Biological Forum – An International Journal **14(1): 1803-1812(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Performance Evaluation of Cotton Stalk Harvesting Machine for *ex-situ* Application

Er. Ch. Sravan Kumar[1*], K.V. Praksah[2], B. Sanjeeva Reddy[3], Sushilendra[4], P Vijay Kumar[2], Krishanmurthy[5] and Nemichandrappa[6]

[1]Ph.D. Scholar, College of Agricultural Engineering, U.A.S. Raichur (Karnataka), India.
[2]Associate Professor, Department of Renewable Energy,
College of Agricultural Engineering, U.A.S. Raichur (Karnataka), India.
[3]Principal Scientist, Department of Farm Machinery and Power,
CRIDA Hyderabad (Telangana), India.
[4]Associate Professor, Department of Farm Machinery and Power,
College of Agricultural Engineering, U.A.S. Raichur (Karnataka), India.
[5]Assistant Professor, Department of Agronomy, U.A.S. Raichur (Karnataka) India.
[6]Professor, Department of Soil and Water Conservation,
College of Agricultural Engineering, U.A.S. Raichur (Karnataka), India.

(Corresponding author: Er. Ch. Sravan Kumar)*
(Received 15 December 2021, Accepted 26 February, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Cotton (*Gossypium hirsutum*) is an important commercial crop in India. Annually 30.79 million tons of cotton stalk residue is being generated in India. In India, after harvesting cotton lint, cotton stalks are removed by either manual uprooting or cutting them using sickle above the ground level, which is a laborious operation and contributes to increase in crop production. After removing cotton stalks from field, farmers are burning cotton stalks in their fields. Burning of stalks increases CO_2, CO, N_2O and NOx in the atmosphere which leads to increase in air pollution. In India, crop residues are removed by manual uprooting or cutting the stalks which is high labour intensive and contributes towards high cost of crop production. Instead of burning the stalks in fields, cotton stalks have the potential to be used for ex-situ application such as, raw material for briquettes due to its high lingo cellulosic nature. Ex-situ utilization cotton stalk aids in generating additional income to farmers. In order to utilize the cotton stalk for ex-situ application a cotton stalk harvester was developed and evaluated in the field conditions. The developed cotton stalk harvesting machine was evaluated for 3 forward speeds *viz*., 2, 3 and 4 km h^{-1}. Operation at 2 km h^{-1} gave the better result with mean chopped length of 112.8 mm, fineness modulus of 1.706, bulk density of 215.33 kgm^{-3} machine output was recorded as 1379.63 kgh^{-1} chopping height was recorded as 88 mm and fuel consumption of 6.8 lh^{-1}.

Keywords: Fineness modulus, Bulk density, machine output, chopping height.

INTRODUCTION

Cotton (*Gossypium herbaceum*) commonly is the import cash crop in India. In India the annual production of crop residue is approximately 500 Mt. The majority of it is used for fodder, raw material for energy production etc., still there is a huge surplus of 140 Mt out of which 92 Mt is burnt every year (Bhuvaneshwari *et al*., 2019). Especially small-scale farmers resort to burning of crop residues, as it is an inexpensive alternative due to the lack of technological awareness and lack of proper disposal opportunities. Burning of crop residues in large scale increases CO_2, CO, N_2O and NO_X in the atmosphere and has led to shocking increase in air pollution (Bhuvaneshwari *et al*., 2019). The biomass left in the field after picking seed cotton is called cotton stalks. One of the approaches that is being actively pursued worldwide towards improved and efficient utilization of agricultural and other biomass residues is their densification in order to produce pellets or briquettes. The briquetting of biomass improves its handling characteristics, increases the volumetric calorific value, reduces transportation costs and makes it available for a variety of applications. Cotton stalks contains about 46 % of alpha cellulose and 26 % lignin (Jha *et al*., 2008). Because of its lignocellulosic nature cotton stalks have the potential to be used as raw material for briquetting. If cotton stalks are left in the field, it serves as an overwintering site for insects such as the pink bollworm, in addition to the residue has little value as a soil amendment, and tillage operations which bury the residue have high energy requirements and often degrade soil structure. In India, cotton stalks are removed by manual uprooting or cutting the stalks which is high labour intensive and contributes towards high cost of crop production. A suitable tractor operated cotton harvesting machine is a promising solution for the farming community. The labor-intensive operation could be replaced with the suitable design of cottonstalk harvesting machine. Keeping the above points in view it is imperative that, for effective utilization of cotton stalks, the cotton stalks should be harvested using appropriate machines, shredded to alter bulk density for easy transportation to application point. Hence, an attempt has been made to developand evaluate a tractor operated cotton stalk harvesting machine for ex-situ application.

MATERIALS AND METHODS

The performance of tractor operated cotton stalk harvesting machine (Fig. 1) was evaluated at Bhurjgaddathanda village, at three different forward speeds *viz*., 2 kmh^{-1}, 3 kmh^{-1} and 4 kmh^{-1}. Each forward speed was replicated 8 times in a plot size of 15 × 25 m. The parameters such as chopping height, bulk density, fineness modulus, mean chopped length machine output, fuel consumption, effective field capacity was recorded during the field tests (as given below). As there is no specific test code available for testing of tractor operated cotton stalk harvesting machine, the pertinent parameters relevant to machine performance determination are measured (Plate 1). The machine field performance was evaluated in a Cotton field planted at 75–90 cm row to row and 30-45 cm intra row spacing in a red soil. The cotton variety is Sadananda BG II. The results were statistically analysed by one factor ANOVA using Opstat software.

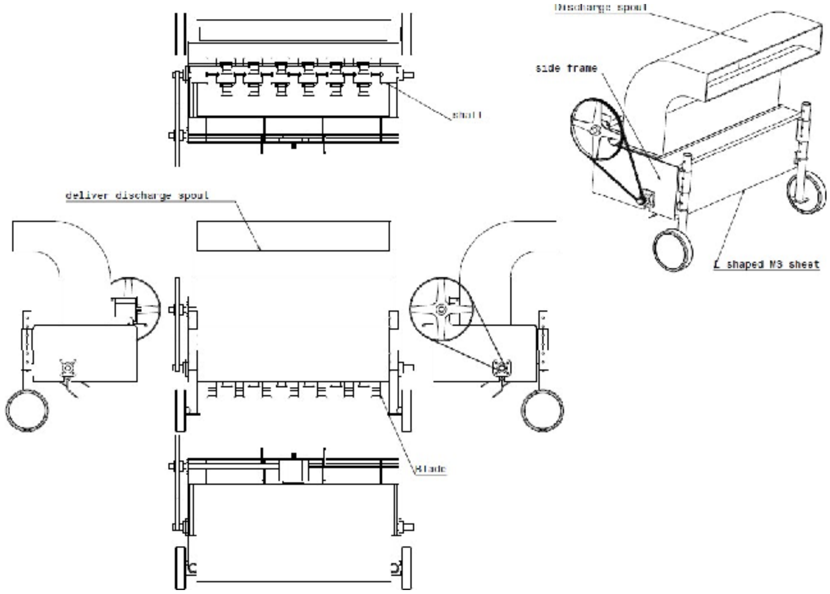

Fig. 1. Isometric views of cotton stalk harvesting machine.

Plate 1. Field evaluation of cotton stalk harvesting machine.

Chopped length. After each experiment a sample of 1 kg from shredded stalks were collected randomly and the finished dimensions in terms of length (shredding efficiency) were measured using a measuring scale and the mean values of length of cut were recorded.

Fineness modulus (uniformity) of shredded cotton stalk. Fineness modulus is empirical factor obtained by summing the percentages of the cumulative weight fractions retained on a specified series of sieves, and dividing the sum by 100 (Celestine *et al.,* 2014). The sample collected of different length from each experiment was used for finding fineness modulusAfter sieving the fineness modulus is calculated by the following formula.

$$\text{Fineness modulus } = \frac{\text{Sum of cumulative \% retained}}{100}$$

Bulk density of shredded cotton stalk. The bulk density of cotton stalks chopped by blades (flails) was filled into a box of known volume (inner) upto the top level and weighed. Then bulk density is calculated by the formula (Rajesh*et al.,* 2016).

$$\text{Bulk density (kg m}^{-3}\text{)} = \frac{\text{Weight of box with cotton stalk - Weight of empty box}}{\text{Inner volume of box}}$$

Machine output. After each experiment, the entire shredded cotton stalks are collected in polythene bag and weight of the shredded cotton stalk is measured using weighing balance. The machine productivity was calculated from the following equation (Mohamed, 2008).

$$P_r = \frac{W}{t}$$

Where,

P_r = Machine productivity kgh^{-1}

W = weight of crop residue, kg

t = machine operating time, h

Chopping height. The height of cut of stalks after harvesting was measured with help of measuring scale.

Effective field capacity

It is the actual area covered by the implement, based on its total time consumed and its width.

Effective field capacity was calculated by following formula (Anand *et al*., 2016).

$$EFC = \frac{A}{T_p - T_n} \times 100$$

Where,

E.F.C. = effective field capacity, ha h^{-1}A = Area, ha

T_p = Productive time, h

T_n = Non-productive time, h (Time loss for turning)

Fuel consumption. The fuel tank was filled to its full capacity before and after the operation. Amount of refuelingafter the operation was measured which was the actual fuel consumption for test. The fuel consumption was expressed as liter per hour (Anand *et al*., 2016).

Selection of power source. The selection of suitable power source is very important while developing any type of agricultural machine. The power required for rotary shredder is 22.06 kW per 1.5 m operating width (Bosoi *et al*., 1990). It is proposed to cover 2 rows spacing's of the crop in the same operation accommodating 75 or 90 cm row spacing's so, overall effective working width is fixed as 1.8 m for development. Hence, the power requirement for cotton stalk harvesting under consideration was estimated as 42.50 kW (57 hp). A 42.50 kW (57 hp) tractor) was used as a power source for the presentstudy.

RESULTS AND DISCUSSIONS

Performance evaluation of tractor operated cotton stalk harvesting machine. The tractor operated cotton stalk harvester was tested in field condition for shredding and conveying cotton stalk. The developed machine is evaluated at three different forward speeds *i.e.* 2 km h^{-1}, 3 km h^{-1} and 4 km h^{-1}. The parameters *viz.*, chopped length, fineness modulus, machine output, chopping height, effective field capacity, fuel consumption, bulk density of shredded cotton stalk are measured as discussed in material and methods section.

Effect of forward speed on chopped length. Effect of forward speed on chopped length. The effect of operational parameter *viz.* forward speed, on fineness modulus of shredded cotton stalks is presented in Table 1.

Table 1: Effect of forward speed on mean chopped length.

Replications	Mean chopped length		
	Forward speed of machine kmh^{-1}		
	2.0	3.0	4.0
1	110.5	135.5	195.5
2	111.5	125.6	210.5
3	114.5	122.5	205.5
4	110.0	131.5	207.8
5	105.5	133.5	206.5
6	114.5	125.6	207.5
7	117.6	127.5	225.5
8	118.5	128.5	185.5

The mean chopped length of shredded cotton stalk by cotton stalk harvesting machine varied from 110 mm to 210.5 mm at a different forward speed. A maximum mean chopped length of 210.5 mm was recorded at a forward speed of 4 km h^{-1}, whereas minimum machine output was recorded as 110 mm at a forward speed of 2 km h^{-1}.

The effect of forward speed on mean chopped length of shredded cotton stalk has been presented in Fig. 1. From the figure, it was observed that, the mean chopped length increased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the machine output at 1 % level of significance (Table 2). The mean comparison Table 15 clearly indicatesthat, the effect of increase in forward speed had significant influence on mean chopped length. Chopped length at 2 kmh^{-1} is lowest than compared to 3 kmh^{-1} and 4 kmh^{-1}. At lower forward speed number of cuts made by blades increased which resulted in increased percentage of stalks of lower length which resulted small mean chopped length at 2 km h^{-1}. The results are concurrence of results reported by Senthilkumar *et al*. (2009).

Table 2: Analysis of variance of mean chopped length at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Square	F-Calculated
Replication	7	275.318		
Forward speed	2	39,313.36	19,656.68	297.317*
Error	14	925.588	66.113	
Total	23	40,514.26		

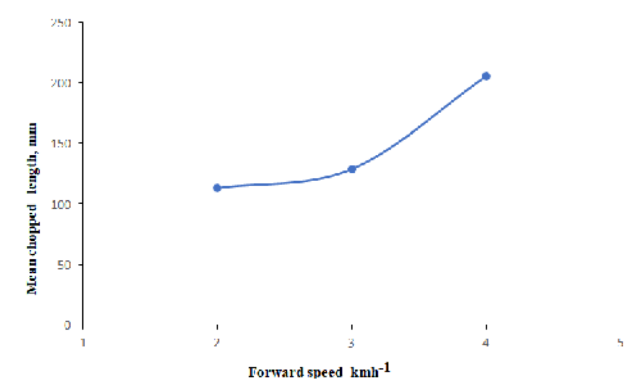

Fig. 2. Effect of forward speed on chopped length.

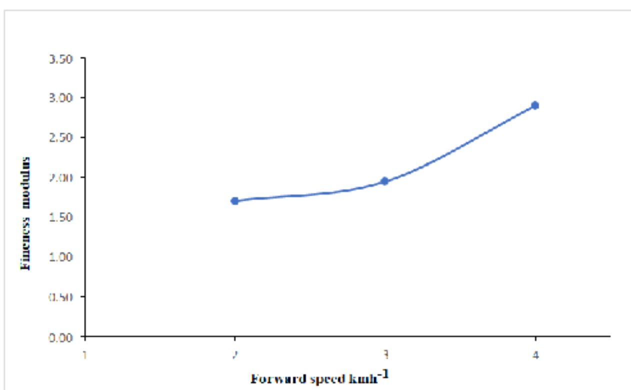

Fig. 3. Effect of forward speed on Fineness modulus (uniformity).

Effect of forward speed on fineness modulus. The effect of operational parameter *viz.* forward speed, on fineness modulus of shredded cotton stalks is presented in Table 3.

The fineness modulus of shredded cotton stalk by cotton stalk harvesting machine varied from 1.62 to 3.06 at a different forward speed. A maximum fineness modulus of 3.06 was recorded at a forward speed of 4 km h^{-1}, whereas minimum machine output was recorded as 1.62 at a forward speedof 2 km h^{-1}.

The effect of forward speed on fineness modulus of shredded cotton stalk has been presented in Fig. 3. From the figure, it was observed that, the fineness modulus increased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the machine output at 1 % level of significance (Table 4). The mean comparison Table 15 clearly indicates that, the effect of increase in forward speed had significant influence on fineness modulus (uniformity). Fineness modulus Uniformity at 2 km h^{-1}

is lowest than compared to 3 kmh^{-1} and 4 kmh^{-1}. At lower forward speed number of cuts made by blades increased which resulted in increased percentage of stalks of lower length. The results are in concurrence of the of the results reported by Mohamed (2008); El-Khateeb and El-Keway (2012).

Table 3: Fineness modulus at different forward speeds.

Replications	Fineness modulus		
	Forward speed of machine kmh^{-1}		
	2.0	**3.0**	**4.0**
1	1.65	1.87	3.01
2	1.75	1.84	3.02
3	1.65	2.08	3.06
4	1.62	1.88	2.8
5	1.67	1.99	2.88
6	1.85	1.78	2.92
7	1.67	1.89	2.55
8	1.79	2.27	2.97

Table 4: Analysis of variance of fineness modulus at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculate
Replication	7	0.183		
Forward speed	2	6.379	3.19	193.731*
Error	14	0.231	0.016	
Total	23	6.793		

Effect of forward speed on bulk density. The effect of operational parameter *viz.* forward speed, on bulk density of shredded cotton stalk by cotton stalk harvesting machine is presented in Table 5.

The bulk density of cotton stalk harvesting machine varied from 143.50 to 225.65 kgm^{-3} at a different forward speed. A maximum bulk density of 225.65 kg m^{-3} was recorded at a forward speed of 2 kmh^{-1}, whereas minimum bulk density was recorded as 143.50 kgm^{-3} at a forward speed of 4 kmh^{-1}.

The effect of forward speed on bulk density of shredded of cotton stalks have been presented in Fig. 4. From the figure, it was observed that, the bulk density decreased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the bulk density at 1 %level of significance (Table 6). The mean comparison Table 15 clearly indicates that, the effect of increase in forward speed had significant influence on bulk density. Bulk density at 2 km h^{-1} is highest than compared to 3 km h^{-1} and 4 km h^{-1}. Results obtained were in consonance with the result of Świetochowski *et al.* (2016).

Table 5: Bulk density at different forward speeds.

Replications	Bulk density kgm^{-3}		
	Forward speed of machine kmh^{-1}		
	2.0	**3.0**	**4.0**
1	220.35	185.69	145.60
2	225.65	175.68	143.50
3	225.60	184.60	145.60
4	220.45	155.71	155.60
5	210.00	175.25	158.90
6	195.60	175.60	150.50
7	210.50	183.50	152.50
8	214.50	175.20	154.50

Table 6: Analysis of variance of bulk density at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculate
Replication	7	279.048		
Forward speed	2	16,876.52	8,438.26	92.34*
Error	14	1,279.26	91.376	
Total	23	18,434.83		

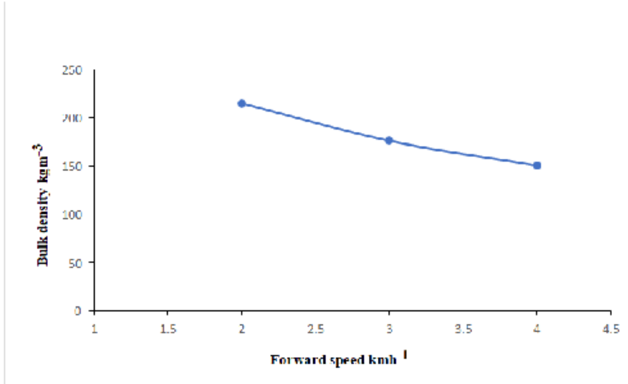

Fig. 4. Effect of forward speed on bulk density.

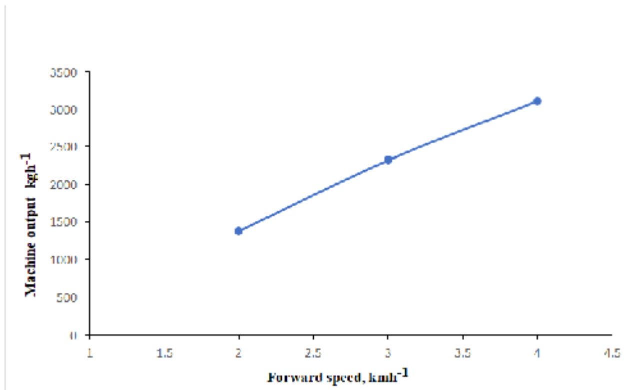

Fig. 5. Effect of forward speed on machine output.

Effect of forward speed on machine output. The effect of operational parameter *viz*., forward speed, on output of cotton stalk harvesting machine is presented in Table 7.

The output of cotton stalk harvesting machine varied from 1259.26 kgh^{-1} to 3333.33 kgh^{-1} at a different forward speeds. A maximum machine output of 3333.33 kg h^{-1} was recorded at a forward speed of 4 km h^{-1}, whereas minimum machine output was recorded as 1259.26 kgh^{-1} at a forward speedof 2 kmh^{-1}.

The effect of forward speed on cotton stalk harvesting machine output has been presented in Fig. 5. From the figure 4, it was observed that, the machine output increased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the machine output at 1 % level of significance (Table 8). The mean comparison Table 15 clearly indicates that, the effect of increase in forward speed had significant influence on machine output.

It was observed that the machine output capacity increased from 1259.26 kg h^{-1} to 3333.33 kgh^{-1} as speed increased from 2 kmh^{-1} to 4 kmh^{-1} (Table 7). With increase in forward speed, area covered per unit time increased resulting in higher machine output. The similar findings were reported by Rajesh *et al.* (2016).

Table 7: Machine output at different forward speeds.

	Machine output, kgh^{-1}		
Replications	**2.0 kmh^{-1}**	**3.0 kmh^{-1}**	**4.0 kmh^{-1}**
1	1407.41	2370.37	3333.33
2	1333.33	2441.14	3259.26
3	1259.26	2296.30	3111.11
4	1409.22	2222.22	3185.19
5	1481.48	2148.15	3109.12
6	1401.11	2291.10	3037.04
7	1331.30	2373.47	2888.89
8	1404.42	2444.44	2962.96

Table 8: Analysis of variance of machine output at different forward speeds.

Source ofVariation	DF	Sum of Square	Mean Squares	F-Calculate
Replication	7	73,144.77		
Forward speed	2	1,20,25,132.57	60,12,566.28	445.721*
Error	14	1,88,853.48	13,489.53	
Total	23	1,22,87,130.82		

Effect of forward speed on chopping height (height of cut). The effect of operational parameter *viz.*, forward speed, on chopping height of cotton stalk harvesting machine is presented in Table 9.

The chopping height (height of cut|) of cotton stalk harvesting machine varied from 85 to 359 mm at a different forward speeds. A maximum chopping height of 359 mm was recorded at a forwardspeed of 4 km h^{-1}, whereas minimum chopping height was recorded as 85 mm at a forward speed of 2km h^{-1}.

The effect of cotton stalk harvesting machine forward speed on height of cut of stalks has been presented in Fig. 6. From the figure, it was observed that, the chopping height increased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the chopping height at 1 % level of significance (Table 10). The mean comparison Table 15 clearly indicates that, the effect of increase in forward speed had significant influence on chopping. Height of cut at 2 km h^{-1} is close to ground than 3 km h^{-1} and 4 km h^{-1}. The height of cut decreased from 35.9 cm to 8.5 cm asforward speed decreased from 4 to 2 km h^{-1} . This may due to the fact that at low speeds the cut was perpendicular to the stalks as the speed increases the stalks are deflected forward and slant height of cut of cotton stalk increased which resulted in increase in height of cut of stalks. The similar findings were reported by Eltarhuny and Fouda (2012); Rajesh Verma (2015); Rajesh *et al.* (2016).

Effect of forward speed on effective field capacity. The effect of operational parameter *viz.*, forward speed, on effective field capacity of cotton stalk harvesting machine is presented in Table 11.

The effective field capacity of cotton stalk harvesting machine varied from 0.17 to 0.45 hah^{-1} at a different forward speed. A maximum effective field capacity of 0.45 hah^{-1} was recorded at a forward speed of 4 kmh^{-1}, whereas minimum effective field capacity was recorded as 0.17 hah^{-1} at a forward speed of 2 kmh^{-1}.

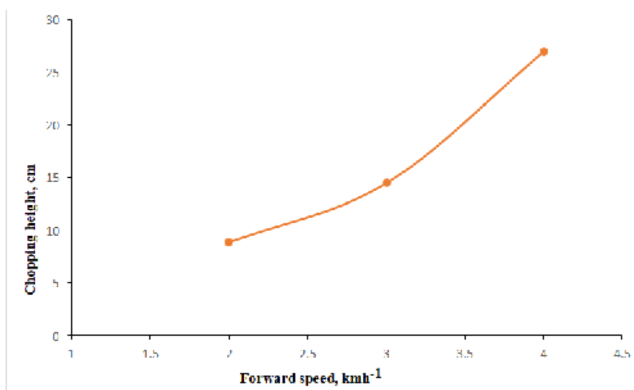

Fig. 6. Effect of forward speed on height of cut of cotton stalk.

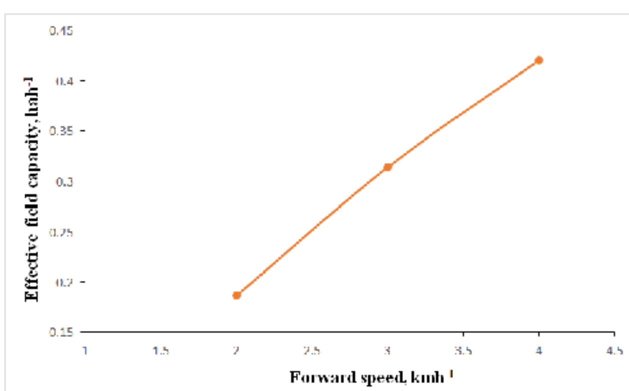

Fig. 7. Effect of forward speed on effective field capacity.

Table 9: Effect of forward speed on chopping height (height of cut).

Replications	Height of cut, mm		
	Forward speed of machine kmh^{-1}		
	2.0	**3.0**	**4.0**
1	92	144	266
2	93	134	245
3	89	142	359
4	87	147	236
5	85	151	247
6	89	146	241
7	88	144	279
8	86	150	282

Table 10: Analysis of variance of chopping height at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Square	F-Calculate
Replication	7	3,679.17		
Forward speed	2	1,36,938.58	68,469.29	121.614*
Error	14	7,882.08	563.006	
Total	23	1,48,499.83		

Table 11: Effective field capacity at different forward speeds.

	Effective field capacity, hah^{-1}		
Replications	**2.0 kmh^{-1}**	**3.0 kmh^{-1}**	**4.0 kmh^{-1}**
1	0.19	0.32	0.45
2	0.18	0.33	0.44
3	0.17	0.31	0.42
4	0.19	0.30	0.43
5	0.20	0.29	0.42
6	0.19	0.31	0.41
7	0.18	0.32	0.39
8	0.19	0.33	0.40

Table 12: Analysis of variance of Effective field capacity at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	7	0.001		
Forward speed	2	0.219	0.11	445.796 *
Error	14	0.003	0.00	
Total	23	0.224		

The effect of forward speed on effective field capacity of cotton stalk harvesting machine has been presented in Fig. 7. From the figure, it was observed that, the effective field capacity increased as the forward speed increased. It was observed that, the forward speed (F) significantly influenced the effective field capacity at 1 % level of significance (Table 12). With increase in forward speed, area covered per unit time increased resulting in higher field capacity. The similar findings were reported by Rajesh *et al.* (2016).

Effect of forward speed on fuel consumption. The effect of operational parameter *viz.* forward speed, on fuel consumption of cotton stalk harvesting machine is presented in Table 13.

The fuel consumption of cotton stalk harvesting machine varied from 6.3 to 11.3 lh^{-1} at a different forward speed. A maximum fuel consumption of 11.3 lh^{-1} was recorded at a forward speed of 4 km h^{-1}, whereas minimum fuel consumption was recorded as 6.3 lh^{-1} at a forward speed of 2 kmh-1.

The effect of forward speed on fuel consumption of cotton stalk harvesting machine has been presented in Fig. 8. From the figure, it was observed that, the fuel consumption increased as the forwardspeed increased. It was observed that, the forward speed (F) significantly influenced the fuel consumption at 1 % level of significance (Table 14). The mean comparison Table 15 clearly indicates that, the effect of increase in forward speed had significant influence on fuel consumption. With increase in forward speed of machine, more power was needed to handle more cotton stalks per for shredding and conveying. Thus, shredding capacity of the machine increased which resulted in increase in fuel consumption of the machine. Kanafojski, C. and Karwawski (1976) reported that cutting resistance increases with increase in machine working speed. To counter increased resistance, more energy is required. Thus, fuel consumption increased with increase in forward speed of machine. The similar findings were reported by Ananda Kumar *et al*. (2016); Rajesh *et al*. (2016).

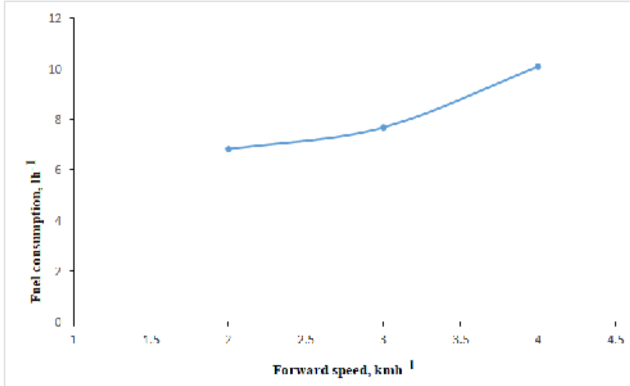

Fig. 8. Effect of forward speed on fuel consumption.

Table 13: Effect of forward speed on fuel consumption.

Replications	Fuel consumption lh^{-1} Forward speed of machine kmh^{-1}		
	2.0	**3.0**	**4.0**
1	6.9	7.5	9.6
2	7.6	7.6	10.8
3	6.6	7.7	9.4
4	6.4	7.9	9.4
5	7.3	7.9	9.7
6	6.9	7.4	10.2
7	6.3	7.5	11.3
8	6.5	7.9	10.2

Table 14: Analysis of variance of Fuel consumption at different forward speeds.

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	7	1.427		
Forward speed	2	45.728	22.864	87.643*
Error	14	3.652	0.261	
Total	23	50.806		

Table 15: Mean comparison at different forward speeds for chopping height, machine output, Bulkdensity, Fineness modulus, mean chopped length fuel consumption.

Treatments	Mean chopped length, mm	Fineness modulus	Bulk densitykgm^{-3}	Machine output, kgh^{-1}	Chopping height, mm	Fuel consumption, lh^{-1}
2 kmh^{-1}	112.8	1.706	215.33	1379.63	88.6	6.81
3 kmh^{-1}	128.7	1.950	176.39	2324.07	144.7	7.67
4 kmh^{-1}	205.5	2.901	150.83	3111.11	269.3	10.07
Overall mean	149.04	2.18	180.85	2271.60	167.5	8.18
CD	8.804	0.139	10.35	124.55	25.69	0.54
CV%	5.455	5.87	5.28	5.11	14.15	6.23

CONCLUSIONS

In order to utilize the cotton stalk for ex-situ application a cotton stalk harvester was developed and evaluated in the field conditions. The developed cotton stalk harvesting machine was evaluated for 3 forward speeds *viz*., 2, 3 and 4 km h^{-1}. Operation at 2 km h^{-1} gave the better result with mean chopped length of 112.8 mm, fineness modulus of 1.706, bulk density of 215.33 kgm^{-3} machine output was recorded as 1379.63 kgh^{-1} chopping height was recorded as 88 mm and fuel consumption of 6.8 lh^{-1}.

FUTURE SCOPE

Based on research work done, it can be used as reliable work for further reference.

The machine should be evaluated for efficient shredding other crop stalks.

Acknowledgement. This is part of the corresponding author's Ph.D thesis work at University of Agricultural Sciences, Raichur, Karnataka.

Conflict of Interest. None.

REFERENCES

Ananda Kumar, T. M., Sanjeeva Reddy, Anantachar, M., Veerangouda, M. and Prakash, K. V. (2016). Development of tractor operated machine for maize stalk in-situ shredding. *Environment & Ecology*, *34*(4), 2420-2424.

Bhuvaneshwari, S., Hiroshan, Hettiaarachchi and Meegoda

Jay, N. (2019). Crop residue burning in India: Policy changes and Potential solutions. *International Journal of Environmental Research and Public Health, 16*(832), 1-19.

Bosoi, E. S., Verniaev, O. V., Smirnov, I. I. and Shakh Sultan, E. G. (1990). Theory, construction and calculations of agricultural machines. Vol.2. Oxonian Press Pvt. Ltd. New Delhi 348-392.

Celestine, I. and Matthew Sunday Abolarinand Ibukun Blessing Ikechukwu (2014). Effect of groundnut paste fineness modulus on quantity of oil extractable. *Elixir Mech. Engg., 73*, 25983-25984.

Eltarhuny, M. M. and Tarek Fouda (2012). Utilization of self-propelled harvester and shredder machines for removing some field crop residues. *Management, economic engineering in agriculture and rural development, 12*(1), 67-70.

El-Khatteb, H. A. and EL-Keway, A. A. (2012) Development and evaluation of cutting knives to suitcutting wet and dry field residues. *J. Soil Sci and Agric. Eng., Mansoura Univ*., *3*(6), 601-616.

Jha, S. K., Amar Singh and Adarsh Kumar (2008). Physical characteristics of compressed cotton stalks. *Biosystems engineering, 99*, 205-210.

Khurmi, R. S. and Gupta, J. K. (2006). A Text book of machine design, Eurasia Publishing House Pvt. Ltd. New Delhi, India. 325-381.

Kanafojski, C. and Karwawski, T. (1976) Agricultural Machines, Theory and construction vol. 2: crop Harvesting machines. National center for scientific, technical and economic information warsaw, Poland.

Mohamed Sayed Omran (2008). Study of the performance of the most widely used shredders for crops residues in Egypt. The 15th Annual conference of the Mirs Society of Ag. Eng. 12-13

Rajesh Goyal, Mahal, J. S. and Manes, G. S. (2016). Performance evaluation of flail unit of forage harvester on sorghum fodder. *Agri. Res. J., 53*(2), 264-267.

Rajesh Goyal, Mahal, J. S., Manes, G. S. and Dixit, A. (2016 b). Performance evaluation of tractor operated flail type forage harvester having chaffing system on maize fodder. *Agri. Res. J., 53*(3), 416-420.

Rajesh Verma,Vishal Bector and Gursahib Singh (2015). Effect of crop geometry, cutter speed and forward speed on performance characteristics of tractor operated forage harvester-cum- chopper. *Agricultural Engineering Today, 39*(4), 49-54.

Senthilkumar, T., Manian, R. and Kathirvel, K. (2009). Development and performance evaluation of a tractor operated cotton stalk shredder cum In-situ applicator. *Agril. Mech. in Asia, Africa, andLatin America*, *40*(2), 65-67.

Świetochowski, A. Lisowski, and ADąbrowska-Salwin, M. (2016). The effect of particles sizes on thedensity and porosity of the material. *Proceedings of International Conference on Trends in Agricultural Engineering*, 7-9, Prague Czech Republic, 609-614.

How to cite this article: Er. Ch. Sravan Kumar, K.V. Praksah, B. Sanjeeva Reddy, Sushilendra, P Vijay Kumar, Krishanmurthy and Nemichandrappa (2022). Performance Evaluation of Cotton Stalk Harvesting Machine for ex-situ Application. *Biological Forum – An International Journal, 14*(1): 1803-1812.