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Groundnut stem crop parameters effect on cutting force and energy

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Abstract
The harvesting of groundnut crop was done mostly by digging method. After harvesting, the methods to remove the pods from the groundnut crop such as stripping, picking and threshing causes damages and wastage of groundnut vines. The groundnut vines consist of higher protein content that offers effectively supplementary nitrogen to ruminants in dry season. These vines are used as green manure, feed to cattle or combined with other vegetation to produce silage. In order to give importance and avoid the damages and wastages of vines, the groundnut vine cutting machine was developed. To develop the machine, the study was done related to investigating the effect of moisture content, stem diameter and cutter bar speed on cutting force and cutting energy required for cutting of single groundnut stalks. A reciprocating cutter bar test rig was used to measure the cutting force. The test rig consists of main frame, speed drive, cutter bar assembly, power transmission, a load cell and a load indicator. The experiments were conducted at four levels of moisture content (40 - 47, 47 – 53, 53 – 60 and 60 – 71%) (Wet basis), four levels of crop stem diameter (3- 4, 4 –5, 5 – 7 and 7- 8 mm) and four levels of cutter bar speed (0.80 – 0.90, 0.90 – 1.00, 1.00 – 1.10 and 1.10 – 1.20 ms^{-1}). The minimum cutting force of 10 - 20 N and cutting energy of 0.10 – 0.30 J was observed at 60 - 71% moisture content, 3 – 4 mm stem diameter, 1.10 – 1.20 ms^{-1}cutter bar speed. The maximum cutting force of 40 - 50 N and cutting energy of 0.70 – 0.90 J was observed at 40 - 47% moisture content, 7 – 8 mm stem diameter, 0.80 – 0.90 ms^{-1}cutter bar speed. The result shows that cutting force and energy was directly and inversely proportional to stem diameter and moisture content, cutting speed, respectively.

Keywords: groundnut, moisture content, stem diameter, cutter bar speed, cutting force, cutting energy

Introduction
The peanut, also known as the groundnut (*Arachis hypogaea*) is a legume crop. It is said to be an oil crop, due to its high oil content and it is grown mainly for its edible quality. Gujarat is the largest producer in India, followed by Tamil Nadu, Andhra Pradesh, Karnataka and Maharashtra. The physical properties of plant stem and the cutting resistance play vital role to understand the force required in harvesting operations. The groundnut is rich in valuable protein for humans. Groundnut crop without pods (groundnut vines) consist of various parts such as hay, straw (vines), leaves, haulms, stover and tops with nutrients. It was used as a source of fertilizer and feed for cattle by farmers.
The maximum cutting force to cut a finger millet stalk was 3.75 kg at 12 mm diameter and at 63.75 per cent moisture content (Nisha and Saravanakumar 2019a) [4]. For the moisture content of 10% in the upper region a less shearing stress of 5.98 MPa and for the moisture content of 80% in the lower region a high shearing stress of 28.16 MPa were observed (Galedar *et al.* 2008) [3]. The moisture content of 45% had a shearing stress of 7.1 MPa. Thus, they reported that increase in moisture content of stalk leads to increase in shearing force (Yilmaz *et al.* (2009) [10]. Development of single knife reciprocating cutter bar test rig to measure the cutting force for finger millets (Nisha and Saravanakumar 2019b). A pendulum type test rig was used to measure the cutting energy of cassava stems (Prasanthkumar and Saravanakumar 2017) [6]. Suggestion of blade optimum parameters and cutting energy for paddy stem. The cutting energy needed to cut the paddy stem was measured using a pendulum type impact shear test apparatus (Reza 2007) [7]. A push type cutter bar mower was developed and the effective wet grass harvesting capacity was 2.24 tonne per hour. The result revealed that the field efficiency was inversely proportional to the forward speeds (Celik 2006) [1]. The effect of operational parameters on cutting force of a reciprocating type cutter bar was studied. The harvesting efficiency increased by the moisture content, cutter bar speed and diameter which influence the peak cutting force. (Kathirvel *et al.* 2011) [2].

The crop cutter machine was developed with the scissoring type of motion. Scissoring action is obtained by the principle of slider crank mechanism. The slider crank mechanism used to convert rotary to reciprocating motion for cutter. (Roshan Ghodkhande *et al*. 2018) [8].

Materials and methods

Materials Used

The cutting force or cutting energy was measured using a reciprocating cutter bar test rig. The cutter bar test rig consisted of main frame, cutter bar assembly, load cell, load indicator, load measuring set up, analog and digital converter, variable speed drive, power transmission assembly and signal conditioning and amplifying unit, digital load measuring set up and power supply.(Fig.1).The crop parameter and the machine such as moisture content stem diameter and cutter bar speed, respectively was taken for the experiment.

Fig 1: Reciprocating Cutter bar Test Rig

Sl. No.	Name
1	Variable speed drive
2	Load cell
3	Cutter bar
4	Load indicator
5	Electric motor
6	Main frame

Measurement of stem diameter

At 10 cm height above the ground level was marked on the stem, before taking samples from the field. The diameter of the single stem at the noted point was measured for under samples. The diameter of the stem was measured using the vernier caliper above the ground level and the readings were noted in mm.

Working of test rig

The test rig works on the principle of slider-crank mechanism. It is operated by one hp three-phase induction electric motor by using two 4 inch B-type pulley, one was attached to the electric motor and another to cutter bar assembly for power transmission. Thus, the cutter bar assembly moves in a rotary motion was converted into the reciprocating motion through crank and connecting rod. The slider-crank mechanism is used to convert the rotary motion into the reciprocating motion.

The diameter from 3 to 7 mm, the sample was placed between reciprocating cutting knife for cutting. The force required was measured by the load cell and noted from the load indicator in kilogram. The force required at different stem diameter was worked out for its average.

Measurement of moisture content

Immediately after cutting the stem a small piece of it was taken as sample for measuring the moisture content. The moisture content was measured by weighing its initial weight in an electronic weighing balance (W_s). A sample was placed on a crucible and kept inside the oven for 24 hours at 105 ^{0}C to eliminate the moisture. The dried weight of the sample was measured and noted as W_d. The moisture content of the sample was worked out on wet basis using the formula, (Talpur *et al.*, 2011).

$$\text{Moisture content} = \frac{\text{Ws} - \text{Wd}}{\text{Ws}} \times 100 \text{ percent} \qquad (1)$$

W_s = weight of groundnut stem before drying, g

W_d= weight of the dried sample of groundnut stem, g

The force required at different moisture content was worked out for its average.

Linear Speed of Cutter Bar

The linear speed of the cutter bar was given by the following equation. (Celik, 2006) [1]

$$\text{Knife speed, } Vk = \frac{s \times n}{30} \qquad (2)$$

Where,

V_k = knife speed, ms^{-1}

s = length of stroke, m

n = crank speed, rpm

The Evaluation parameter such as cutting force and cutting energy was obtained from the experiment.

Cutting Force

The cutting force required to cut the groundnut stem was measured by using the load cell. It is expressed in kilogram and values were noted.

Cutting Energy

The cutting energy was calculated by using the formula. (Nisha and Saravanakumar 2019a) [4].

$$\text{Cutting Energy Ec} = \text{Fc} \times \text{D} \qquad (3)$$

Where,

E_c = cutting energy, J

F_c = cutting force, N

D = diameter, mm

The operational parameters such as four levels of moisture content (40 - 47, 47 – 53, 53 – 60 and 60 – 71%) (wet basis), four levels of crop stem diameter (3- 4, 4 –5, 5 – 7 and 7- 8 mm) and four levels of cutter bar speed (0.80 – 0.90, 0.90 – 1.00, 1.00 – 1.10 and 1.10 – 1.20 ms^{-1}) was taken for the experiment.

Results and Discussion

The comparison among different moisture content, cutting force and cutting energy was shown in Table 1. At minimum moisture content of 40 - 47%, the maximum cutting force and cutting energy of 40 - 50 N and 0.70 – 0.90 J, respectively was measured. At maximum moisture content of 60 - 71%, the minimum cutting force and cutting energy of 10 - 20 N and 0.10 – 0.30 J, respectively was measured. The result shows that, when the moisture content increased from 40 – 71%, the cutting force and cutting energy decreased from 50 – 10 N and 0.90 – 0.10 J, respectively is given in Fig.2.

Table 1: The comparison of moisture content, cutting force and cutting energy

Moisture content (%) (w.b)	Cutting force (N)	Cutting energy (J)
40 -47	40 – 50	0.70 – 0.90
47 – 53	30 - 40	0.50 – 0.70
53 – 60	20 – 30	0.30 – 0.50
60 - 71	10 – 20	0.10 – 0.30

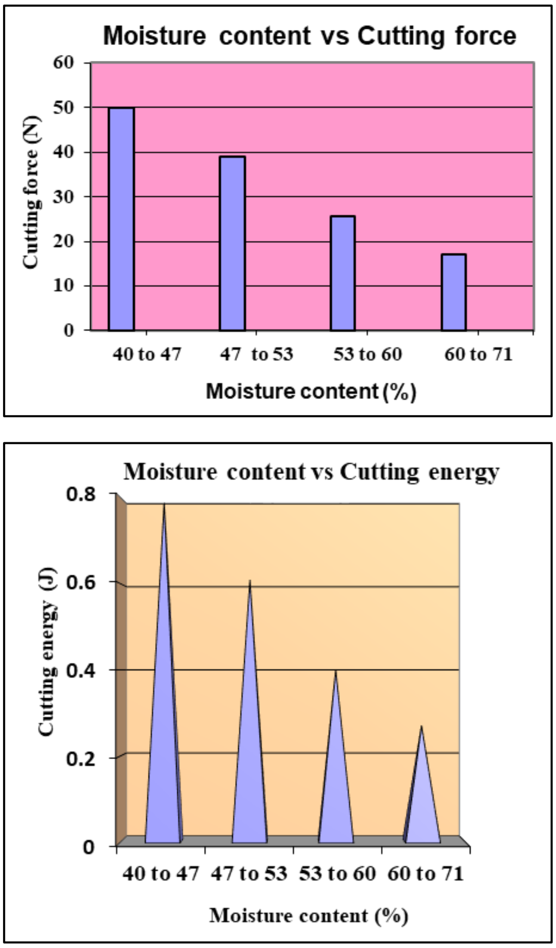

Fig 2: Effect of moisture content on cutting force and energy

The comparison among different stem diameter, cutting force and cutting energy was shown in Table 2. At maximum stem diameter of 7 – 8 mm the maximum cutting force and cutting energy of 40 - 50 N and 0.70 – 0.90 J, respectively was measured. At minimum stem diameter of 3 – 4 mm, the minimum cutting force and cutting energy of 10 - 20 N and 0.10 – 0.30 J, respectively was measured. The result obtained was, when the stem diameter increased from 3 – 8 mm, the cutting force and cutting energy also increased from 10 – 50 N and 0.10 – 0.90 J, respectively is presented in Fig.3.

Table 2: The comparison of stem diameter, cutting force and cutting energy

Stem Diameter (mm)	Cutting force (N)	Cutting energy (J)
3 - 4	10 – 20	0.10 – 0.30
4 - 5	20 – 30	0.30 – 0.50
5 – 7	30 - 40	0.50 – 0.70
7 - 8	40 – 50	0.70 – 0.90

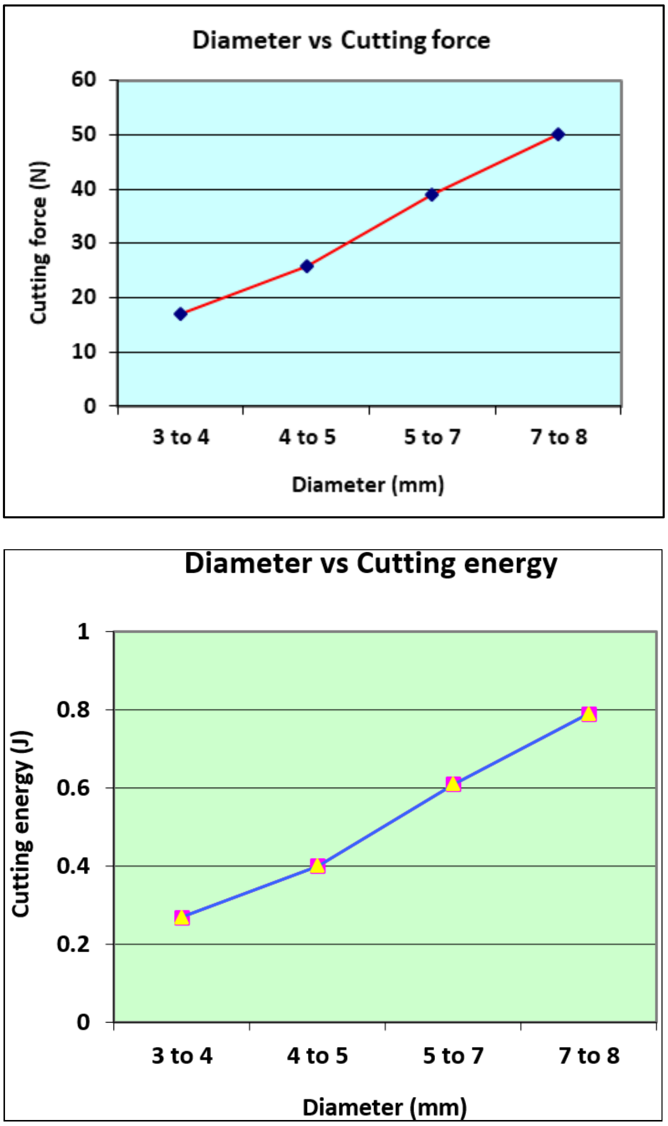

Fig 3: Effect of stem diameter on cutting force and energy

The comparison among different cutter bar speed, cutting force and cutting energy was shown in Table 3. At minimum cutter bar speed of 0.80 – 0.90 ms^{-1}, the maximum cutting force and cutting energy of 40 - 50 N and 0.70 – 0.90 J, respectively was measured. At maximum moisture content of 1.10 – 1.20 ms^{-1}, the minimum cutting force and cutting energy of 10 - 20 N and 0.10 – 0.30 J, respectively was measured. The result was, when the utter bar speed increased from 0.80 – 1.20 ms^{-1}, the cutting force and cutting energy decreased from 50 – 10 N and 0.90 – 0.10 J, respectively is illustrated in Fig. 4.

Table 3: The comparison of cutter bar speed, cutting force and cutting energy

Cutter bar speed (ms^{-1})	Cutting force (N)	Cutting energy (J)
0.80 – 0.90	40 – 50	0.70 – 0.90
0.90 – 1.00	30 - 40	0.50 – 0.70
1.00 – 1.10	20 – 30	0.30 – 0.50
1.10 – 1.20	10 – 20	0.10 – 0.30

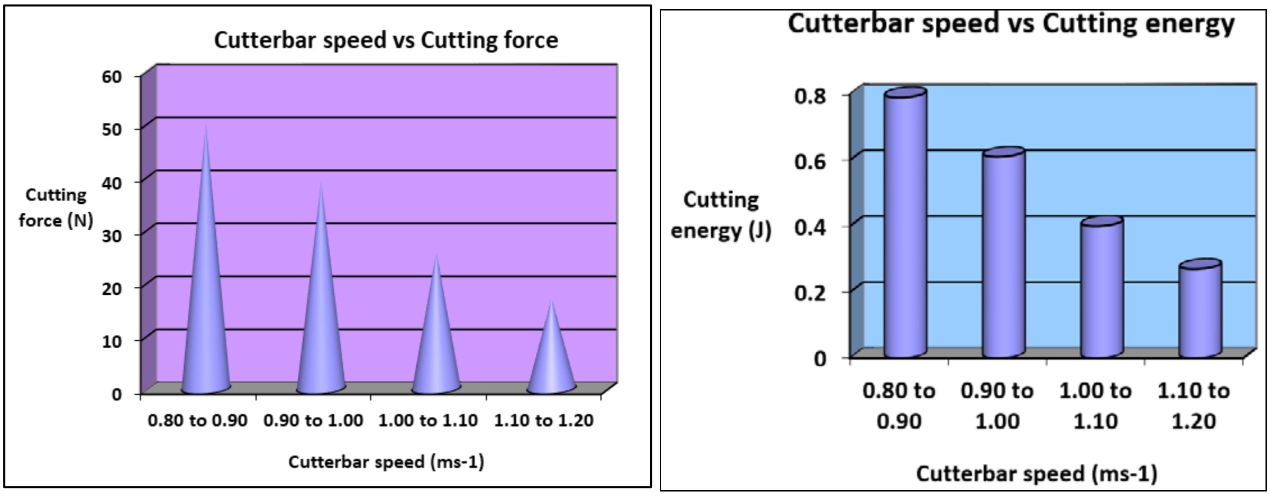

Fig 4: Effect of cutter bar speed on cutting force and energy

The analysis of variance for the effect of moisture content, stem diameter and cutter bar speed on cutting force is shown in Table 4. The effect of stem diameter and cutter bar speed on cutting force had 1% significant. The effect of moisture content on cutting force had 5% significant.

Table 4: Analysis of variance for the effect of crop diameter, moisture content and cutter bar speed on cutting force.

Anova Results	df	Sum	Sq Mean	Sq F Value	Pr (>F)
Diameter	1	631.7	631.7	589.1	0.0169**
Residuals	2	2.1	1.1		
Moisture Content	1	628.3	628.3	225.1	0.00441*
Residuals	2	5.6	5.6		
Cutter bar Speed	1	621.8	621.8	215.2	0.0315**
Residuals	2	5.1	5.1		

The effect of moisture content, stem diameter and cutter bar speed on cutting force and cutting energy

The effect of moisture content, stem diameter and cutter bar speed on cutting force and cutting energy was studied. The minimum cutting force of 10 – 20 N and cutting energy of 0.10 – 0.30 J, respectively was obtained at 60 – 71% of moisture content, 3 – 4 mm of stem diameter and 1.10 – 1.20 ms^{-1} of cutter bar speed. The maximum cutting force of 40 – 50 N and cutting energy of 0.70 – 0.90 J, respectively was obtained at 40 – 47% of moisture content, 7 – 8 mm of stem diameter and 0.80 – 0.90 ms^{-1} of cutter bar speed. The result revealed that the cutting force and cutting energy increased with increase in stem diameter, decreased with increase in moisture content and cutter bar speed.

Conclusion

In this study, the effect of groundnut stem parameters on cutting force and cutting energy was observed. When increase in stem diameter, the per cent increase in cutting force and cutting energy was 0.65. When increase in moisture content and cutter bar speed, the per cent decrease in cutting force and cutting energy was 1.93. Therefore, the result obtained was that the cutting force and cutting energy was inversely proportional to the moisture content and cutter bar speed and directly proportional to the stem diameter.

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