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Assessment of Cotton Uprooter

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***Abstract* :-** Cotton is essential to India's economy, supporting millions and fuelling the textile industry. Spanning 117 lakh hectares, India dominates global cotton with 37.5% of the area and 26% of production, impacting 60 million livelihoods. However, post-harvest cotton plant residue management is challenging, often leading to environmentally harmful practices like applying harmful chemical & burning. This study discovers a sustainable solution using a tractor-operated mobile shredder at the Regional Agricultural Research Station in Nandyal, Andhra Pradesh. The shredder, mounted on a 45 HP tractor, efficiently processed cotton stalks, enhancing soil health by accumulation of nutrients and organic matter. The study measured physical parameters & operational parameters like moisture content, and operational efficiency, revealing that the shredder improved soil nutrient profiles, field efficiency, and reduced fuel consumption. Theoretical and effective field capacities were highest at 0.33 ha/hr and 0.28 ha/hr, respectively, at 1.65 km/hr. The approach mitigates environmental impact, conserves soil health, and offers a viable alternative to residue burning. This study underscores the potential for widespread adoption of advanced residue management technologies, promoting sustainable agriculture and benefiting farmers.

Keywords *– Shredder, Uprooter, Theoretical field capacity, Effective field capacity, cotton*

1. Introduction

Cotton is a root of India's economy, sustaining the livelihoods of millions and helping as a crucial raw material for the nation's thriving textile industry (Senthil *et al*., 2011). With cultivation spread over 117 lakh hectares, India commands 37.5% of the global cotton area and contributes 26% to world production (Khan *et al*., 2023). This significant share underscores cotton's uniqueness to India's agricultural sector and its broader economic fabric. The industry supports nearly 60 million people involved in various stages from cultivation to export, illustrating the crop's extensive socio-economic impact (Ahmed *et al*., 2020). The textile industry alone, which primarily relies on cotton, contributes approximately 4% to India's GDP and is a major source of foreign exchange, highlighting the economic importance of cotton beyond agriculture (Senthilkumar & Thilagam 2015).

Geographically, cotton production in India spans three major zones the Northern Zone (Punjab, Haryana, and Rajasthan), the Central Zone (Gujarat, Maharashtra, Madhya Pradesh, and Orissa), and the Southern Zone (Andhra Pradesh, Telangana, Karnataka, and Tamil Nadu) (Senthil *et al*., 2009). These regions together account for the bulk of the country's cotton output, reflecting diverse agricultural practices adapted to local climatic conditions. The regional distribution of cotton cultivation demonstrates the crop's adaptability and the strategic importance of each zone in maintaining India's status as a leading cotton producer (Ramanjaneyulu *et al*., 2021). This geographical spread not only diversifies risk but also ensures a steady supply of raw materials for the domestic textile industry.

The historical path of cotton production in India reveals a remarkable transformation. From producing predominantly short and medium staple cotton at the time of independence, India has evolved to include long and extra-long staple varieties, which now make up more than 50% of the total production (Vyas & Mathur, 2019). This shift has been driven by advancements in agricultural research and development, resulting in improved varieties and hybrids. The peak production year of 2013-14, with 398 lakh bales, showcases the heights of productivity achieved through these innovations. However, fluctuations in production, such as the decline in the late 1990s and early 2000s, and recent challenges like pest infestations and adverse weather conditions, highlight the dynamic nature of cotton agriculture (Shirwal, S., & Palled, V. 2023).

Government policies have played a crucial role in supporting the cotton sector. Initiatives focusing on research and development have led to the development of high-yield and pest-resistant varieties, enhancing both quality and quantity of production. Subsidies for quality seeds and pesticides, along with price support measures, have further incentivized farmers to adopt improved practices and technologies (Mamadaliyev *et al.,* 2021). These efforts have not only ensured self-sufficiency but have also positioned India as a net exporter of cotton since the mid-1990s. The government's continued support underscores the strategic importance of cotton in India's agricultural policy and its critical role in the national economy, reflecting a commitment to sustaining and enhancing this vital sector.

Managing cotton plant residues post-harvest poses significant challenges for farmers, often leading to environmentally detrimental practices such as field burning, burying of cotton stalks, and shredding of stalks in the field. The primary components left after picking cotton include the main stem, branches, leaves, unmatured bolls, and cotton lint with seeds, which are unwieldy to remove manually. Burning these residues, while an expedient solution, contributes to severe environmental pollution and raises concerns about soil health due to the excessive use of chemicals & fertilizers (Ramadan 2010). Research indicates that cotton plant residues can be valuable sources of nutrition and energy. Studies have shown that cotton stalks are rich in essential nutrients, including nitrogen, phosphorus, potassium, sulphur, copper, iron, manganese, and zinc, suggesting their potential use as organic fertilizers to improve soil health (Shaikh *et al.,* 2010).

The process of converting cotton plant residues into useful compost or manure is labour-intensive and requires mechanical intervention for efficiency. Traditional stationary machines used for shredding residues are not only laborious but also time-consuming & costly operation. Innovations in agricultural machinery, such as the development of tractor-operated mobile shredders, have significantly improved the efficiency of this process. These mobile shredders facilitate the fine-size reduction of cotton stalks, enhancing the ease of incorporating shredded material into the soil. The addition of these residues as organic matter boosts soil properties by increasing nutrient availability, organic carbon content, and water-holding capacity, thereby fostering a more sustainable agricultural practice and reducing soil erosion.

Frontline demonstrations of these advanced residue management techniques have yielded promising results. For instance, the use of tractor-operated mobile shredders has been shown to improve soil nutrient profiles significantly. A study involving the in-situ application of shredded cotton stalks reported notable increases in available nitrogen, phosphorus, potassium, and organic carbon in the soil. The operational efficiency and cost-effectiveness of these shredders were evaluated, revealing their potential to replace environmentally harmful practices like burning with more sustainable alternatives. These advancements not only alleviate the burden on farmers but also contribute to environmental conservation and soil health improvement, highlighting the multifaceted benefits of adopting innovative agricultural technologies.

2. Materials and methods

The frontline demonstration of cotton plant residue management was conducted in the farmers' cotton fields at the Regional Agricultural Research Station (RARS) in Nandyal, Andhra Pradesh, India. The study focused on cotton crops grown under irrigated farming conditions. The shredding operation was performed in January, post the final cotton picking. The demonstration utilized a mobile shredder mounted on a 2-wheel drive farm tractor, which generated (45 HP) of power with a constant PTO speed of 540 rpm. This setup, detailed in Table 1, allowed for efficient and effective shredding of cotton stalks. The three-point hitching system facilitated the mounting of the shredder on the tractor, enabling the processing of one row of cotton crops at a time.

During the operation, the mobile shredder cut the above-surface parts of the cotton stalks before shredding the feed material in the field. This method helped reduce soil erosion, provided essential nutrients to the soil from the chopped stalks, and effectively killed pink bollworm pests. The shredder featured a central-driven feeder roller system and a shredding mechanism. The feeder system included four feeder drums, with the front drums equipped with disc cutters to enhance feeding efficiency. The shredding system comprised a large flywheel with six blades, which finely chopped the stalks. The design also included an outlet at the top of the shredder that evenly distributed the shredded material back onto the field, ensuring a uniform spread and improved incorporation into the soil.

The demonstration showcased the effectiveness of the tractor-operated mobile shredder in managing cotton plant residues. By converting the stalks into nutrient-rich mulch, the process improved soil health and fertility (Lobell *et al.,* 2018). The shredded material not only added organic matter and essential nutrients to the soil but also enhanced its water-holding capacity, promoting better crop growth in subsequent planting seasons. This approach offers a sustainable alternative to burning residues, addressing environmental concerns while simultaneously benefiting farmers through improved soil quality and pest management. The successful demonstration at RARS highlights the potential for widespread adoption of such technologies, which can lead to more sustainable agricultural practices and enhanced productivity in cotton farming.

2.1 Feeding System

The feeding system mainly consists of guiding arms and two vertical drum disc cutters mounted on shafts rotating in opposite directions for cutting the plant stalks above the ground level. Two pressure roller drums, one with spring-loaded swing type for optimum and uniform feeding of the cotton stalks into the shredding unit. The feeding system of the cotton shredder is shown on **Fig.1**

Fig.1 Feeding System of Mobile Shredder

2.2 Shredding System

A flywheel with 6 number of blades mounted at equal distances in the shredding chamber for shredding the plant stalks into pieces. Lift paddles are provided on the periphery of the flywheel to give an additional lift to the chapped crop so that it can be spread on the field. The entire system is enclosed in a box-like frame. The shredding system of cotton shredder is shown in **Fig.2.**

Fig.2. Shredding System of shredder

2.3 Uprooting Assembly with adjustable Seating Mechanism

A commercially available tractor-operated cotton stalk shredder is used for shredding the cotton plant stalks. After completion of the shredding operation, the left-out stubbles in the field were to be uprooted by providing an uprooting assembly unit to the frame of the shredder, and these uprooted stubbles are collected manually and fed into the shredding unit through stubble feeding duct. To collect these uprooted stubbles from the field, a proper seating arrangement is made at the back of the mainframe adjacent to the uprooting assembly.

The uprooting assembly mainly consists of a shank, a T-type blade, and U-clamps. A shank of 2 cm thickness,107 cm length with a tapered width of 15 cm at the top and 7 cm at the bottom is fixed to the mainframe with suitable U-clamps. The shank is fabricated using mild steel. Provision is made at the bottom of the shank for fitting the blade with bolts and nuts. Provision was also made to increase or decrease the depth of operation. The complete system is attached to the main frame at any distance from the shredding unit based on the row spacing of the cotton crop.

On the main frame, a square pipe having a cross-section of 5 cm and 150 cm length was fixed to the main frame with suitable U-clamps. Another end of the pipe seating arrangement is made for collecting the uprooted plant stubbles and dropping them into the stubble feeding duct. Provision was made for lowering or raising the seat. The adjustable seating mechanism is shown in **Fig.3** respectively.

Fig.4 Seat attached to the shredder

2.4 Stubble feeding duct

A feeding duct made of a GI sheet was provided to drop the uprooted cotton stubbles manually into the feeding chamber. A proper slope was provided for sliding the uprooted cotton stubbles into the feeding chamber through gravity. The feeding duct arrangement is shown in **Fig.5**.

Fig.5 The arrangement of feeding duct

Table .1 Specifications for the developed Uprooter

Developed Up rooter parameters	Specifications
Length of shank (cm)	107
Width of shank (cm)	7
Thickness of shank (cm)	2
No. of blades	1
Width of the blades (cm)	100,150,200
The angle of blade contact with soil	32°-35°
The blade thickness of cutting side (cm)	1.5

2.5 Physical parameters of cotton crop

The physical parameters of the cotton crop in all demonstration fields were accurately recorded to assess the effectiveness of the mobile shredder. Key measurements included the row-to-row and plant-to-plant distances, ensuring consistency in the cultivation practices across the fields. Additionally, the height (in mm) and weight (in kg) of the cotton plants were measured by randomly selecting 10 plants from each field. These physical characteristics provided a baseline for evaluating the performance of the shredder and understanding its impact on different plant profiles. The data collected on plant height and weight were crucial in determining the shredder's efficiency and the overall feasibility of the residue management practice.

2.6 Field Capacity

Field capacity is the ratio of field coverage by uprooter cum shredder. Turning time after the completion of the field operation was added with the actual operating time for effective field capacity determination.

2.7 Theoretical field capacity

The theoretical field capacity for the cotton stalk-up rooter cum shredder was determined by the following equation (Verma and Dewangan., 2006).

Theoretical field capacity, ha.hr^{-1} = (S×W)/10

Where,

T.F.C = Theoretical field capacity, ha. h^{-1}

S = forward speed, km. h-1

W = width of coverage, m

2.8 Effective field capacity

Effective field capacity is the actual average rate of a field covered by the Machine, based on the total field time and given (Raju Yadav *et al*.,2023).

Ceff = A/T

Where,

Ceff= effective field capacity, ha. h^{-1}

A = Field coverage, ha

T = Actual time of operation, h.

2.9 Field efficiency

It is the ratio of effective field capacity to theoretical field Capacity and was expressed as %. The field efficiency was calculated by using the following equation.

Field efficiency Ef= EFC/TFC ×100

Where,

Ef = Field efficiency, %

EFC = Effective field capacity, ha. h^{-1}

TFC = Theoretical field capacity, ha. h^{-1}

2.10 Uprooting efficiency

The uprooting of the cotton roots was performed using the uprooting unit of the shredder. It is the ratio of several cotton roots uprooted during the shredding operation to the total number of roots in the field. The uprooting efficiency is expressed in percentage.

$$\text{Uprooting Efficiency} = \frac{\text{Number of roots uprooted}}{\text{Total number of roots}} \times 100$$

2.11 Fuel consumption measurement

Experiments were conducted in a selected plot to measure the fuel consumption of with test implement tractor. Before the operation, the fuel tank of the tractor was filled with fuel up to the brim. The tractor operated with the developed equipment in the selected plot. The amount of added fuel to fill the fuel tank up to the brim was noted as fuel consumed by the tractor.

Fuel Consumption Ft = V/t

Where,

F = fuel consumption rate, l h-1

V = volume of fuel consumed, l

t = total operating time, h

3. Results & Discussion

3.1 Physical properties of cotton stalk

The average moisture content of the cotton stalk and soil at that time of uprooting was 27.3% and 11.1 % respectively. The important parameters of the cotton stalk-like P.H., T.D., and diameter of the stem were measured at 10 different locations and their mean and S.D values were calculated in Table 2.

Table. 2. Physical properties of the cotton stalk

Sl. No	Parameters (cm)	No. observations	Avg (cm)	S.D	C.V (%)
1	Plant height	10	17.4	± 7.8	6.6
2	Tap root depth	10	34.7	± 2.6	7.4
3	Diameter of stem	10	2.2	± 0.2	10.9

3.2 Effect of Selected Levels of Variables on Uprooting Efficiency (%)

The data was statistically analyzed to examine the single factor and interaction effect and presented. Effect of cutting width and depth at 1.3 km. h^{-1} operating speed on uprooting efficiency is shown in Figure 7. It was observed that the uprooting efficiency increased with the increase in blade width and depth of operation. This may be due to the increase in the horizontal width of the working tool and contact area. Minimum and maximum uprooting efficiency of 24.0 and 65.4 % were obtained at 5 and 15 cm depth respectively at 1.3 km. h^{-1} for the cutting width of the blade was 10 cm shown in Fig. 7. The working width of the uprooting blade was 15 cm the minimum and maximum uprooting efficiency was 26.6 % and 69.7 % at 5 cm and 15 cm depth and at speed of 1.3 km. h^{-1} shown in Fig.7. A minimum and maximum uprooting efficiency was 37.7% and 75.2% at the depth of 5 cm and 15 cm the working width of 20 cm blade and at a speed of 1.3 km. h^{-1} shown in Fig. 7.

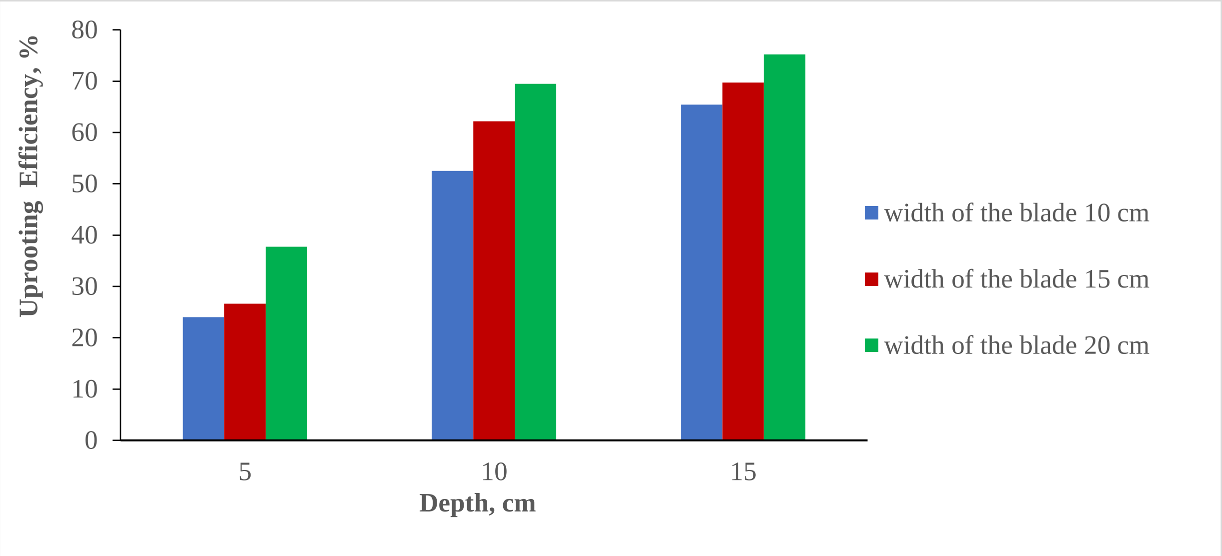

Fig.7 Effect of Depth and Width on Uprooting Efficiency at speed 1.3 km.h^{-1}

Minimum and maximum uprooting efficiency of 32.9 % and 69.8 % were obtained at 5 and 15 cm depth respectively at 1.5 km. h-1 for the cutting width of the blade was 10 cm shown in Fig.8. The working width of the uprooting blade was 15 cm the minimum and maximum uprooting efficiency was 37.2% and 74.3% at 5cm and15cm depth and at a speed of 1.5 km.h-1 shown in Fig.8. A minimum and maximum uprooting efficiency was 38.9 % and 82.9 % at the depth of 5 cm and 15 cm the working width of 20 cm blade and at speed of 1.5 km. h^{-1} shown in Fig.8.

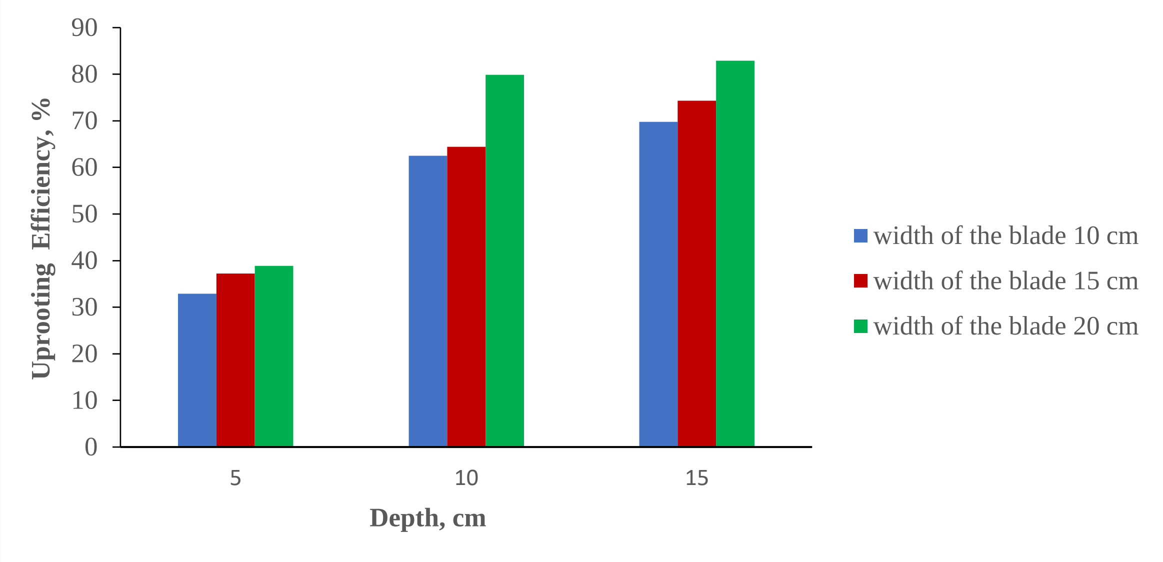

Fig.8 Effect of Depth and Width on Uprooting Efficiency at speed 1.5 km.h^{-1}

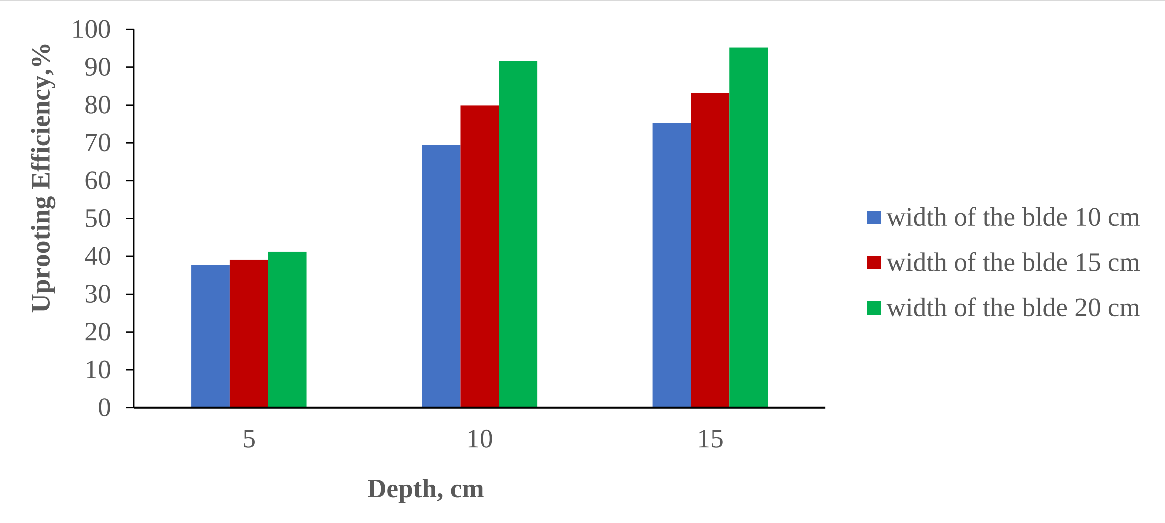

Fig .9 Effect of Depth and Width on Uprooting Efficiency at speed 1.65 km. h^{-1}

Minimum and maximum uprooting efficiency of 37.7% and 75.2% were obtained at 5 and 15 cm depth respectively at 1.65 km. h^{-1} for the cutting width of the blade was 10 cm shown in Fig.9. The working width of the uprooting blade was 15 cm the minimum and maximum uprooting efficiency was 39.1 % and 83.2 % at 5 cm and 15 cm depth and at speed of 1.65 km. h^{-1} shown in Fig.9. A minimum and maximum uprooting efficiency was 41.2 % and 95.2 % at the depth of 5 cm and 15 cm the working width of the blade was 20 cm respectively and at a speed of 1.65 km. h^{-1}as shown in Fig.9.

3.3 Means of S×D×W interaction for Uprooting efficiency (%)

The analysis of variance for individuals and the interaction effect of variables on Uprooting efficiency was summarized in Table 3. The analysis of variance indicates that highly significant difference among the three individual variables set and the interaction effect of S X D, S X W, D×W ($P<0.01$) was significant. The interaction effect of all variables viz., Depth, Width, and speed was significant. No significant difference between S×D×W.

Table.3 Means of S×D×W interaction for Uprooting efficiency (%)

S. No.	Source	D.F.	S.S.	M.S.	F-cal
1.	**Replications**	2	1.62		
2.	**Forward speed (S)**	2	1746.566	873.783	44.308**
3.	**Depth (D)**	2	4143.645	2071.823	105.058**
4.	**Width (W)**	2	26910.009	13455.004	682.278**
5.	**S X D**	4	310.907	77.727	3.941**
6.	**S X W**	4	407.607	101.902	5.167**
7.	**DX W**	4	318.330	79.583	4.035**
8.	**S X D X W**	8	141.287	17.661	0.896 NS
9.	**Error**	27	1064.919	19.721	
10.	**Total**	53	35044.270		

**=Significantat1 percent level ($P<0.01$),*=Significant at 5 percent level ($P<0.05$) NS =Non-significant

The uprooting efficiency of 91.6 % is better for the 20 cm width of the blade at an operational depth of 10 cm and 1.65 km. h^{-1}operational speed. As compared with 15 cm depth uprooting efficiency is 95.2 %. Hence, the depth of the cotton stalk uprooter cum shredder increases the draft force as well as wheel slip.

3.4 Theoretical Field Capacity

The maximum theoretical field capacity obtained was 0.33 ha. h^{-1} at the forward speed of 1.65 km. h^{-1}. The minimum theoretical field capacity was obtained at 0.30 ha. h^{-1} at the forward speed of 1.3 km. h^{-1}.

3.5 Effective Field Capacity

The effective field capacity was 0.16 ha. h^{-1}, 0.22 ha. h^{-1} and 0.28 ha. h^{-1} at an operating speed of 1.3 km. h^{-1}, 1.5 km. h^{-1} and 1.65 km. h^{-1}. The field capacities increased with an increase in the forward speed of the cotton stalk uprooter cum shredder.

3.6 Field Efficiency

The field efficiency of the cotton stalk uprooter cum shredder was calculated depending on the theoretical and effective field capacity. As the forward speed increased, both theoretical and effective field capacities were increased. It is the ratio of both field capacities. The field efficiencies were 61.5, 73.3, and 84.8 % at forward speeds of 1.3, 1.5, and 1.65 km h^{-1} respectively. The field efficiency is also influenced by the shape of the field, which the turns reduce or increases the number of turns. Depending on several turns, there will be more time losses, thereby decreasing the field efficiency.

3.7 Fuel Consumption

The fuel consumption was found to be varied from 4-5 lit. h^{-1} at a varied depth of operation of 5 cm and 10 cm depth, the fuel consumption was found to be 5 to 6 lit. h^{-1}. The increase in fuel consumption is due to the increased width of the blade, depth, draft force, and wheel slippage.

Conclusion

The most important feature for removing the previous cotton stalks is to remove the pink boll-warm insect (PBW). Present in the furrows of cotton plant stalks and affects the next crop surely.

High labour demand during peak rends. Manually pulling is highly labour intensive, time-consuming, and involves high cost. These can be reduced only through the interdiction mechanical cotton stalk shredding.

1. The average stalk stem diameter, Height of plant, and Taproot length were, 2.2 cm,117.4 cm and 32.7 cm respectively
2. The Moisture content of cotton stalk and soil at the time of uprooting was 27.1% and 11.1% respectively.
3. Theoretical field capacity of cotton stalk uprooter cum shredder with a working width of 20 cm blade was 0.26 ha.h^{-1}, 0.30 and 0.33 ha.h^{-1} at an operational speed of 1.3 km. h^{-1}, 1.5 km. h^{-1} and 1.65 km. h^{-1}respectively.
4. The effective field capacity was 0.16 ha.h^{-1}, 0.22 ha.h^{-1} and 0.28 ha.h^{-1} at an operating speed of 1.3 km.h^{-1}, 1.5 km.h^{-1} and 1.65 km.h^{-1} respectively. It was observed that the field capacities increased with an increase in the forward speed of the cotton stalk uprooter cum shredder.
5. The amount of consumption of fuel was found to be varied from 4-5 lit.h^{-1} at 5 cm operational depth and 10 cm depth, the fuel consumed was found to be 5 - 6 lit.h^{-1}. The increase in fuel consumed is due to the increased width of the blade, depth, draft force, and wheel slippage.

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