chopped paddy residue of size up to 10 cm do not cause any problem in subsequent tillage and sowing operation and small straw size might decompose quickly [15]. Also, Performance of the strip-till drill was satisfactory under the combine harvested paddy field which was initially chopped by a stubble harvester cum chopper at forward speed 2.0-2.5 km $h^{-1}$ and rotor shaft speed 1500 rpm where the straw size reduction percentage was varied between 76.24 – 84.07 % (up to 10 cm) [19]. As fuel consumption is increased with increase in rotor shaft speed, treatment R2V1 with Y-blade was selected to have maximum percentage of paddy residue size reduction (76 %) up to 10 cm.

*3.1.2.2 10-15 cm*

The results indicated that, F, V and interactions of F & R and F & V were having significant effect at 1 % level and R was having significant effect at 5 % level on percentage of paddy residue size reduction (10-15 cm). It was observed that, least mean percentage of paddy residue size reduction (10-15 cm) was observed at rotor shaft speed R3 (24.96 %) followed by R2 (24.82 %) and R1 (25.59 %) with Y-type flail blade and all these were on par with each other. It was found that, least mean percentage of paddy residue size (10-15 cm) was obtained at forward speed V1 (24.11) with Y-type flail blade. Therefore, treatment R2V1 with Y-blade was selected to have least percentage of paddy residue size reduction (10-15 cm).

*3.1.2.3 Above15 cm*

The results indicated that, F, V & R and interactions of F & R and F & V were having significant effect at 1 % level on percentage of paddy residue size reduction (above 15 cm). Whereas interactions between R & V and F, R & V were not significant. As paddy residue size of 15 cm was not desirable, the effect of type of flail blade, rotor shaft speed and forward speed on paddy residue size of above 15 cm was not taken into the consideration for the optimization.

**Table 7: Analysis of variance on effect of no. of strip-till blades per flange, rotor shaft speed, and forward speeds on strip tillage parameters**

| Variables | Furrow cross sectional area, $cm^2$ | Furrow soil backfill, % | Mass median diameter, mm |
|---|---|---|---|
| No. of strip-till blades per flange | | | |
| 2-blades | $21.96^c$ | $21.73^a$ | 0.281 |
| 4-blades | $23.50^b$ | $16.68^b$ | 0.282 |
| 6-blades | $24.27^a$ | $11.98^c$ | 0.281 |
| Rotor shaft speed, rpm | | | |
| 1350 | $22.37^a$ | $18.42^a$ | 0.282 |
| 1500 | $23.26^b$ | $17.11^b$ | 0.281 |
| 1650 | $24.09^c$ | $14.86^c$ | 0.281 |
| Forward speed, km $h^{-1}$ | | | |
| 2.0 | 22.98 | 17.44 | 0.283 |
| 2.5 | 23.24 | 16.75 | 0.281 |
| 3.0 | 23.50 | 16.21 | 0.280 |
| Source of variation | | | |
| Number of strip-till blades per flange (S) | 0.00** | 0.00** | 0.57 |
| Rotor shaft speed (R) | 0.00** | 0.00** | 0.25 |
| Forward speed (V) | 0.00** | 0.00** | 0.05 |
| Interaction S X R | 0.04* | 0.00** | 0.09 |
| Interaction S X V | 0.95 | 0.15 | 0.56 |
| Interaction R X V | 0.97 | 0.17 | 0.07 |
| Interaction S X R X V | 0.88 | 0.63 | 0.34 |

Note: ** <0.01 represents significant value at 1% level and * < 0.05 represents significant value at 5 % level. Superscripts with same letter were not significantly different.

## 3.2 Effect of no. of strip-till blades per flange, Rotor shaft and Forwards Speeds on Strip Tillage Parameters

The results and analysis of effect of no. of strip-till blades per flange (S), rotor shaft speed (R) and forward speed (V) on the tillage parameters viz., furrow cross sectional area, furrow soil backfill and mass median diameter of soil clods are given in Table 5 and 7 respectively.

### 3.2.1 Furrow cross sectional area

The results indicated that, S and R were having significant effect at 1 % level and V and interaction of S & R were having significant effect at 5 % level on furrow cross sectional area. Whereas interactions between S & V, R & V and S, R & V were not significant. It was found that, lowest mean furrow cross sectional area 21.96 $cm^2$ was obtained with 2 nos. of strip-till blades per flange. Lowest mean furrow cross sectional area was obtained at R1

(22.37 cm$^2$) followed by R2 (23.26 cm$^2$). Higher rotary speeds resulted greater furrow cross sectional areas throwing more soil out of the furrow affecting seed emergence in the studies on modified strip tillage blades for two-wheel tractors for maize crop establishment under conservation agriculture [17]. There was no significant change in furrow cross sectional area with increase in forward speed. As both flail and strip-till blades were mounted on the same rotor shaft. the blade configuration of 2 nos. of strip-till blades per flange with rotor shaft speed1500 rpm and forward speed 2.0 km h$^{-1}$ (R2V1) was selected to get furrow cross sectional area 21.47 cm$^2$.

**3.2.2 Furrow soil backfill**

The results indicated that, S, R and V were having significant effect at 1 % level and interaction of S & R was having significant effect at 5 % level on furrow soil backfill. Whereas interactions between S & V, R & V and S, R & V were not significant. It was found that, highest mean furrow soil backfill 21.73 % was obtained with 2 nos. of strip-till blades per flange. Highest mean furrow soil backfill was obtained at R1 (18.42 %) followed by R2 (17.11 %). A high furrow soil backfill is desired to adequately cover seeds to ensure seed emergence and reduce the risk of bird damage [17]. There was no significant change in furrow soil backfill with increase in forward speed. As both flail and strip-till blades were mounted on the same rotor shaft. the blade configuration of 2 nos. of strip-till blades per flange with rotor shaft speed1500 rpm and forward speed 2.0 km h$^{-1}$ (R2V1) was selected to get furrow soil backfill 22.55 %.

**3.2.3 Mass median diameter of soil clods**

The results indicated that interaction of S and R was having significant effect at 5 % level on mass median diameter of soil clods. Whereas S, R, V and interactions of S & V and R & V and were not significant. It was observed that, there was no significant effect of no. of blades per flange, rotor shaft and forward speeds on the mass median diameter of soil clods. The mass median diameter was varied between 0.274-0.283 mm for all the treatment combinations. As maximum breakage of soil clods after strip-tillage operation might be taken at rotor shaft speed 1350 rpm and forward speed 2.0 km h$^{-1}$ itself, further significant change in mass median diameter was not observed with increase in either rotor shaft speed or forward speed. As both flail and strip-till blades were mounted on the same rotor shaft, a blade configuration of 2 nos. of strip-till blades per flange with rotor shaft speed 1500 rpm and forward speed 2.0 km h$^{-1}$ (R2V1) was selected to get mass median diameter 0.278 mm.

## 4. CONCLUSION

The stubble managing unit developed for simultaneous mulching and strip tillage operation worked satisfactorily under combine harvested paddy field conditions with Y-type flail blade, two nos. of strip-till blades per flange, rotor shaft speed 1500 rpm and forward speed 2.0 km $h^{-1}$. Further, a crop planting unit could be attached to stubble managing unit for sowing of rice fallow pulse crop in the tilled furrow strips.

## REFERENCES


1. Busari MA, Kukal, SS, Kaur, A, Bhatt R, Dulazi, AA. Conservation tillage impacts on soil, crop, and the environment. International Soil and Conservation Research. 2015; Accessed 21 August 2019. Available: http://dx.doi.org/10.1016/j.iswer.2015.05.002
2. Corsi S, Friedrich T, Kassam A, Pisante M, Moraes JC. Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: A literature review. Integrated crop management. 2012;16:101.
3. Conservation Tillage Information Center (CTIC). 2004. National crop residue management survey. West Lafayette, IN: Conservation Technology Information Center; 2004.
4. Lal R. Soil erosion in the tropics: Principles and management. McGraw-Hill, New York; 1990.
5. Singh Y, Singh M, Sidhu HS, Khanna PK, Kapoor S, Jain AK, Sidhu GK, Singh SK., Singh A, Chaudhary DP, Minhas PS. Options for effective utilization of crop residues. Tech Bull 3/2010. Directorate of Research, Punjab Agricultural University, Ludhiana. 2010;1-32.
6. ANGRAU Greengram Outlook Report-January to December. Acharya N.G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh; 2021.
7. Ramulu Ch, Pateriya, RN, Azad Deepshika. 2018. Machinery for residue management of different crops: A review. Journal of Pharmacognosy and Phytochemistry. 2018;7(6):2203-2207.
8. Garg IK. Design and development of tractor operated paddy straw chopper cum spreader. Journal of Punjab Agricultural University. 2004;41(1):130-138.
9. Reddy JS. Investigation on the effect of soil machine and operational parameters towards the development of rotary strip till drill. Ph.D. Thesis. TNAU. Coimbatore. 2010; *(In press)*.

10. Yanshan Yang, John Fielke, Qishuo Ding, Ruiyin He. Field experimental study on optimal design of the rotary strip-till tools applied in rice-wheat rotation cropping system. Int. J. Agric & Biol. Eng. 2018;11 (2):88-94.
11. FAO. The Economics of Conservation Agriculture. 2010; Accessed 14 July 2020. Available: http://ftp.fao.or g/agl/agll/docs/ecconsagr.pdf
12. Chaosu Li, Yonglu Tang, Allen D, McHugh, Xiaoli Wu, Miao Liu, Ming Li, Tao Xiong, Dong Ling, Qing Tang, Min Liao, Shizhou Du, Jie Zhu, Yan Huang. Development and performance evaluation of a wet resistant strip-till seeder for sowing wheat following rice. Biosystems Engineering. 2022;220:146-158.
13. Gathala, MK, Timsina J, Islam MS, Krupnik TJ, Bose, TR, Islam N, Rahman, MM, Hossain MI, Harun AR, Rashid, Ghosh AK, Hasan MMK, Khayer MA, Islam MZ, Tiwari TP, McDonald AJ. Productivity, profitability, and energetics: a multi-criteria and multi-location assessment of farmers tillage and crop establishment options in intensively cultivated environments of South Asia. Field Crop. Res. 2016;186:32–46.
14. Ramulu Ch. Development of a machine for residue management of combine harvested paddy field. Ph.D. Thesis. G.B. Pant University of Agriculture and Technology, Pantnagar. 2020; *(In press)*.
15. Singh A, Dhaliwal IS, Dixit A. Performance evaluation of tractor mounted straw chopper cum spreader for paddy straw management. Indian J. Agric. Res. 2011;45(1): 21-29.
16. Matin AMd, Fielke MJ, Desbiolles AMJ. Furrow parameters in rotary strip-tillage: Effect of blade geometry and rotary speed. Biosystems Engineering. 2014;118:7-15.
17. Hoque AM, Gathala KM, Hossain MMd, Ziauddin, MTA, Krupnik JT. Modified strip tillage blades for two-wheel tractor seed drills improves maize crop establishment under conservation agriculture. Development Engineering. 2021;6:100061.
18. Punmia BC, Jain AK, Jain AK. Soil Mechanics and Foundations. Laxmi Publications, New Delhi. 2005;44.
19. Thakur SS, Garg IK. Paddy Straw Management by Chopping for Sowing Wheat in. Combine Harvested Field. J. Res. Punjab Agric. Univ. 2007;44 (3):243-248.