International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(6): 1064-1067

https://www.mathsjournal.com
Received: 18-11-2023
Accepted: 25-12-2023

Kamendra
Senior Research Fellow, Central Institute of Agricultural Research-ICAR, Bhopal, Madhya Pradesh, India

Shalini Singh
Department of Agricultural Processing and Food Engineering, OUAT, Bhubaneswar, Odisha, India

Divakar Chaudhary
Engineering and Technology Centre for Animal Sciences, RAJUVAS, Bikaner, Rajasthan, India

Nitin Tanwar
Department of Statistics, Lady Shri Ram College for Women, University of Delhi, New Delhi, India

Corresponding Author:
Kamendra
Senior Research Fellow, Central Institute of Agricultural Research-ICAR, Bhopal, Madhya Pradesh, India

Investigating the cutting force requirements for groundnut taproot

Kamendra, Shalini Singh, Divakar Chaudhary and Nitin Tanwar

Abstract
Groundnut (*Arachis hypogaea* L.) is a crucial oilseed crop in India, rich in oil, protein, and carbohydrates. Harvesting, a significant operation in groundnut cultivation, often leads to considerable pod loss and contributes substantially to cultivation costs. This research focuses on determining the cutting force required for designing of efficient groundnut harvesting blades, considering taproot diameter and moisture content. A comprehensive study using a TA. XT textural analyzer involved measuring cutting forces for different taproot diameters and moisture levels. Results indicate that cutting force increases with larger taproot diameters and decreases with higher taproot moisture content. The study underscores the importance of understanding cutting force dynamics for designing effective groundnut diggers, ultimately reducing losses in mechanized harvesting.

Keywords: Groundnut (*Arachis hypogaea* L.), protein, cultivation costs, groundnut diggers

1. Introduction
Groundnut, or peanut (*Arachis hypogaea* L.) is one of the major oilseed crops of India and grown in tropical and warm temperate zones (Weiss, 2000) [10]. It is a leguminous crop that help to maintain the soil fertility and reduce soil erosion. It is rich in oil (42-52%), protein (25-32%) and carbohydrates (13-16%) (Abdzad and Noorhosseini, 2010; Putnam *et al*., 2013) [1, 8]. It can be used as whole seeds, processed into peanut butter, oil and other products, and its shells can be used as mulching material (Ayanlaga and Sanwo, 1991) [3].

Groundnut is a vital self-pollinated oilseed crop grown in over 100 countries with varying agro climatic conditions. India, the second largest producer of groundnut after China, produced 9.95 MT of groundnut (Anonymous. 2022-23) [2]. The major unit operation in groundnut cultivation is seedbed preparation, sowing, fertilizer application, plant protection, irrigation, harvesting and threshing. Harvesting is one of the major operation which account for highest pod loss (16-47%) and 23% of the total cultivation cost (Seshadri, 1962) [9]. The prevalent methods of groundnut harvesting are manual uprooting using hand tools or using diggers powered by animal, power tiller, tractor etc. The manual harvesting methods such as hand pulling or uprooting may result in pod loss due to the unpredictable growth pattern and pods below the soil surface. Though, animal power based harvesting system are more useful than manual methods but it still involves higher cultivation cost that can be reduced by using mechanical powered diggers. The function of groundnut digger required is to penetrate under the plant row to loosen the soil and cut the taproot of crop and uproot the crop, then windrow in to the field.

For efficient harvesting of groundnut, the difference in the diameter of groundnut taproot and the cutting resistance must be identified with the aim of knowing the behaviour of material with respect to different operating conditions of harvesting. Failure in shear or impact or both is possible while acting a system of forces on the taproot and before shear failure, the taproot is essentially first compressed then bend resulted in increased work required in a cutting operation (Kepner *et al*., 1978) [5]. When critical value of pressure applied by the blade reaches; taproot cutting completes and results in multiple modes of tissue failure (Persson, 1987) [7]. Enhanced awareness in mechanized crop harvesting and reducing the harvesting losses the force required to cut groundnut taproot needed to be study.

The main objective of this study is to determine the force required to cut the groundnut taproot which influences the harvesting of groundnut and should consider while designing the groundnut digger.

2. Materials and Methods: The experiments were conducted in the laboratory of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar. The force required to cut the taproot was measured for Devi variety (ICGV–91114). The taproot diameter was measured of ten randomly selected plants at different moisture level. The measurement was done using a Vernier Caliper (Fig. 1).

Fig 1: Measurement of Groundnut taproot

2.1 Experimental procedure

The experiment was carried out by using TA. XT textural analyzer (Stable Micro System; Version: 07, 13 H; load cell 500 N) shown in Fig 2 (a) and (b). The analyzer was connected to a computer, which used the software tool exponent V.32 to record the data. The cutting force required to cut the taproot of the groundnut plant was measured for different diameters (3, 4.5 and 5.5 mm) at different level of taproot moisture content (35-40, 40-45 and 45-50%) by using textural analyzer.

The textural analyzer was equipped with a probe carrier on which, a knife was fastened to cut the groundnut taproot. The groundnut taproot was placed in a slot and a test speed of 0.1 mm s^{-1} was employed with a 500 N load cell. The load was measured against the depth of cut in real time. The peak force was calculated using sample data provided by a cutting force. The whole area under the force-deformation curve was employed to work out the overall plant cutting force. Cutting force was measured for ten plants of each taproot diameters at each moisture content and maximum value of cutting force were taken for the study. The detailed experimental parameters and their levels has been shown in Table 1.

Table 1: Experimental design for determining cutting force

Independent parameters	Levels	Dependent parameters
Taproot moisture content (%, wb)	M_1 = 35-40%	Cutting force (N)
	M_2 = 40-45%	
	M_3 = 45-50%	
Taproot diameter (mm)	D_1 = 3 mm	
	D_2 = 4.5 mm	
	D3 = 5.5 mm	

(a) TA. XT textural analyzer (b) Plants after cutting by probe

Fig 2: Setup for measurement of cutting force

3. Result and Discussion

3.1 Cutting force analysis of taproot of groundnut plants

The method of harvesting of groundnut crop by digging blades is usually done by cutting the taproot of plants. The force required for cutting of the taproot of the groundnut plants depends on the diameter of the taproot. For the design of effective cutting tool, the cutting force analysis was done.

The effect of taproot diameter and taproot moisture content on required cutting force has been shown in Fig. 3. The maximum cutting force was found to be 39.54±0.51 N, 50±0.83 N and 64.23±0.57 N for 3, 4.5 and 5.5 mm taproot diameter, respectively at 35-40% taproot moisture content. The minimum cutting force was found to be 26.26±1.06 N, 33.87±0.65 N and 45.23±0.85 N for 3, 4.5 and 5.5 mm taproot diameter, respectively at 45-50% taproot moisture content.

From Fig. 3, it is observed that the cutting force of the taproot increased with increase in the diameter of the taproot. The reason may be due to the fact that larger diameter taproot has more material that needs to be cut through and therefore requires more force for cutting. Similar findings were reported by Zareiforoush *et al.* (2011) [11] for wheat and Kim *et al.* (2017) [6] for lettuce. It is also observed that the force required to cut the groundnut taproot increased with the decrease in taproot moisture content. It might be due to less hard pith or less stiffness of fiber to be cut at higher moisture content than at lower moisture content Dauda *et al.* (2015) [4].

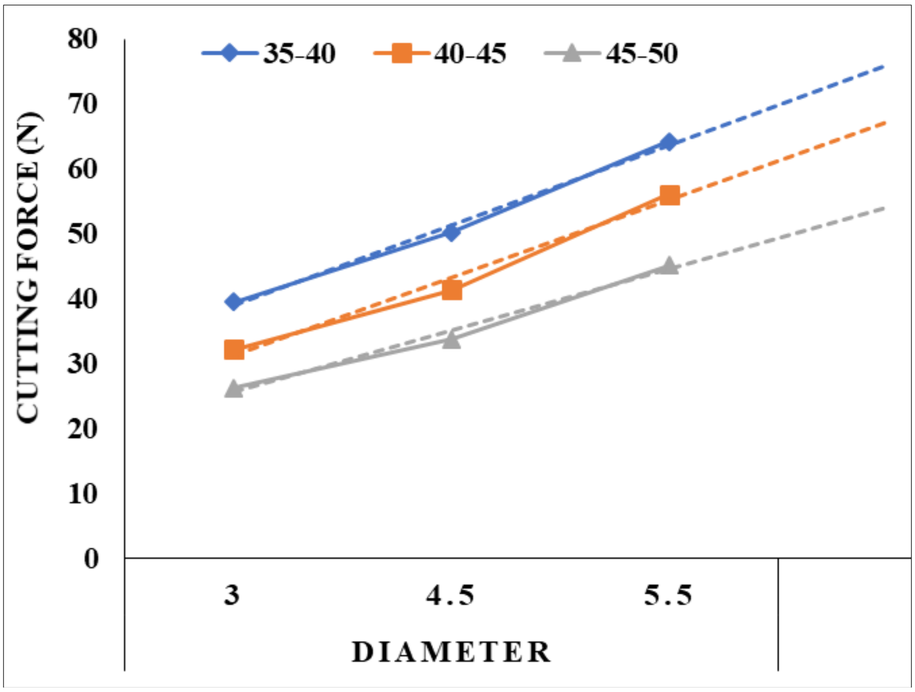

Fig 3: Maximum force required to cut the taproot of different diameters

3.2 Analysis of variance (ANOVA)

The analysis of variance (ANOVA) was conducted considering taproot diameter (A) and taproot moisture content (B) as independent variable and force required for cutting as a depended variable. The results from the ANOVA analysis in mentioned in Table 2. It is evident from the Table 2 that taproot diameter and taproot moisture content affected the force required for cutting significantly at 1% level of significance. However, the combined effect of taproot diameter and taproot moisture content was found to be non-significant. This may be due to opposite effect of concerned variables on torque required for cutting.

Table 2: ANOVA for the effect of parameters on cutting force

Source	Sum of Squares	DF	Mean Square	F-value	p-value
Model	2167.20	3	722.40	80.45	< 0.0001**
A	1102.20	1	1102.20	122.75	< 0.0001**
B	496.54	1	496.54	55.30	< 0.0001**
AB	14.91	1	14.91	1.66	0.2218 ns
Residual	107.75	12	8.98		
Lack of Fit	39.24	4	9.81	1.15	0.4015 ns
Pure Error	68.51	8	8.56		
Cor Total	2274.95	15			
CV (%)	6.52				
R^2	0.952				

** Significant at 1% level of significance, * Significant at 5% level of significance, ns- Not significant

4. Conclusion

The study successfully determined the cutting forces required for groundnut taproot at varying diameters and moisture levels. The findings reveal that taproot diameter and moisture content significantly influence the force needed for cutting, highlighting the importance of these factors in designing effective groundnut harvesting equipment. Larger taproot diameters and lower moisture content increase cutting forces, necessitating careful consideration in the design process. The analysis of variance confirms the individual significance of taproot diameter and moisture content on cutting force. These findings are crucial for the design of groundnut diggers, contributing to more efficient and cost-effective mechanized harvesting practices.

5. References

1. Abdzad Gohari A, Noorhosseini Niyaki SA. Effects of Iron and Nitrogen Fertilizers on Yield and Yield Components of Peanut (*Arachis hypogaea* L.) in Astaneh Ashrafiyeh, Iran. Am-Eurasian J Agric Environ Sci. 2010;9(3):256-262.
2. Anonymous. Directorate of Agriculture and Food Production, Odisha and Directorate of Horticulture, Odisha economic survey, Govt. of Odisha; c2022-23.
3. Ayanlaga SA, Sanwo JO. Management of soil organic matter in the farming system of the low land humid tropic of West Africa. Rev Soil Technol. 1991;4(3):265-277.

4. Dauda SM, Ahmad D, Khalina A, Jamarie O. Effect of cutting speed on cutting torque and cutting power of varying Kenaf-stem diameters at different moisture contents. Pertanika J Trop Agric Sci. 2015;38(4):549-561.
5. Kepner RA, Bainer R, Barger EL. Principles of farm machinery. New York: Wiley; c1978.
6. Kim D, Lee D, Lee D, Kim H. Development of a force measurement system for the evaluation of the mechanical harvesting performance of lettuce. Biosyst Eng. 2017;157:20-29.
7. Persson S. Mechanics of cutting plant material. St. Joseph, MI: ASAE; c1987.
8. Putnam DH, Oplinger ES, Teynor TM, Oelke EA, Kelling KA, Doll JD, *et al*. Peanut. Purdue University; c2013.
9. Seshadri CR. Groundnut. Indian Central Oilseeds Committee; c1962. p. 172-203.
10. Weiss EA. Oilseed crops. London: Blackwell Science; c2000. p. 121.
11. Zareiforoush H, Minaei S, Tabatabaeefar A. The effect of stem diameter on cutting force and specific energy in wheat harvesting using combine harvester. Agric Eng Int: CIGR Journal. 2011;13(1):1-8.