MANUFACTURE AND PERFORMANCE EVALUATION OF A CIRCULAR SAW MOWER FOR CUTTING SOME CROP RESIDUES

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ABSTRACT

The object of the present study was to manufacture and evaluate a small self propelled machine for cutting some crop residues grown during Egyptian summer season. It consists of twin saw circular discs and transmission system to transmit the rotating motion from the machine engine to the saw circular discs. This machine was constructed and evaluated to find out the optimum operating parameters for cutting cotton, maize and sunflower residues at four saw disc rotating speeds of 1500 (19.50), 1800 (23.40), 2100 (27.30) and 2500 (32.50), rpm (m/s); four machine forward speeds of 0.8, 1.0, 1.2 and 1.5 km/h and four average stalks moisture contents of 18.45, 25.15, 31.20 and 42.10 %; 29.32, 37.66, 41.26 and 53.41 % and 17.88, 23.27, 29.35 and 40.63 % for cotton maize and sunflower stalks, respectively. The obtained results revealed that: Field capacity and cutting height increased as the kinematic parameter decreased. Field efficiency and cutting efficiency increased as the kinematic parameter increased. Required power and consumed energy decreased as the kinematic parameter decreased. Kinematic parameter of 81.98 recorded minimum criterion cost. Stalks moisture contents of 31.20, 41.26 and 29.35 % considered the suitable values for cutting cotton, maize and sunflower residues, respectively.

1. INTRODUCTION

Cotton, maize and sunflower are the most important crops planted across all Egyptian summer fields. The cutting of stalks is an important process after harvesting period to clear the fields to be prepared for the next winter crops. The sickle, scythe, knife and hoe which were old traditional tools have been replaced by stalk cutting machines. These are the reciprocating types and the rotary impact types. The latter is being increasingly used in these operations due to its simplicity in construction, low maintenance cost and ability to cut both small and large diameter stalks (**McRandal and McNulty, 1978**). **Awady et al. (1986)** investigated the performance of rotary harvester in cutting cotton stalks by changing the forward speeds and the cutter cover. The rotary harvester was tested with a cutting saw have 25 cm diameter, from 600 to 1500 rpm and 60 teeth.

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The height of stubbles and the number of remaining uncut stalks were registered for the evaluation. They found that the low speed of 0.75 km/h gave clean cut with high cutting efficiency of 93.3 %. A high speed of 1.35 km/h gave a ruptured cut with low cutting efficiency of 83.3 %. Also, the forward speed of 1.15 km/h gave the optimum rate of performance and field efficiency. **Sahar (1988)** mentioned that the use of big machinery for cutting crop residues is inappropriate for the following reasons: a) It needs high technical experience for operation and maintenance. b) High capital requirements. And c) Low field efficiency in small holdings and losses of straw are high on irregularly furrowed soils. **Imbabi (1992)** designed and developed a rotary harvester to be suitable for the reaping of sesame in the Egyptian farms circumstances. The designed and manufactured harvester was tested and evaluated with taking into consideration the followings: single and double cutter discs having 9, 12 and 16 inch diameter, different forward speeds and different rotary speeds. The results could be summarized as: height of plant stubble after cutting ranged from 9.0 to 11.9 cm, field capacity ranged from 0.10 to 0.20 fed/h, field efficiency ranged from 70 to 90 %, the energy requirements ranged from 100 to 400 kW.h/fed and the cost ranged from 15.81 to 59.58 LE/fed. **Morad (1995)** stated that the proper adjustment of kinematic parameter for the rotary mower during the mowing operation is of great importance to increase crop yield and decrease cost requirements. Decreasing the rotary mower kinematic parameter lead to increase field capacity and cutting height, while decreased field efficiency, cutting efficiency, fuel consumption and energy requirements. Rotary mower kinematic parameter value of 25 minimized the mowing cost. **Imbabi (1997)** tested three shapes of cutter blades namely: cutter discs, circular saw and cutter blade in cutting maize stalks. He found that using circular saw is preferable at forward speed of 0.83 km/h and rotary speed of 1200 rpm (kinematic parameter of 83.22) which gave the highest cutting efficiency of 97.4 %, actual field capacity of about 0.1 fed/h, useful time efficiency of 78.11 %, energy required of 104.10 kW.h/fed and lowest cutting cost of 11.50 L.E/fed. **Chattopadhyay and Pandey (2001)** reported that the energy required for the cutting unit of stalk cutter may be categorized as: friction in the moving parts of the machine and air friction; kinetic energy required to accelerate the chopped material; energy required to overcome friction of the chopped material against the stationary parts of the machine; and energy required to cut the stalk. **Lungkapin et al. (2007)** indicated that the highest cutting quality of cassava cutting unit at more than 60 number of circular saw teeth when operated at faster than 1200 rpm cutting shaft speed and slower than 50 rpm cam shaft speed. Cutting capacity depended on cam shaft speed. At 50 rpm cam shaft speed, minimum cutting capacity was found to be 5034 stakes per hour (40272 stakes per day of 8 h) with 83.91% cutting efficiency. **Hoseinzadeh et al. (2009)** showed that the effects of wheat variety, knife bevel angle, moisture content and shearing speed on shearing energy were significant ($P<0.01$). Shearing energy decreased with decreasing moisture content and bevel angle and with increasing shearing speed. Maximum shearing energy was obtained with Kohdasht variety at 0.86 MJ mm^{-2}. **Tavakoli et al. (2009)** found that an increase in moisture content of straw lead to a decrease in the bending strength and Young's modulus and an increase in the shear strength and specific shearing energy in weight straw. The aim of this work is to construct and evaluate a self-propelled machine for cutting cotton, maize and sunflower stalks in terms of cutting efficiency, field capacity and efficiency, energy and cost requirements as a function of change in saw disc speed, machine forward speed and stalks moisture contents.

2. MATERIALS AND METHOD

Field experiments were carried out at private farm in Damietta governorate during the summer season of 2010 to construct and evaluate the performance of a **s**elf-propelled cutting machine with twin rotating saw discs in the same direction.

2.1. MATERIALS:

2.1.1. Crop residues:

The crop residues used through the tests were cotton, maize and sunflower stalks having different characteristics, shown in Table 1.

Table 1. Characteristics of crop residues.

Crop characteristics	Crop residues			Unit
	Cotton	Maize	Sunflower	
Crop variety	Giza-86	Giza-122	Giza-102	----
Av. Stalks length	104.85	180.28	192.45	mm
Av. Stalks diameter	11.5	25.1	2٦.٨	mm
Av. Stalks population	11.6	8.3	7.6	Stalks/m^2

2.1.2. Cutting machine:

A self propelled cutting machine was constructed and evaluated to overcome the problems appearing at using the traditional method for pulling or cutting cotton, maize and sunflower stalks manually with hand tools, which consumed more time, effort and cost. Also, the use of tractor with ordinary attached cutter bars or rotating discs machines could be compact the soil layers due to its heavy weight. To overcome these problems, a small self propelled machine was manufactured and evaluated to give the best cutting efficiency, adequate field capacity and efficiency, save energy consumed and total cost requirements, and also reduce soil compaction to the minimum values. The overall specifications and top view of the constructed cutting machine were given in Table 2, Fig.1. and Photo 1.

Table 2. Overall specifications of the constructed saw cutting machine.

• Machine:	
Model	Stiga Villa (Sweden made)
Gear box (Fast-Slow)	(5 forward & 1 reverse) speeds
Power	12.5 hp (9.38 kW)
Rated speed	3200 rpm
Fuel	Benzene
Working width	120 cm
Overall length	260 cm
Overall width	100 cm
Overall height	120 cm
• Cutting device:	
Saw disc (Same direction)	2
Swath bar	2
Gear box	2
Pulleys (one double and two single)	3
V-belt	2

The cutting device of the constructed machine consists of the followings:

a- Saw discs: The cutting machine have two serrated metal saw discs, each disc have diameter of 250 mm, thickness of 1.2 mm and 40 teeth number. The two discs rotate in the same direction through a gear box and two pulleys having diameter of 100 mm and two other pulleys having diameter of 50 mm with connecting two V belts shown in Fig.1. and Photo 2.

b- Dividers: The developed cutting machine has two dividing units, each two dividers were fixed with the main frame. These dividers have a triangular shape and tapered front section to collect, catch and guide the stalks toward the saw circular disc. The machine includes two such units which has the following geometric dimensions, shown in Fig.1. and Photo 2.

- Length: is the horizontal length between the front and the rear ends, 640 mm.
- Height: is the vertical length between the two divider edges, 100 mm. The rear side of the divider connected to the main frame.

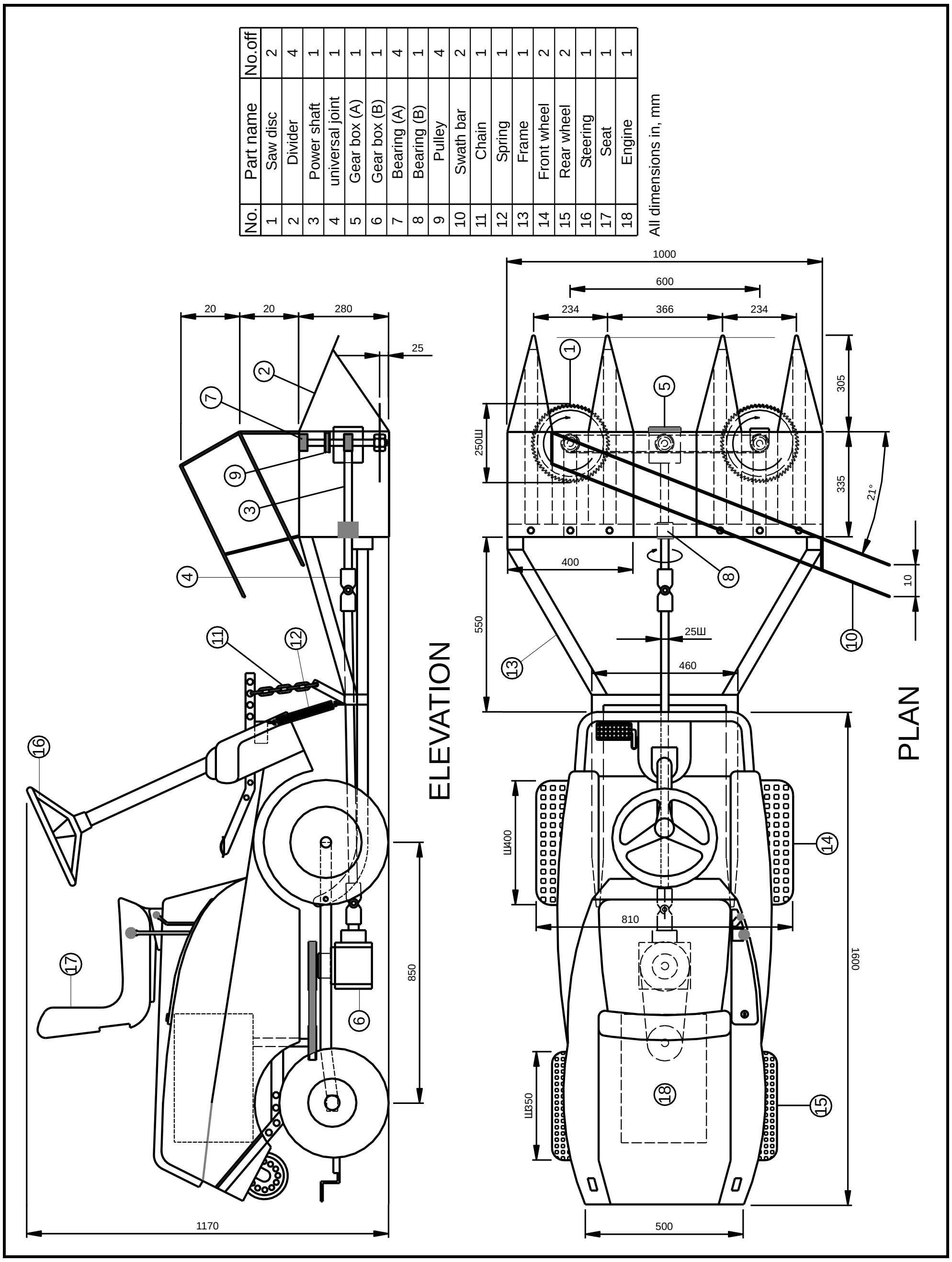


Fig.1. Elevation and plan of the developed saw disc-cutting machine.

- Forward peach: is the forward distance between the center line axis of two dividers in the same unit, 234 mm, and 600 mm between the center line axes of the two units.

Photo 1. The constructed cutting machine.

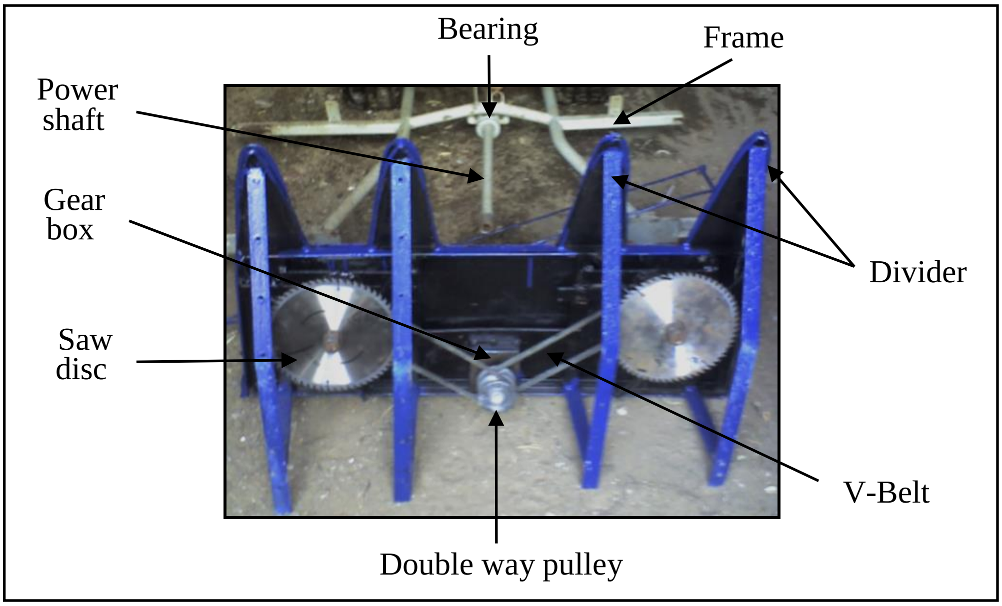


Photo 2. The constructed cutting device.

c- Swath bar: Two swath bars were fixed above the cutting unit to transport the cutting stalks at the right side of the machine. The swath bars made from steel, each one has dimensions of 5 mm in diameter and 1150 mm in length. The vertical distance between the two swath bars is 200 mm, while the horizontal distance is 100 mm and the inclination angle of the rear end to the front is 21° to keep the cutting stalks moving to the right side of the machine in a vertical position and also keep the stalks away from the operator. Fig.1 and Photo 1.

d- Transmission system: The power is transmitted from the machine engine to the saw rotating discs as shown in Fig. 2.

- 3000 rpm at engine pulley which has diameter of 112 mm can be transmitted to gear box (B) pulley having diameter of 150 mm using V-belt between the two pulleys to be equal 2100 rpm, with reduction ratio of 1: 1.43.
- 2100 rpm at gear box (B) pulley transported to the power shaft through a universal joint having length of 980 mm.
- The power shaft transport its motion to the cutting saw discs through a small gear box (A) with constant ratio of 1: 1.

No.	Part name	No.off	No.	Part name	No.off
1	Saw disc	2	7	Bearing (B)	1
2	Hex. Nut	4	8	Universal joint	1
3	Gear box (A)	1	9	Gear box (B)	1
4	Pulley	4	10	Gear box (B) pulley	1
5	Bearing (A)	4	11	Engine pulley	1
6	Saw shaft	2	12	Machine engine	1

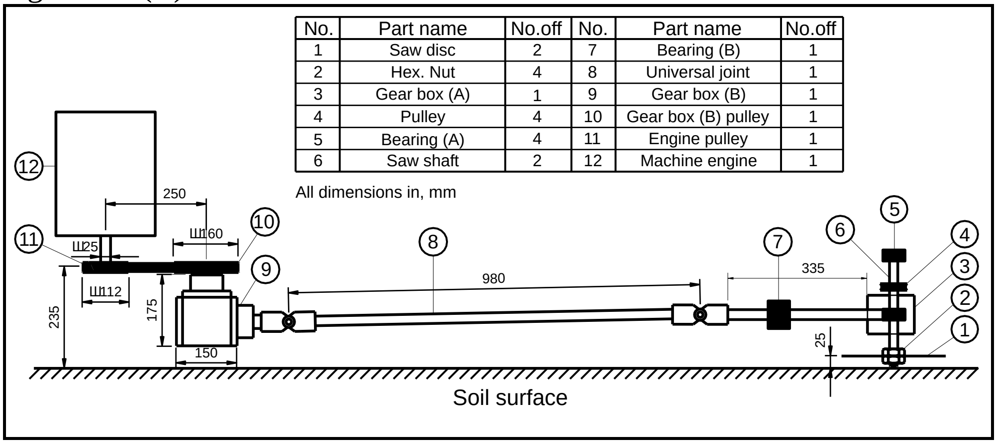


Fig. 2. Power transmission from machine engine to saw the discs.

<u>2.2. METHOD:</u>

The present study was conducted to investigate the optimum relation between speed of circular saw and machine forward speed (kinematic parameter) and their affect on maximum cutting efficiency, energy consumed and cutting cost for different crop stalks. The tungsten carbide tipped circular saw available in local market with (60 numbers of teeth and diameter of 250 mm) was used in laboratory and field tests. The total experimental area was about 5.5 feddans divided into three sub blots of 1.75 feddans for cotton, maize and sunflower residues. The constructed cutting machine was operated at each crop after harvesting period and the stalks were ready to remove. The cutting machine was evaluated taking into consideration the following parameters:

- Types of crop residues: cotton, maize and sunflower stalks.
- Saw disc rotating speeds: 1500 (19.50), 1800 (23.40), 2100 (27.30) and 2500 (32.50) (m/s) rpm.
- Machine forward speeds: 0.8, 1.0, 1.2 and 1.5 km/h.
- Stalks moisture contents: cotton (18.45, 25.15, 31.20, and 42.10 %), maize (29.32, 37.66, 41.26 and 53.41 %) and sunflower (17.88, 23.27, 29.35 and 40.63 %) in average.

The moisture contents of stalks were measured according to ASAE Standard S.352 (**ASAE, 1979**) in laboratory of faculty of agriculture, Zagazig University. The sample of stalks (from one third at the bottom part) was kept in an oven for 24 hours at 105 °C. The loss in weight of the sample was recorded and the moisture content in percent was determined as in equation (1).

$$M.C_{wb} = (W_i \times W_d / W_i) \times 100 \quad (1)$$

Where: $M.C_{wb}$ = moisture content, (%).

W_i = Initial weight of sample, (kg). W_d = dried weight of sample, (kg).

2.3. MEASUREMENTS:

2.3.1. Cutting efficiency: was calculated using the following formula:

$$E_C = \frac{A - B}{A} \times 100 \quad (2)$$

Where: E_C = Cutting efficiency, (%).

A = Height of plant stalks above the soil before cutting, cm.

B = Height of plant stalks above the soil after cutting, cm.

2.3.2. Actual field capacity: was the actual average time consumed during digging operation (lost time + productive time). It can be determined from the following equation:

$$F.C_{act} = \frac{60}{Tu + Ti}, \quad \text{fed/h} \quad (3)$$

Where: $F.C_{act}$ = Actual field capacity of the cutting machine.

T_u = Utilization time per feddan in minutes.

T_i = Summation of lost time per feddan in minutes.

- Field efficiency: was calculated by using the values of the theoretical field capacity and effective field capacity rates as:

$$\eta_f = \frac{F.C_{act}}{F.C_{th}} \times 100, \quad \% \quad (4)$$

Where: η_f = Field efficiency, %.

2.3.3. Energy consumed: To estimate the engine power during cutting process, the decrease in gasoline fuel level in fuel tank accurately measuring immediately after each treatment. The following formula was used to estimate the engine power (**Hunt, 1983**):

$$EP = \left[F.C\left(1/3600\right)\rho f \times L.C.V \times 427 \times \eta_{thb} \times \eta_m \times (1/75) \times (1/1.36)\right], \text{kW} \quad (5)$$

Where: F.C = Fuel consumption, (l/h).

ρf = Density of fuel, (kg/l), (for gasoline = 0.72).

L.C.V = Calorific value of fuel, (11.000 k.cal/kg).

η_{thb} = Thermal efficiency of the engine, (for Otto engine, 25%,).
427 = Thermo-mechanical equivalent, (kg.m/k.cal).
η_{m} = Mechanical efficiency of the engine, (for Otto engine, 85%).
The energy can be calculated as following:

$$\text{Energy consumed} = \frac{\text{Engine power, (kW)}}{\text{Actual field capacity, (fed/h)}}, \quad \text{kW.h/fed} \qquad (6)$$

2.3.4. Cutting cost: The operating cost of spreading operation was estimated using the following equation (**Awady et al. 1982**):

$$\text{Operating cost} = \frac{\text{Machine cost(L.E/h)}}{\text{Actual field capacity (fed/h)}}, \quad \text{L.E/fed} \qquad (7)$$

Machine cost was determined by using the following equation (**Awady, 1978**):

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (1.2\,W.S.F) + \frac{m}{144} \qquad (8)$$

Where:

C = Hourly cost, L.E/h.
P = Price of machine, L.E.
h = Yearly working hours, h/year.
A = Life expectancy of the machine, y.
i = Interest rate/year.
1.2 = Factor accounting for lubrications.
t = Taxes, over heads ratio.
W = Engine power, hp.
r = Repairs and maintenance ratio.
F = Fuel price, L.E/l.
m = Monthly average wage, L.E
S = Specific fuel consumption, l/hp. h.
144 = Reasonable estimation of monthly working hours.

The criterion cost was determined using the following equation **(Awady et al. 1982)**:

Criterion cost = (operating cost + product losses cost), L.E/fed (9)

Product losses cost = (stalk yield/fed)(100-η_{cut})(stalk price/kg), L.E/fed (10)

3. RESULTS AND DISCUSSION

From the pre experimental tests, it could be noticed that the circular saw could be rotated at maximum speed of 3000 rpm at different machine forward speeds, which represents different kinematic parameters as shown in Table 3. It was observed that the kinematic parameter around 80 is the suitable one, which gave a clean cutting shape and adequate cutting efficiencies in different crop stalks. So that, the constructed cutting machine was operated under constant saw rotating speed of 2100 rpm (27.30 m/s) and different forward speeds to investigate the effect of saw rotating speed, machine forward speed (kinematic parameter) and type of crop residues and their moisture contents on machine performance.

Table 3. Kinematic parameters at different saw rotating speeds and different machine forward speeds.

Machine forward speed		Saw disc rotating speed, (rpm)			
		1500	**1800**	**2100**	**2500**
		Saw disc linear speed, (m/s)			
(km/h)	**(m/s)**	**19.50**	**23.40**	**27.30**	**32.50**
0.8	**0.222**	87.84	105.41	122.97	146.40
1.0	**0.278**	70.14	84.17	98.20	116.91
1.2	**0.333**	58.56	70.27	81.98	97.60
1.5	**0.417**	46.76	56.12	65.47	77.94

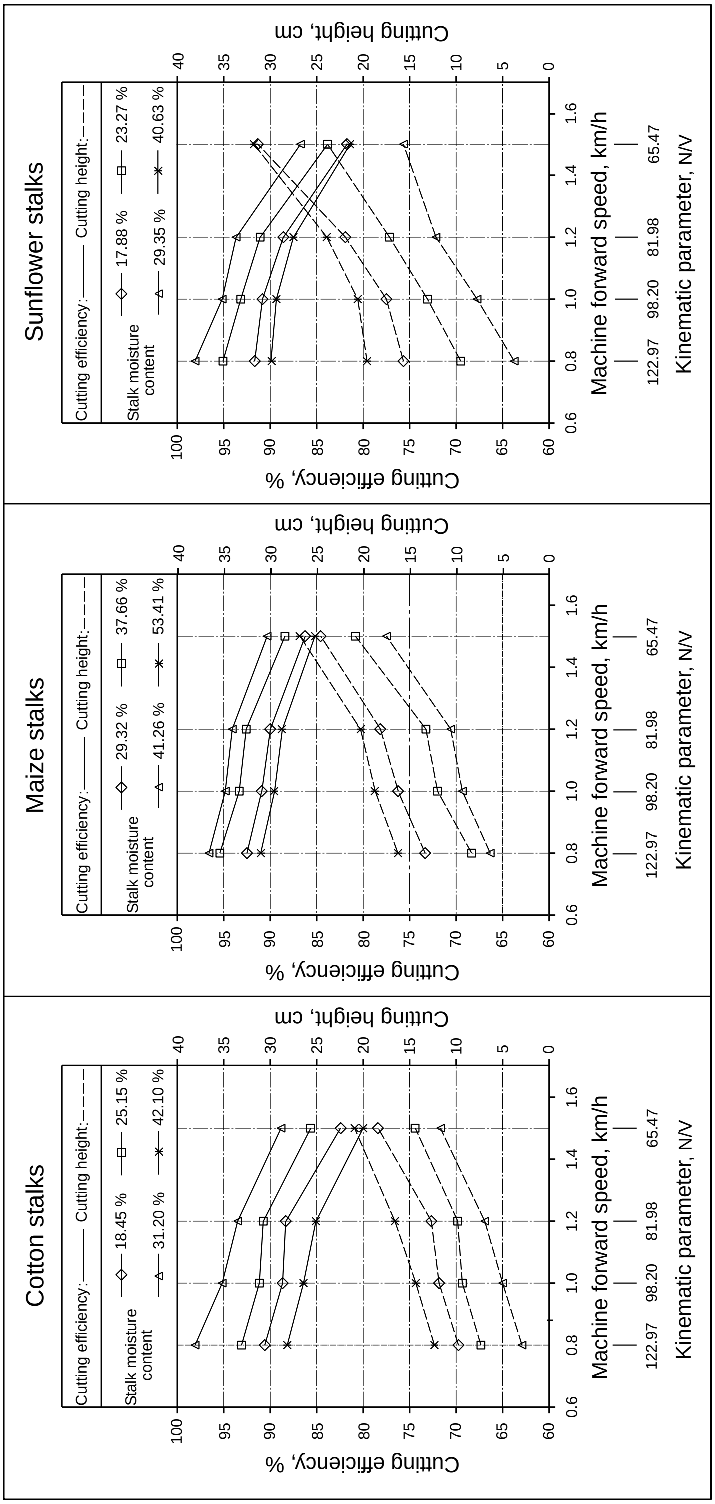
3.1. Cutting height and cutting efficiency:

3.1.1. Effect of kinematic parameter on cutting height and cutting efficiency:

Fig.3. presents the relationship between kinematic parameter and both cutting height and cutting efficiency at different crop stalks and different moisture contents. Results show that the cutting efficiencies decreased with decrease in kinematic parameter and their maximum values of 97.15, 96.55 and 98.05 % corresponding to high kinematic parameter of 122.27 with cutting heights of 2.99, 6.22 and 3.75 cm at different stalks moisture contents of 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively. While the minimum values of the cutting efficiencies were 80.00, 85.10 and 81.42 % with cutting heights of 20.97, 26.86 and 35.76 cm at low kinematic parameter of 63.93 at different stalks moisture contents of 42.10, 53.41 and 40.63 % for cotton, maize and sunflower, respectively. The decrease in cutting efficiency at low kinematic parameter can be explained by the fact that at higher forward speed the impact force was small to sufficiently cut the stalks.

3.1.2. Effect of stalks moisture content on cutting height and efficiency:

Fig.3. shows the effect of stalks moisture content on cutting efficiency. The optimum values of moisture contents, which gave maximum cutting efficiencies of 97.15, 96.55 and 98.05 % (cutting heights of 2.99, 6.22 and 3.75 cm) were 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively. Any further decrease less to or increase more than these values, the cutting efficiency decreased to 90.65, 92.65 and 91.80 % ; 88.25, 91.00 and 89.85 % since the cutting height increased to 9.80, 13.25 and 15.78 cm; 12.32, 16.23 and 19.53 cm for cotton, maize and sunflower, respectively. Decreasing stalks moisture content under the optimum values lead to decrease cutting efficiency due to uneven conditions to operate the machine since the stalks are too dry.



- Constant saw rotating speed of (2100 rpm or 27.30 m/s)

Fig.3. Effect of kinematic parameter on cutting efficiency and cutting height at different stalk moisture contents and different crop stalk residues.

Also, increasing stalks moisture content above optimum values leads to decrease cutting efficiency due to more elastic conditions for stalks resulting in more bending and un-cutting stalks.

3.1.3. Effect of crop type on cutting efficiency:

Relating to the effect of crop type on cutting efficiency, Fig.3. illustrated that the sunflower stalks recorded the maximum cutting efficiency of 98.05 %, followed by cotton stalks of 97.15 % followed by maize stalks of 96.55 % under constant kinematic parameter of 122.97 and stalks moisture contents of 29.35, 31.20, 41.26 and % for sunflower, cotton and maize, respectively. The deference values between these cutting efficiencies were too small since the saw cutting disc clear the area smoothly and the differences may be attributed to the construction of sunflower stalks, which were very easy to cut, compared with cotton stalks followed by maize stalks.

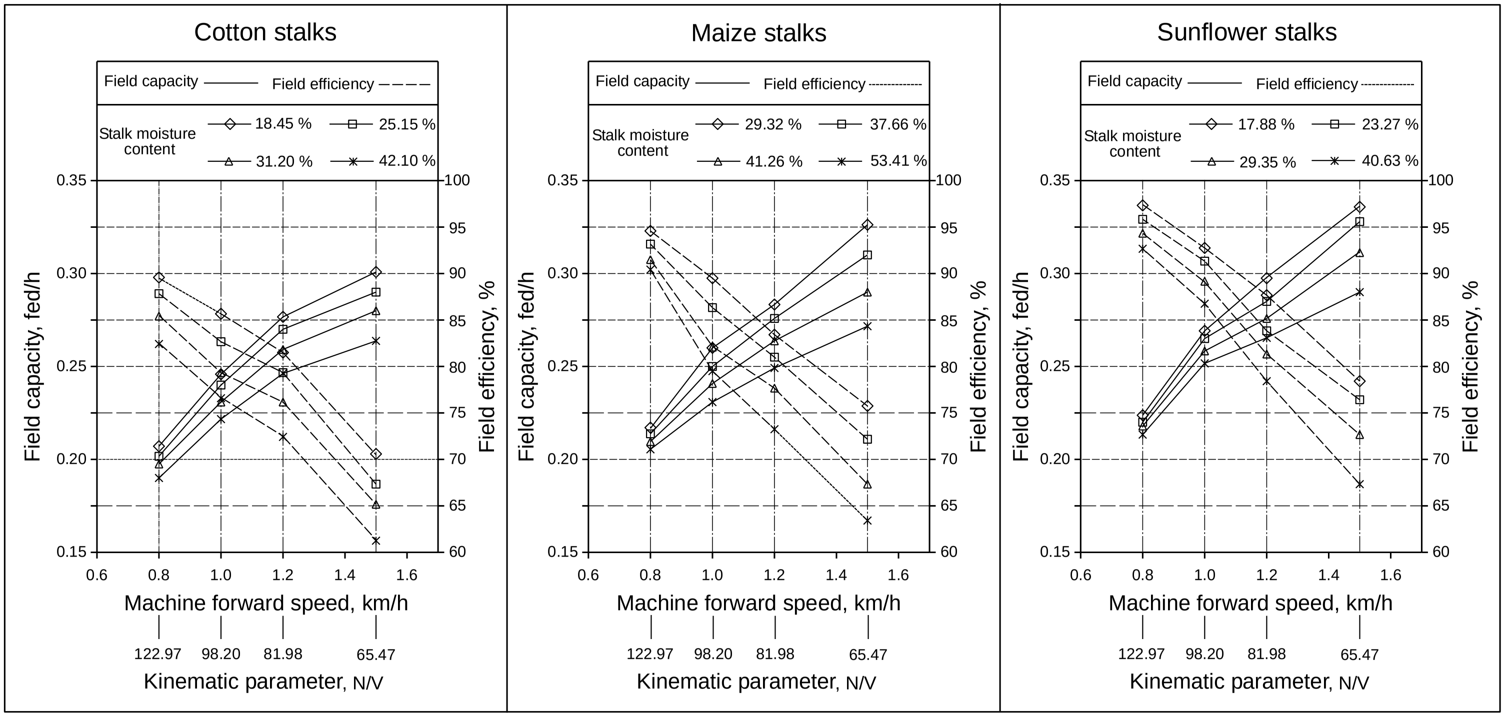
<u>3.2. Field capacity and field efficiency:</u>

3.2.1. Effect of kinematic parameter on field capacity and field efficiency:

Fig.4. show that the field capacity and field efficiency are highly affected by the change in kinematic parameter values. Decreasing the saw mower kinematic parameter from 122.97 to 65.47 increased the field capacity from 0.206 to 0.304, from 0.217 to 0.326 and from 0.224 to 0.336 fed/h, while the field efficiency decreased from 89.66 to 70.62, from 94.44 to 75.90 and from 97.22 to 78.22 % at lower stalk moisture contents of 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively. The increase in field capacities and reduction in field efficiencies by decreasing the kinematic parameter are due to the less theoretical time consumed in comparison with the other items of time loss.

3.2.2. Effect of stalks moisture content on field capacity and field efficiency:

Fig.4. shows that generally, increasing stalks moisture content led to decrease both field capacity and field efficiency at different machine forward speeds. Increasing stalks moisture contents from 18.45 to 42.10 %; from 29.32 to 53.41 % and from 17.88 to 40.63 %, led to decrease the field capacities and field efficiencies from 0.277 to 0.247, from 0.283 to 0.249 and from 0.298 to 0.266 fed/h; from 81.61 to 72.60, from 83.33 to 73.20 and from 87.65 to 78.22 % at constant machine forward speed of 1.2 km/h, for cotton, maize and sunflower, respectively. The decrease in both field capacities and field efficiencies by increasing stalks moisture content may be attributed to more elastic conditions for the stalks resulting in more resistance for cutting action.



- Constant saw rotating speed of (2100 rpm or 27.30 m/s)

Fig.4. Effect of kinematic parameter on field capacity and field efficiency at different stalk moisture contents and different crop stalk residues.

3.2.3. Effect of crop type on field capacity and efficiency:

The field capacity and field efficiency are greatly affected by the crop type. Fig.4. shows that at the same kinematic parameter of 81.98 and the optimum stalks moisture contents of 31.20, 41.26 and 29.35 %, the field capacity and field efficiency were found to be 0.259 fed/h and 72.60 % for cotton crop less than 0.264 fed/h and 77.62 % for maize crop less than 0.276 fed/h and 81.25 % for sunflower crop. These results illustrated that the good standing and no branching for sunflower and maize crops increased both field capacity and field efficiency since the cutting efficiency was also very good.

3.3. Required power and consumed energy:

3.3.1. Effect of kinematic parameter on power and consumed energy:

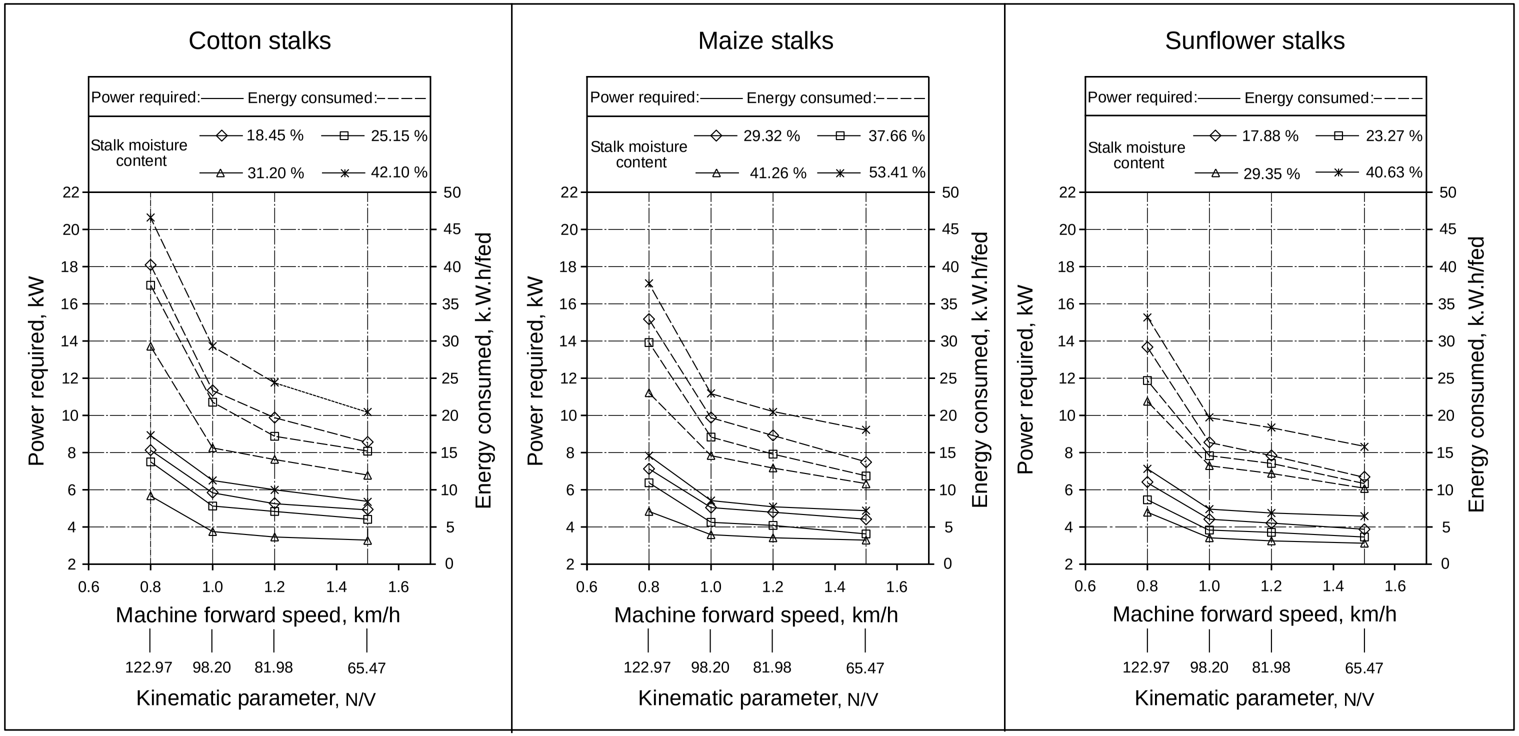
Required power as well as consumed energy is too related to kinematic parameter. Fig.5. shows that both required power and consumed energy decreased as the kinematic parameter decreased. Decreasing saw mower kinematic parameter from 122.97 to 65.47 decreased the required power from 8.29 to 4.96, from 7.11 to 4.43 and from 6.44 to 3.85 kW; from 40.26 to 16.30, from 32.76 to 13.59 and from 28.75 to 11.46 kW.h/fed, at lower stalks moisture content of 18.45, 29.32 and 17.88 % for cotton, maize and sunflower, respectively. The decrease of required power and consumed energy by decreasing the kinematic parameter may be attributed to the increase of field capacity, resulted in low values of fuel and consumed energy in the unit area.

3.3.2. Effect of stalks moisture content on power and consumed energy:

Fig.5. shows that the stalks moisture contents of 31.20, 41.26 and 29.35 % are considered the optimum values during cutting cotton, maize and sunflower, respectively which recorded the minimum required power and consumed energy of 3.31 kW, 11.82 kW.h/fed; 3.29 kW, 11.34 kW.h/fed and 3.19 kW, 10.22 kW.h/fed, respectively at lower kinematic parameter of 65.47. Any further decrease or increase in stalks moisture content less to or more than the optimum values mentioned above, both required power and consumed energy increased under all experimental conditions due to the increase in cutting resistance force lower moisture contents and increase elastic plant conditions at higher moisture contents which consumed more fuel during cutting operation.

3.3.3. Effect of crop type on required power and consumed energy:

Required power and consumed energy varied with the crop type. Results in Fig.5. shows that cotton stalks required more power and consumed energy than maize than sunflower.



- Constant saw rotating speed of (2100 rpm or 27.30 m/s)

Fig.5. Effect of kinematic parameter on required power and consumed energy at different stalk moisture contents and different crop stalk residues.

This is due to the high resistance of cotton stems-solid- comparing with maize and sunflower stems which were hollow stems. The cotton stalks recorded higher required power and consumed energy of 8.90 kW, 46.84 kW.h/fed followed by maize stalks of 7.76 kW, 37.67 kW.h/fed followed by sunflower stalks of 7.10 kW, 33.33 kW.h/fed at constant kinematic parameter of 65.47 and different stalks moisture contents of 42.10, 53.41 and 40.63 %, respectively.

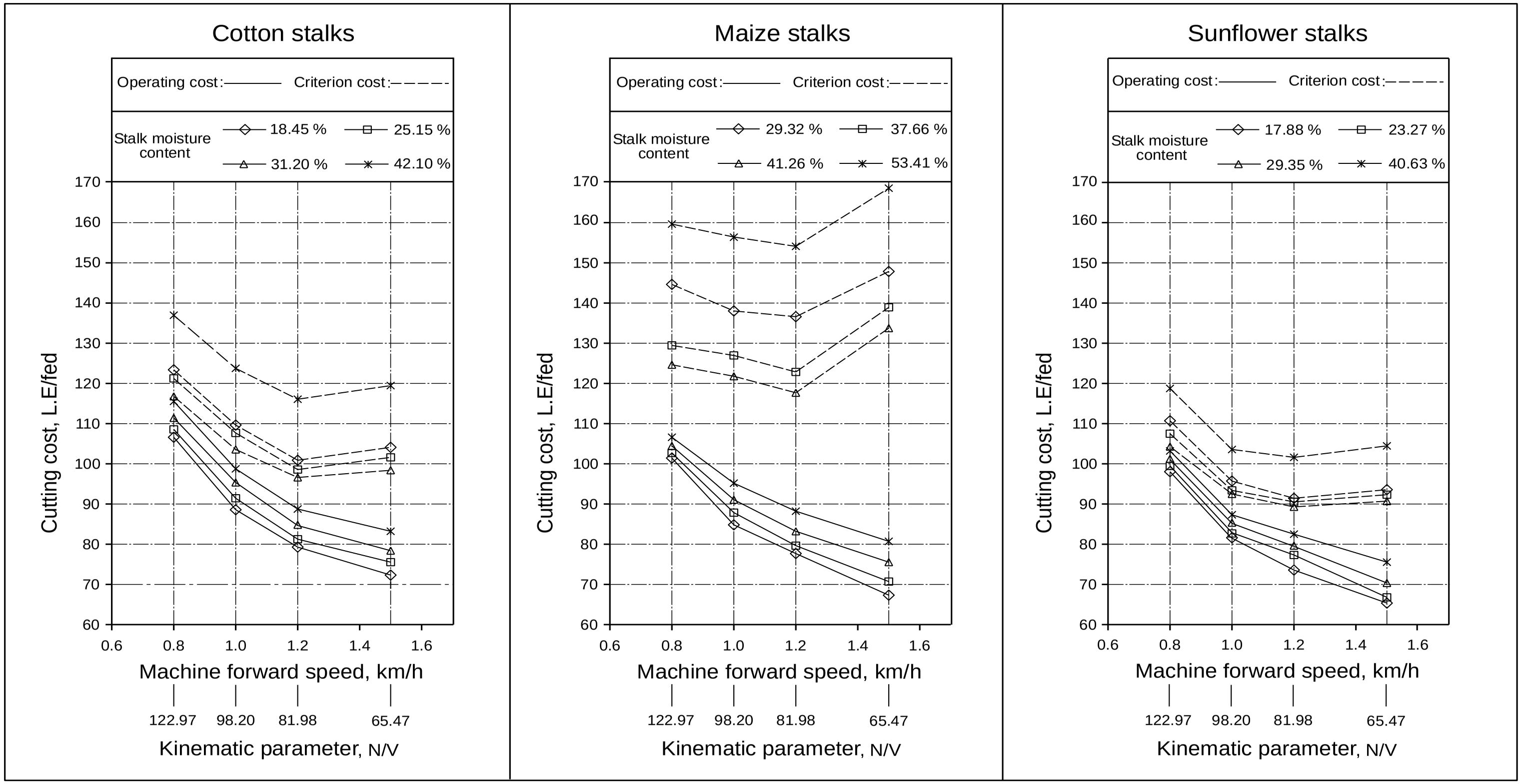
3.4. Cutting cost requirements:

3.4.1. Effect of kinematic parameter on cutting cost requirements:

Fig.6. shows that, decreasing kinematic parameter of saw mower from 122.97 to 65.47, decreased operating costs from 111.42 to 78.39, from 104.52 to 75.69 and from 101.15 to 70.35.L.E/fed at different stalks moisture contents of 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively, while decreasing kinematic parameter of saw mower from 122.97 to 81.98, decreased criterion costs from 116.61 to 96.76, from 124.81 to 117.83 and from 104.17 to 89.26 L.E/fed at different stalks moisture contents of 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively. Any further decrease in kinematic parameter from 81.98 to 65.47, the criterion costs increased from 96.76 to 98.52, from 117.83 to 132.61 and from 89.26 to 90.73 L.E/fed for cotton, maize and sunflower, respectively. The higher values of criterion costs at lower saw mower kinematic parameter were attributed to the increase of cutting height, resulting in considerable increase of stalks losses.

3.4.2. Effect of stalks moisture content on cutting cost requirements:

Fig.6. shows the effect of stalks moisture content on operating and criterion costs. The optimum stalks moisture contents which recorded the minimum criterion costs of 96.76, 117.83 and 89.26 L.E/fed, were 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively. Any further decrease in stalks moisture contents less to the optimum values led to increase the criterion costs from 96.76 to 101.01, from 117.83 to 136.36 and from 89.26 to 91.33 L.E/fed during cutting cotton, maize and sunflower, respectively. While any further increase in stalks moisture contents more than the optimum values led to increase the criterion costs also from 96.76 to 116.08, from 117.83 to 154.01 and from 89.26 to 101.82 L.E/fed during cutting cotton, maize and sunflower, respectively. The higher values of criterion costs at lower or higher stalks moisture contents were attributed to the lower values of cutting efficiencies resulting in more stalks stubbles after cutting operation.



- Constant saw rotating speed of (2100 rpm or 27.30 m/s)

Fig.6. Effect of kinematic parameter on operating cost and criterion cost at different stalk moisture contents and different crop stalk residues.

3.4.3. Effect of crop type on cutting cost requirements:

Fig.6. shows that the crop type was clearly affected on operating and criterion costs. Sunflower crop recorded the minimum criterion cost of 89.26 L.E/fed followed by cotton crop which recorded 96.76 L.E/fed followed by maize crop which recorded 117.83 L.E/fed at constant kinematic parameter of 81.98 and optimum stalks moisture contents of 29.35, 31.20 and 41.26 % for sunflower, cotton and maize, respectively.

4. CONCLUSION

A manufactured self propelled machine with two saw discs constructed at the front of the mower was evaluated during cutting operation of cotton, maize and sunflower residues versus different kinematic parameters and different stalks moisture contents. From the obtained data, it can be concluded the followings:

The proper adjustments of saw mower kinematic parameter and stalk moisture contents during cutting operation are great importance to increase cutting efficiency and decrease cost requirements. The most economical kinematic parameter is 81.98, which represents the least criterion cost per feddan during cutting cotton, maize and sunflower stalks. Decreasing the saw mower kinematic parameter increased both field capacity and cutting height, while decreased field efficiency, cutting efficiency, required power and consumed energy. The optimum stalks moisture contents, which recorded minimum criterion costs were 31.20, 41.26 and 29.35 % for cotton, maize and sunflower, respectively.

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الملخص العربي

تصنيع وتقييم أداء محشة ذات منشار دوراني لقطع بقايا بعض المحاصيل

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يهدف هذا البحث إلى تصنيع وتقييم أداء آلة لقطع سيقان المحاصيل الأكثر شيوعاً في الموسم الصيفي في دلتا مصر ألا وهي القطن، الذرة وعباد الشمس. هذه الآلة صغيرة الحجم، بسيطة التركيب وسهلة التشغيل والصيانة كما أنها مناسبة للحيازات الصغيرة والظروف المصرية. من ناحية أخرى فهي تساعد على التغلب على مشكلة نقص الأيدي العاملة في المجال الزراعي وتوفير النفقات وتجنب التكاليف العالية عند استخدام الآلات المتوسطة والكبيرة الحجم عند إخلاء الأرض من بقايا المحاصيل المختلفة.

تم تصنيع أجزاء وحدة القطع في ورشة قسم الهندسة الزراعية - كلية الزراعة - جامعة الزقازيق وتم اختبارها في أحد المزارع الخاصة بمحافظة دمياط. تتركب هذه الآلة من الأجزاء الآتية:

١- **القرص المسنن:** تحتوي هذه الآلة على زوج من الأقراص المسننة بقطر ٢٥٠ مم وسمك ١,٢ مم والمسافة الأفقية بينهما ٦٠٠ مم. تستمد الأقراص حركتها الدورانية من محرك الآلة بقدرة ٩,٣٨ كيلووات عبر صندوقي تروس ووصلة مرنة وعمود إدارة للوصول إلى سرعة القطع اللازمة.

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٢- **المجزءات:** تحتوي الآلة على وحدتين ، كل وحدة مكونة من زوج من المجزءات بطول ٦٤٠ مم وعرض ٤٠٠ مم من الجهة الخلفية وتكون مدببة من الجهة الأمامية لتسهيل دخول سيقان المحاصيل وتوجيهها إلى القرص المسنن. كما أن المسافة بين مركز الوحدتين ٦٠٠ مم لتناسب المسافة بين صفوف بقايا النباتات المطلوب قطعها.

٣- **عصا الإمالة:** عبارة عن زوج من القضبان المعدنية بطول ١١٥٠ مم وقطر ٥ مم تركب فوق المجزءات مباشرةً وبميل للخلف من الجهة اليمنى بزاوية ٢١° ومسافة رأسية بينهما ٢٠٠ مم ومسافة أفقية ١٠٠مم وذلك لتسهيل حركة السيقان المقطوعة جانبياً وتجنب سقوطها إلى أسفل الآلة.

٤- **جهاز نقل الحركة:** يقوم بنقل القدرة من محرك الآلة إلى الأقراص المسننة بالسرعة اللازمة وذلك عبر صندوقي تروس ووصلة مرنة وعمود إدارة وطارات وسيور للوصول إلى مجال واسع من السرعات الدورانية يتراوح ما بين ٧٠٠ و ٣٠٠٠ لفة/د.

تم دراسة عدد من المتغيرات لتقييم هذه الآلة بعد التصنيع والتركيب والتي تشمل استخدام ثلاث أنواع من بقايا المحاصيل هي القطن ، الذرة وعباد الشمس ؛ سرعات أمامية للآلة هي ٠,٨٠ ، ١,٠٠ ، ١,٢٠ و١,٥٠ كم/س ؛ سرعة ثابتة للقرص المسنن ٢١٠٠ لفة/د (٢٧,٣٠ م/ث) تنتج أربع معاملات كينماتيكية هي ١٢٢,٩٧ ، ٩٨,٢٠ ، ٨١,٩٨ و٦٥,٤٧. وقد تم تقييم أداء هذه الآلة من خلال القياسات التالية: كفاءة القطع ؛ السعة الحقلية والكفاءة الحقلية ؛ استهلاك الوقود ، القدرة اللازمة والطاقة المستهلكة ؛ تكاليف التشغيل والتكاليف الكلية لعملية التقطيع.

وقد أظهرت النتائج المتحصل عليها ما يلي:

- أعلى كفاءة قطع كانت ٩٧,١٥ ، ٩٦,٥٥ و ٩٨,٠٥ % عند السرعة المنخفضة ٠,٨ كم/س ورطوبة ٣١,٢٠ ، ٤١,٢٦ و ٢٩,٣٥ % والتي تحقق عندها أقل طول قطع وهو ٢,٩٩ ، ٦,٢٢ و ٣,٧٥ سم لكل من القطن ، الذرة وعباد الشمس ، على الترتيب.

- أعلى كفاءة حقلية كانت ٨٩,٦٦ ، ٩٤,٤٤ و ٩٧,٢٢ % تحققت عند السرعة الأمامية المنخفضة ٠,٨ كم/س (معامل كينماتيكي مرتفع ١٢٢,٩٧) و رطوبة منخفضة ١٨,٤٥ ، ٢٩,٣٢ و ١٧,٨٨ % ، لكل من القطن ، الذرة و عباد الشمس ، على الترتيب. بينما أعلى سعة حقلية كانت ٠,٣٠٤ ، ٠,٣٢٦ و ٠,٣٣٦ ف/س عند السرعة الأمامية العالية ١,٥ كم/س (معامل كينماتيكي منخفض ٦٥,١٢) ورطوبة منخفضة ١٨,٤٥ ، ٢٩,٣٢ و ١٧,٨٨ % لكل من القطن ، الذرة وعباد الشمس ، على الترتيب.

- حقق المعامل الكينماتيكي ٨١,٩٨ أقل استهلاك وقود ، قدرة لازمة وطاقة مستهلكة وهي ١,٧٨ ، ١,٧٥ و ١,٧٠ لتر/ف ؛ ٣,٤٩ ، ٣,٤٣ و ٣,٣٤ كيلووات و ١٣,٤٧ ، ١٢,٩٩ و ١٢,١٠ كيلووات.س/ف عند رطوبة ٣١,٢٠ ، ٤١,٢٦ و ٢٩,٣٥ % لكل من القطن ، الذرة وعباد الشمس ، على الترتيب.

- أقل تكاليف حدية تحققت عند المعامل الكينماتيكي ٨١,٩٨ وكانت ٩٦,٧٦ ، ١١٧,٨٣ و ٨٩,٢٦ جنيه/ف عند رطوبة سيقان ٣١,٢٠ ، ٤١,٢٦ و ٢٩,٣٥ % لكل من القطن ، الذرة وعباد الشمس ، على الترتيب.

- وبالتالي يوصى باستخدام آلة تقطيع بقايا المحاصيل ذات المنشار الدوراني حول المعامل الكينماتيكي ٨٠ ومتوسط نسبة رطوبة للسيقان ٣١,٢٠ ، ٤١,٢٦ و ٢٩,٣٥ % لكل من القطن ، الذرة وعباد الشمس ، على الترتيب والتي تعطي أقل تكاليف حدية للفدان.