Development of Tractor Operated Cotton Stalk Puller

Elnougomi. A. Gadir[1*] and Taief M. Gibreel[2*]

[1]College of Agricultural Studies-Sudan University of Science and Technology-Sudan.
[2]College of Agricultural Studies-Sudan University of Science and Technology-Sudan.

Authors' contributions

This work was carried out in collaboration between all authors. Author EAG designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author TMG managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

ABSTRACT

The implement was designed and developed in a workshop held at the Agricultural Engineering Department, College of Agricultural Studies, Sudan University of Science and Technology between April 2011 and June 2012. The implement was constructed from a series of disc blades mounted on a frame. The two discs arranged together with specific space and angles to adapt with cotton stalks pulling operation. The implement mounted on the tractor by three hitches linkage.

The field performance test was done for the implementation in Gezira Scheme by measuring the tilt and rake angles parameters, operation speed, pulling operation cost for both systems; manual and mechanical and total cost to product the implement. The experimental design was split plot in a complete randomized block adopted with three replications.

The results revealed that the best performance efficiency of the implement (94%) was found at both 30, 20 degrees of tilt angle and rake angle respectively. The suitable operating speed was found to be 2.8 km/h. When estimated, the total cost to achieve the cotton stalks removal per using two systems hand puller and designed implement found that 200,50 SDG required per feddans respectively. The current implement design can be

Corresponding author: Email: massagomi@yahoo.com, taiefg@hotmail.com;

manufactured in both industrial and semi-industrial factories and even small workshops due to design simplicity. Finally it was found that the total manufacturing cost of the implement was 3000 SDG (500$).

1. INTRODUCTION

Cotton is a versatile fiber crop, grown commercially in many countries throughout the world [1]. According to [2] the benefits from using the cotton stalks are (general such as Renewable raw material to boards industries, Generation of Rural Employment, Many people will be involved on daily wages in collecting, cleaning and chipping cotton stalks, and Industry employs people in factories and transport, and Environmental Benefits [3] explained that a good quality Kraft paper, can be prepared by digesting cotton plant stalk chips. The international length of stem or branch of atypical upland variety exceeds 0.15 m (6 in) under the best of growing conditions, and is usually less than 0.07 m (3 inch) at the extreme. Destruction of old roots and stems is needed to combat plant diseases. Manual pulling of cotton stalks is difficult and time consuming for the manual power which could be devoted to some other productive work. Therefore, planning, and development are needed to develop equipments and methods to meet the requirements of stalks clearing. [4] Stated that in conventional method, remained cotton stalks and their roots were removed using deep tillage and roots were gone under the topsail during forward movement of tractor. [5] Explained that the chain type stalks chopper which is pulled by a tractor is used methods, cotton stalks and their roots were removed using deep tillage. The roots were therefore buried under the tops oil during forward movement of tractor by passing roots, whereas the remains were mixed with the soil. The disadvantages of conventional method are therefore spending more money and time to perform deep tillage. [6] Tested a tool carrier single shank and a blade which had 80 cm cutting width and cut two rows at same time. [7] In his development of stalk pulling machine utilized the idea of cutting roots by a u-shape cutting blade having 36 cm cutting width. Plus a pulling mechanism, which consists of two cylindrical rollers and none of these blades were really satisfactory to provide the first step of cutting the root and the removal of stalks. This research was therefore undertaken in order to overcome this problem. The study main objective is to design and construct equipment for pulling cotton stalks, and evaluate its performance.

2. MATERIALS AND METHODS

The research contains two experiments:

1- Design and fabrication of the implement.
2- Field test performance.

2.1 Design Components and Units Working Mechanism

The implement was designed and fabricated from series of disc blades mounted on a frame or main chassis, Fig. (3.1). each two discs were placed in front of each other and were set at a tilt angle. Distance between discs at the nearest point to each other should be equal to maximum diameter of stalks (1.5-2cm).

Fig. 3.1 General view of the implement

The disc blades used are conical and has outside surface flattened to a specific angle (Fig 3.2). The rotary discs were well tangent to increase discs and soil movement and although discs were even driven when pulling, stalks from soil are continued.

Fig. 3.2 Conical disc

Discs are fixed on flanges and the flanges are connected to the mechanism by axles, so when the tractor pull the discs, the cotton stalks between two discs will exposed to the pulling forces. Hence, the cotton roots were been loosened and could easily be removed from the soil. The shank is tangent to horizontal beam of chassis. The frame is connected to the tractor by three points hitch, hence rake angles could be adjusted by screwing in or out.

2.2 Field Performance Test

The field test was conducted at Gezira Scheme (Sudan); Hawasha No 899 Elglagla, major block no 20, Figs. (3.3, 3.4 and 3.5). The cotton species used in the test was long staple cotton.

Fig. 3.3 Cotton Stalks Before Pulling

Fig. 3.4. The equipment under operation

Fig. 3.5. Cotton stalks after pulling

2.3 Performance Parameters

Effective parameters for testing the puller are tilt and rake angles. Parameters test factors were selected in order to determine a range of chosen variable parameter while testing. The effect of their changing was recorded and evaluated. It was well documented that equipment performance parameters is a function of discs penetration depth rate, width of discs, length of stalks, the harvested amount of cotton stalk per hour, disc involvement area, and involvement area conditions. Construction of the equipment which should give these changes was designed. The blades of the equipment are somewhat smaller than those of standard disc plough (0.52m diameter). The minimum proper value of rake angle was found by using three levels of rake angles degrees; (15- 20 – 25). (Figs.3.6 A, B). The maximum allowed rake angle was determined. Rake angle was determined so that engagement zone should remain under the soil while increasing of rake angle. Because of stalks pulling up function would ended in first half of engagement from primary engagement point to middle engagement point, hence the middle engagement point must remains under the soil. Accordingly, the maximum allowed rake angle was calculated. Through increasing discs penetration, the pressure on plates will increase and so will the engagement of discs with soil. Maximum proper penetration depth of discs was determined, which was found equal to effective root depth from 0.06 to 0.15 m. Range of allowed rake angle will be eliminated in each tilt angle. It was found that the result of increasing tilt angle, entrance width increased and pulling up height reduced, hence three levels of tilt angles were used (20 – 25 – 30) degrees, Fig. (3.7). Test and evaluation of implement performance was performed using a split plot design experiment with two factors; Tilt and the Rake angles arranged in a completely randomized block design. The size of plots was equal to the implement width (1.80m) at length of 100.00 m. The distance between plots is 2.00 m. Three replications were used in length way. Each factor was therefore tested and evaluated.

Fig. 3.6A. Adjustment of rake angle

Fig. 3.6B. Adjustment of rake angle

Fig. 3.7. Adjustment of the tilt angle

2.4 Operation Speed, Time, the Harvested Amount of Cotton Stalks and Fabrication Cost

In each replication, operation speed was measured by monitoring a stopwatch. A comparison between the implement and the hand pulling was made. Also, the weight of the harvested amount of stalk per hour was determined using a balance. The time required by the implement to achieve the pulling operation was calculated and compared to the hand pulling method using a stopwatch. Also, the total fabrication cost of the implement was determined.

3. RESULTS AND DISCUSSIONS

The experiment obtained data were analyzed using SPSS software. Analysis of variation (ANOVA) shown in Table (4.1) revealed a significant variation of the tilt angle at the 0 .001 level of probability. Also, significant difference between some of the treatments and their interactions were recorded at the 0.05 level of probability.

Table 4.1. Anova tilt angles

Sig	F	Mean Square	df	Type III Sum of Squares	Source
.001	10.160	74.037	2	148.074[a]	Corrected Model
.000	29373.398	214045.037	1	214045.037	Intercept
.001	10.160	74.037	2	147.074	Tilt
		7.287	24	174.889	Error
			27	214368.000	Total
			26	322.963	Corrected Total

Table 4.2 below shows that the maximum percentage of pulled stalks (94%) is related to third factor of tilt angle treatment (30degree) and is significantly different with others.

Table 4.2. Percentage of efficient of stalks pulled at different tilt angles

Minimum	Maximum	Median	Std. Deviation	N	Mean	tilt angle (degree)
83.00	91.00	87.0000	2.5712	9	87.1111	20
82.00	93.00	89.0000	3.6056	9	87.6667	25
90.00	94.00	92.0000	1.5000	9	92.3333	30
82.00	94.00	90.0000	3.5244	27	89.0370	Total

As shown in the Fig. 4.1, the results showed that the pulled after Tilt 25 degree increased and reached the maximum at Tilt 30 degree in agreement with the results of [8]. Also, the results agreed with [9] who stated that performance of 30 - 32 degrees shows the best equipment performance. Therefore, the appropriate selection for the tilt angle is 30 degrees.
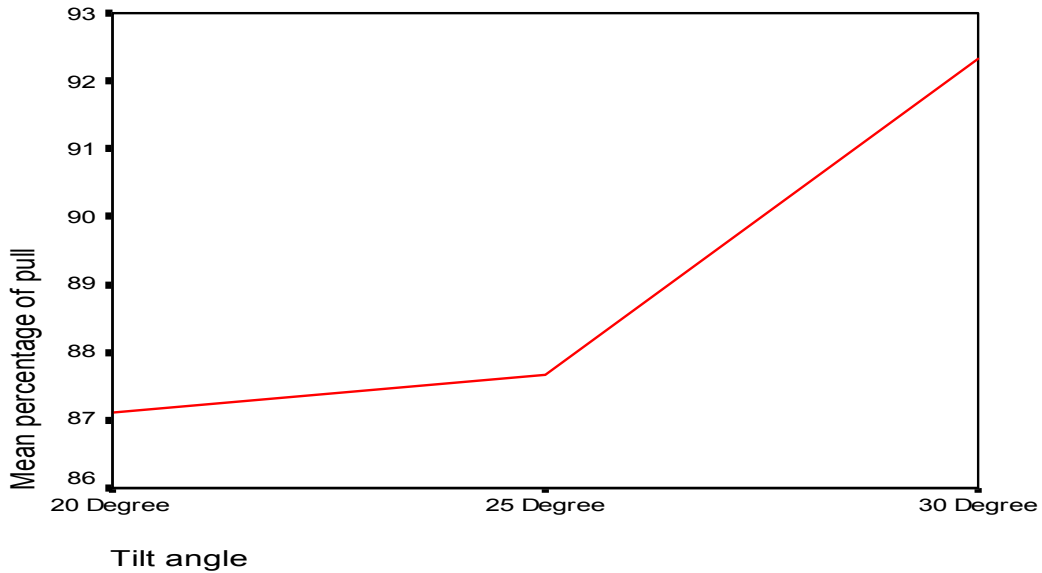
Fig. 4.1. pulled stalks (%) versus Tilt angles

Analysis of variance (ANOVA) shown in table (4.3) revealed that there is no significant difference between some of the treatments and their interactions.

Table 4.3. ANOVA Rake Angles

Sig	F	Mean square	df	Sum of squares	Source
0.997	0.003	3.704E-02	2	7.407E-02a	Corrected Model
0.000	15909.748	214045.037	1	214045.037	Intercept
0.997	0.003	3.704E-02	2	7.407E-02	RAKE
		13.454	24	322.889	Error
			27	214368.000	Total
			26	322.963	Corrected Total

The levels of rake angle treatments in are shown in Table 4.4, which reveals that there is no significant difference between selected angles. But, the maximum percentage of pulled stalks (89.1) is at 20 degree.

Table 4.4 Percentage of efficient of stalks pulled at different rake angles

Mini	Maxi	Median	Std.Dev	N	Mean	(Degree)
82.00	94.00	90.0000	4.4441	9	89.0000	15
85.00	94.00	89.0000	3.0596	9	89.1111	20
83.00	93.00	90.0000	3.3541	9	89.0000	25
82.00	94.00	90.0000	3.5244	27	89.0370	Total

This result represents proper penetration of discs in the angle of 20 degree Fig. 4.2.
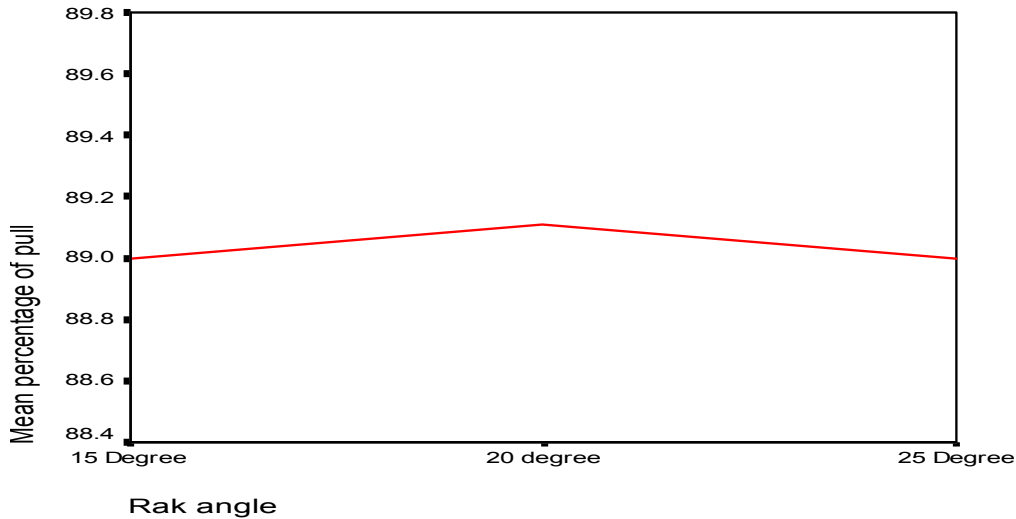

Fig. 4.2. pulled stalks (%) - Rake angles

Interactions of tilt angles and rake angles are significant at the 0.01 level of probability and it's less than probability and that explain the maximum percentage of pulled stalks. In the level of tilt angle 30 degree selected with a rake angle 20 degree, it was found that the efficiency percentage of the pulled stalks was 94%.Table (4.5).

Table 4.5. ANOVA interaction Tilt and Rake angles

Sig	F	Mean square	df	Type III sum of squares	Source
.000	9.470	32.620	8	260.963a	Corrected Model
.000	62142.108	214045.037	1	214045.037	Intercept
.000	21.495	74.037	2	148.074	Tilt
.989	.011	3.704E-02	2	7.407E-02	RAK
.001	8.188	28.204	4	112.815	Tilt * RAKE
		28.204	18	62.000	Error
		3.444	27	214368.000	Total
			26	322.963	Corrected Total

3.1 Working Speed, Harvested Amount of Cotton Stalks and Cost of the Implement

The tractor speed was 2.80 km/hr and so the time required to pull out the stalks in one Hawasha is 3 to 4 hours while the hand pulling needs about 7 to 8 days. The harvested amount of cotton stalks per hour manually and by using the equipment was found to be 430kg and 5160kg, respectively.

The fabrication cost of the implement is 3000 SDG (500$) and the cost required to pull out the stalks per faddan by the equipment is 50 SDG while the work using manual pulling needs 200 SDG.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The cotton stalk puller equipment was designed and fabricated and field performance test was done by testing the effect of the implement using the two parameters of Tilt and Rake angles. The highest percent efficiency was found to be 94% which was achieved by 30 degrees tilt angle. The tilt angle, on the other hand scored 89.1% at 20 degrees.

4.2 Recommendations

The following recommendations could be concluded for future work:

1-Collector system can be added for an industrial manufacturing.
2-More pulling units can be added to increase implement field capacity.
3-A leveling mechanism to the soil surface after pulling can be added.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Manian, Rao MK. Kumar S, Kathirvel K. Efficiency of cotton stalk Puller as influenced by forward speed wheel, rotational speed and wheel tilt angle. India Tamil – Nadu. Agricultural University; 1999.
2. Patil G, Shaik H, Balasubranarrya M. Liker P, Varadarjan V. Cotton plant stalk–An Alternative Raw material to Board on cotton industry. Central institute for research on cotton technology. Mumbai 400019 India; 2006.
3. Sheikh AJ, Varadarajan PV. Pulp paper and corrugated boxes from cotton stalks. Central Institute for research on cotton technology Mumbai; 2006.
4. Borchard MA. Apparatus and method for removing plant stalks from a field and shredding the plant stalks. U.S patent 2001;6185919.
5. Cevdet S. Kaplan F, Refik P. Astudy on the chopping and mixing of cotton stalks. African Biotechnology. 2009;9:477.
6. Elzubeir A an investigation into the mechanization of cotton pushes pulling MSC thesis Khartoum University; 1966.
7. Mahmoud AR. Development of a stalk pulling machine Iowa State University of Science and Technology; 1968.

8.   Mostofi S, Minae. Evaluation of a cotton stalk Puller Performance. Am Eurasians. Sustain; 2008.

9.   Kepner AR. Bainer, Barger EI. Principles of Farm Machinery. Long man. 1992;1.

_____