SHREDDING EFFICIENCY OF AGRICULTURAL CROP SHREDDER AS INFLUENCED BY FORWARD SPEED OF OPERATION, NUMBER OF BLADES AND PERIPHERAL VELOCITY

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ABSTRACT

In India, annually 500 million tons of crop residues are produced, out of which 81-141 million tons of residues are burned in the field. Burning of crop residues, which causes environmental pollution as well as loss of plant nutrients like N, P, K and S. Therefore, appropriate management of crop residues assumes a great significance. Shredders are used widely and their performance study is an important factor for wide scale adoption. Hence, the present investigation was taken up to assess the shredding efficiency of agricultural crop shredders as influenced by operational parameters. A total number of 81 field experiments were conducted in cotton field. The influence of the selected level of variability of three levels of operational speed (viz. 2, 3 and 5 km hr⁻¹), three levels of peripheral velocity (viz. 18.75, 24.27 and 27.80 m s⁻¹) and three levels of number of blades (viz. 2, 4 and 6) on the shredding efficiency of an experimental shredder, in terms of length of cut of the stalk were investigated. Increase in peripheral velocity from 18.75 to 27.80 m s⁻¹, number of blades from 2 to 6 and reducing the forward speed of operation from 5 to 2 km hr⁻¹ resulted in decreased length of cut. Six numbers of blades with 2 km hr⁻¹ forward speed of operation and 27.80 m s⁻¹ peripheral velocity recorded the lowest value of length of cut at the highest per cent in selected different scale level L₁= 18.30, L₂=23.66, L₃=30. 98, L₄= 22.09 and L₅= 4.97 per cent respectively.

Key words: Number of blades, Forward speed, Peripheral velocity, Shredding efficiency.

1. INTRODUCTION

The annual production of crop residues approximately is 500 Mt in India (MNRE, 2009). There is a large variability in crop residues generation and their use, depending on the cropping intensity, productivity and crops grown in different states of India. The amount of crop residue, which does not have any identifiable end use is either left in the fields to rot or is burnt away, is termed as Surplus Biomass. The estimated total crop residue surplus in India is 84-141 Mt yr⁻¹, where cereals and fiber crops contribute 58 per cent and 23 per cent, respectively. Remaining 19 per cent is from sugarcane, pulses, oilseeds and other crops (Management of Crop Residue NAAS, India). Burning of crop residues causes environmental pollution which is hazardous to human health and also produces greenhouse gases causing global warming and results in loss of plant nutrients like N, P, K and S adverse impacts on soil properties and wastage of valuable crop residues. The root sections decompose slower than other plant parts and the equipment for disposal of cotton residue should include provision for reducing it to a length of 8 to 15 cm and burying it in depth of 10 cm (Cowlick et al., 1971). The crop residues improve the soil fertility by improving nutrient availability and enriching the organic matter content of soil. Sorghum stubble incorporation in the soil added 6.06 kg ha⁻¹ of N, 2.6 kg ha⁻¹ of P and 9.5 kg ha⁻¹ of K (Shanmugasundaram et al., 1975). In India, crop residues are removed by manual uprooting or cutting the stalks which is highly labor intensive. Shredders are mostly suggested for shredding the crop residues and their performance study is an important factor for wide scale adoption. Hence, the type of shredding mechanism should be selected based on the efficiency in terms of finished dimensions of the stalk required for incorporation in the soil to facilitate quick decomposition. A rotary cutter is an implement in the mechanization chain of crop production. After harvesting the crop, these machines cut the stalk and distribute them on the field surface. The rotary cutter consists of blades pivoted horizontally on a vertical shaft and moves forward on the field. They are simple and sturdy in construction, with less wearing parts and, therefore, the frictional power loss is minimized (Guzel and Zeren, 1990).
Hence, a study to assess the performance of shredders was contemplated. Keeping the above facts in view, the present investigation entitled “To assess the shredding efficiency of shredders as influenced by operational parameters” was taken up with following specific objectives.

- To identify the influence of selected variable on shredding efficiency.
- To optimize the selected variable for suggesting the future development of the new unit.

2. MATERIALS AND METHODS

The efficiency of a shredder is the ability to cut the crops/straw/stalk into very small pieces. The shredder performance depends mainly on the number of rotating blades, peripheral velocity, and forward speed of operation.

2.1. Selected level of variables on length of cut

In the field test, the effect of peripheral velocity of rotary impact cutter blade, forward speed operation and the number of blades on length of cut of crop stem at different scale levels was investigated. For achieving maximum shredding efficiencies of crop stalk the following variables were selected for the investigation.

i. Peripheral velocity (V)

   - Forward speed of operation (S)
   - Number of blades (N)

2.1.1. Peripheral velocity (V)

The quality of the cut crop stem is highly influenced by the peripheral velocity of the blade. Peripheral velocity of the blade is an important parameter in cutting and shredding operation. The rotary cutter is an implement in the mechanization chain of cotton production. After harvesting the cotton, these machines cut the cotton stalk and distribute them on the field surface. The evaluation of rotary cutters with the peripheral velocity of the blade ranged between 800 to 1000 rpm was done by Guzel and Zeren, 1990. Hence, peripheral velocity of cutter blade of shredder viz., 18.75, 24.27 and 27.80 ms\(^{-1}\) was selected for the investigation.

2.1.2. Forward speed of operation (S)

The efficiency of the machines depends upon the removed plant, plant condition (density and moisture content), machine type and forward speed. The field efficiency decreases by increasing forward speed, so the field efficiency is the ratio of the productivity of machine under field conditions to the theoretical maximum productivity. The shredder machine is recommended to be used in removing residues of both cotton and sunflower stalks, while a self-propelled harvester is recommended in removing rice straw. The shredder machine was recommended for removing residues of corn stalks at forward speeds between 2 to 4 km h\(^{-1}\) and similarly 3 to 5 km h\(^{-1}\) forward speed was recommended for self-propelled harvester for removing barley straw (Eltarhunyl .M.M. and Fouda, 2007). Hence, three levels of forward speed of operation viz., 2, 3 and 5 km h\(^{-1}\) were selected for the investigation.

2.1.3. Number of blades

The length of cut of crop stem is highly influenced by a number of blades in the shredder unit. Number of blades is also one of the important parameters in cutting and shredding operation. Hence, number of cutter blade of shredder viz., 2, 4, 6 were selected for the investigation.

2.2. Field experiments

A total number of 81 experiments were conducted in a cotton field in the department of cotton, TNAU, Coimbatore with selected level variables as shown in Plate 2.1.
After the completion of shredding, the sample was collected randomly from the field. The collected samples were analyzed several times to separate shredding crop residues into five categories by scale (referred to Luis et al. 1993) according to their length of cut off the stem (\( L_1 = 0 - 5 \) cm, \( L_2 = 5 - 10 \) cm, \( L_3 = 10 - 15 \) cm, \( L_4 = 15 - 20 \) cm, \( L_5 = >20 \) cm) as shown in Plate 2.2.
The values of finished dimensions of cotton stalks in terms of length of cut were recorded for all treatments. The effect of selected levels of variables on finishing dimensions of the cotton stalk in terms of length of cut was analyzed.
3. RESULTS AND DISCUSSION

In this chapter, the effect of peripheral velocity of the rotary cutter blade, forward speed of operation and number of blades on length of cut of crop stem by using different scale level is presented. The optimization of the selected variables for achieving the best performance of crop stem shredding in terms of minimum length of cut of crop stem with impact type rotary cutter shredder is presented.

3.1. Effects of selected variables on length of cut

The influence of selected level of variables on length of cut of agricultural crop stems with impact type rotary cutter shredders is discussed below.

3.1.1. Effect of peripheral velocity (V) on length of cut at 2 (N₁) number of blade with different forward speed of operation (S)

The relationship between the length of cut and the peripheral velocity for the 2 number of blades with different levels of forward speed of operation is depicted in Fig. 3.1.

**Forward speed of operation 2 km h⁻¹**

![Bar chart showing the effect of peripheral velocity on length of cut at 2 blades with different forward speeds.]

**Forward speed of operation 3 km h⁻¹**

![Bar chart showing the effect of peripheral velocity on length of cut at 2 blades with different forward speeds.]

Forward speed of operation 5 km h\(^{-1}\)

Fig.3.1 Effect of peripheral velocity (V) on length of cut at 2 (N\(_1\)) number of blade with different forward speed of operation (S)

An increase in peripheral velocity from 18.75 to 27.80 ms\(^{-1}\) resulted in decreased length of cut. It is evident that at lower peripheral velocity, the length of cut of cotton stems decreases. This might be due to fact that at lower peripheral velocity of rotary cutter blade, the impact of blade was too less to fail the stem cutting and hence energy requirement is increased. At higher velocities, the increase in the cutting energy may be owing to the kinetic energy imparted by the cutter blade to the separate parts of the stem after cutting (Yiliep et al., 2005; Prasad and Gupta, 1975 Manjeet Singh et al., 1998; T.Senthilkumar et al., 2004). The lowest value of length of cut was observed at the shredder with 2 (N\(_1\)) numbers of blades, 2 km h\(^{-1}\) forward speed of operation and 27.800 ms\(^{-1}\) (V3) peripheral velocity.

3.1.2. Effect of peripheral velocity (V) on length of cut at 4 (N\(_2\)) number of blade with different forward speed of operation (S)

The effect of peripheral velocity (V) of cutter blade on length of cut at 2 (S\(_1\)), 3 (S\(_2\)) and 5 (S\(_3\)) kmh\(^{-1}\) forward speed of operation with 4 number of blades in cotton crop field is shown in Fig 3.2

The trend of increase in peripheral velocity from V\(_1\) to V\(_3\) resulted in decreased length of cut at varies scale level (L\(_1\) to L\(_5\)) with different operational speed at 2 (S\(_1\)), 3 (S\(_2\)) and 5 kmh\(^{-1}\) respectively.

Forward speed of operation 2 km h\(^{-1}\)
Forward speed of operation 3 km h\(^{-1}\)

![Graph showing the effect of peripheral velocity on length of cut at different scale levels.]

Forward speed of operation 5 km h\(^{-1}\)

![Graph showing the effect of peripheral velocity on length of cut at different scale levels.]

**Figure 3.2** Effect of peripheral velocity (V) on length of cut at 4 (N\(_2\)) number of blade with different forward speed of operation (S)

3.1.3. Effect of peripheral velocity (V) on length of cut at 6 (N\(_2\)) number of blade with different forward speed of operation (S)

An increase in peripheral velocity from 18.75 to 27.80 ms\(^{-1}\) resulted in decreased length of cut. The above result was in conformity with the findings of Manjeet Singh et al., (1998). The lowest value of length of cut at the highest per cent in selected different scale level L\(_1\)= 18.30, L\(_2\)=23.66, L\(_3\)=30.98, L\(_4\)= 22.09 and L\(_5\)= 4.97 per cent, respectively occurs with 6 numbers of blades, 2 km h\(^{-1}\) forward speed of operation and 27.80 ms\(^{-1}\) peripheral velocity as shown in **Fig. 3.3**

A 6 number of blade with 2 km hr\(^{-1}\) forward speed of operation and V\(_3\) level of peripheral velocity combination recorded lowest value of length of cut when compared with other combinations. In the case of number of blades, 6 blades with S\(_1\) operating speed and 27.80 ms\(^{-1}\) peripheral velocity recorded lowest value of length of cut. Increase in number of blade with reduction of operating speed resulted in increased length of cut for all the levels of peripheral velocity.

3.2 Optimization of levels of variables with experimental agricultural crop shredder

The selected levels of variables were optimized for achieving the best performance of cutter blade in terms of minimum length of cut at all selected levels of scale.

The treatment combination of S\(_1\)N\(_2\)V\(_3\) yielded the minimum length of cut shredded crop stem at maximum per cent in all levels of scale was L\(_1\)= 18.30, L\(_2\)=23.66, L\(_3\)=30.98, L\(_4\)= 22.09 and L\(_5\)= 4.97 per cent respectively.
Forward speed of operation $2 \text{ km h}^{-1}$

![Bar chart showing effect of peripheral velocity on length of cut at 6 (N) number of blade with different forward speed of operation (S)].

Forward speed of operation $3 \text{ km h}^{-1}$

![Bar chart showing effect of peripheral velocity on length of cut at 6 (N) number of blade with different forward speed of operation (S)].

Forward speed of operation $5 \text{ km h}^{-1}$

![Bar chart showing effect of peripheral velocity on length of cut at 6 (N) number of blade with different forward speed of operation (S)].

Figure 3.3 Effect of peripheral velocity ($V$) on length of cut at 6 (N) number of blade with different forward speed of operation ($S$)
4. CONCLUSION

Increase in peripheral velocity and number of blades from 18.75 to 27.80 ms\(^{-1}\), 2 to 6 and reducing forward speed of operation from 5 to 2 km h\(^{-1}\) resulted in decreased length of cut. The lowest value of length of cut of stem at high percentage in different scale level was \(L_1=18.30, L_2=23.66, L_3=30.98, L_4=22.09\) and \(L_5=4.97\) per cent was observed in the shredder with 6 number of blades, 2 km h\(^{-1}\) operational speed and 28.60 ms\(^{-1}\) peripheral velocity.

REFERENCES


