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Investigation on Effect of Stroke Length, Cutter Bar Speed, Moisture Content of Crop and Stem Diameter on Cutting Force for Development of Bengal Gram Harvester

S. Ramachandran[1*] and D. Asokan[2]

[1]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, 621712, Trichy, India.
[2]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, 641003, Coimbatore, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author SR conducted the whole study at the Lab level and prepared the manuscript. Author DA advised and gave the necessary technical support throughout the study. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The effects of crop and machine parameters on cutting force for Bengal gram crop were investigated.
Study Design: Experiments were carried out at two levels by using the standard protocol.
Place: The study was carried out in the farm machinery work shop of Agricultural Engineering College & Research Institute, Kumulur, Trichy, Tamil Nadu, India.
Methodology: A double knife cutter bar test rig was developed for measuring the cutting force required for harvesting of Bengal gram crop. Experiments were carried out on JG 11 variety of Bengal gram crop at two levels of stroke length of the double knife cutter bar, four levels of cutter bar speeds, three levels of stem diameter and three ranges of moisture content (at harvesting stage, at 5 days before and after harvesting).

**Corresponding author: E-mail: ramsukkiran@gmail.com;*

Results: The minimum cutting force of 16.14 N was observed at 1.0 ms^{-1} for cutting 3 to 4.5 mm diameter with 14.08 to 15.1 per cent moisture content of stem. The maximum value of cutting force of 39.83 N was observed at 0.25 m s^{-1} for cutting more than 6 mm diameter with 20.2 to 20.45 per cent moisture content of stem. The double knife cutter bar with a stroke length of 76.2 mm registered 4.3 to 11.12 percent reduction in cutting force as compared to 50 mm stroke length for the all selected levels of parameters.

Keywords: Double knife cutter bar; cutting force; stroke length and cutter bar speed.

1. INTRODUCTION

Bengal Gram is an important leguminous food grain in India. It contains more protein compared to cereals. In India, Bengal gram is cultivated in 10.56 Mha with production of 11.38 Mt and a productivity of 1078 kg ha^{-1}. Nearly 97 per cent of Bengal gram is cultivated in the states of Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka which contribute to more than 90 per cent of total production in India [1]. Generally harvesting of Bengal gram is done by pulling the plants manually. Conventionally available harvesters designed for harvesting of wheat and paddy crops. In main problem encumbering mechanical harvesting of Bengal gram is the excessive grain losses at cutting operation. Bengal gram crop is difficult to harvest due to short, uneven ripening, pods near to ground surface and cultivating land is too rough. Harvesting of Bengal gram at optimum maturity is essential for ensuring quality and productivity of crops. Efficiency of harvester is expressed by cutting force and energy required for harvesting of crop [2]. The moisture content is inversely proportional to cutting force of plants [3]. The Cutting force of crop decreased with increase in moisture content [4-6]. When decreasing the cutting speed resulted in increased cutting force of the crop [7]. Operational speed of the cutter bar is the most significant features of reciprocating cutter bar [8].

2. MATERIALS AND METHODS

A double knife cutter bar test rig was developed (Fig. 1) for measuring the cutting force. The quality of crop harvesting is mainly influenced by cutter bar speeds. Uniformity of cut and cutting efficiency are influenced by stroke length of cutter bar knife and operational speeds. Other than stroke length and cutter bar speed, the main factor affecting the cutting force required for cutting is the diameter of crop stem and moisture content of the crop. Hence, the following parameters selected for measuring the cutting force using double knife cutter bar test rig.

The cutting force value obtained using cutter bar test rig with the load cell was indicated in kilogram in the load indicator. The cutting force required to cut the crop were recorded and used for analysis.

$$F_c = PF_c \times 9.87 \quad (1)$$

F_c = cutting force of the crop, N
PF_c = peak cutting force of the crop, kg

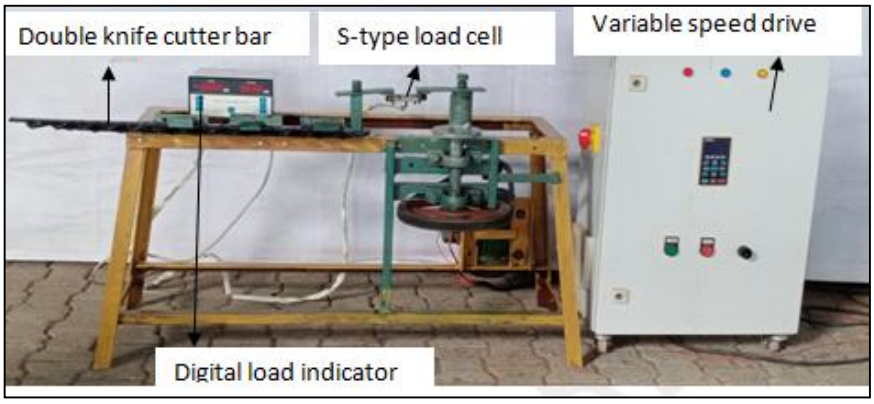

Fig. 1. Double knife cutter bar test rig

Experiments were carried out at two levels of stroke length of the cutter bar 50 mm and 76.2 mm, four levels of cutter bar speeds 0.25, 0.50, 0.75 and 1.0 ms^{-1}, three levels of stem diameter 3 to 4.5 mm, 4.51 to 6 mm and greater than 6 mm and three ranges of moisture content 20.2 to 20.45 (at 5 days before harvesting stage), 18.1 to 18.6 (at harvesting stage), and 14.8 to15.1 per cent (at 5 days after harvesting stage). The cutting force required for harvesting of Bengal gram was recorded for all the treatments

3. RESULTS AND DISCUSSION

The effect of crop and machine parameters viz., diameter of the stem, moisture content of the crop at selected level of harvesting, cutter bar speed and stroke length on cutting force required for harvesting Bengal gram crops were analyzed and the results were discussed below.

From the Figs. 2 and 3, the cutting force increased with increase in diameter of crop from 3 to 4.5 mm to greater than 6 mm at all selected levels of cutter bar speed. Increase in moisture content from 14.08 to 20.45 per cent resulted in 14.15 per cent to 22.08 per cent reduction of cutting force required for the selected levels of diameter of crop and cutter bar speed. There is an inverse relation was observed between cutting speed and cutting force. Increase in cutter bar speed from 0.25 to 1 m s^{-1} resulted in reduction of cutting force required for harvesting the selected levels of stem diameter of Bengal gram. The minimum cutting force of 16.14 N was observed at 1.0 ms^{-1} for cutting 3 to 4.5 mm diameter with 14.08 to 15.1 per cent moisture content of stem and stroke length of 76.2 mm. The maximum value of cutting force of 39.83 N was observed at 0.25 ms^{-1} for cutting more than 6 mm diameter with 20.2 to 20.45 per cent moisture content of stem and stroke length of 50 mm. The overall reduction in cutting force varied from 4.11 to 13.12 per cent with 76.2 mm stroke length of cutter bar when compared to 50 mm stroke length. The above results were in close agreement with the findings of Kathivel, et al. [9, 10].

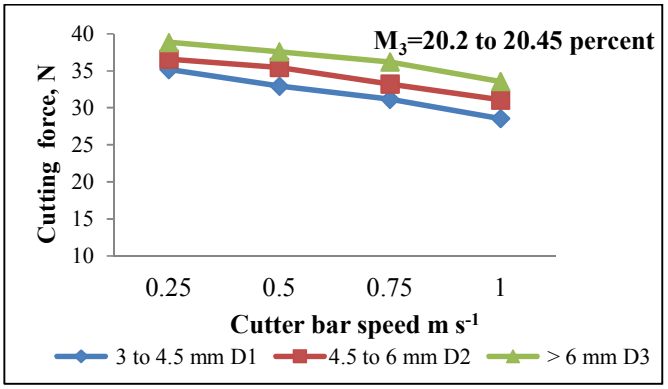

Fig. 2a. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_1) of Bengal gram crop for 50 mm stroke length of cutter bar (L_1)

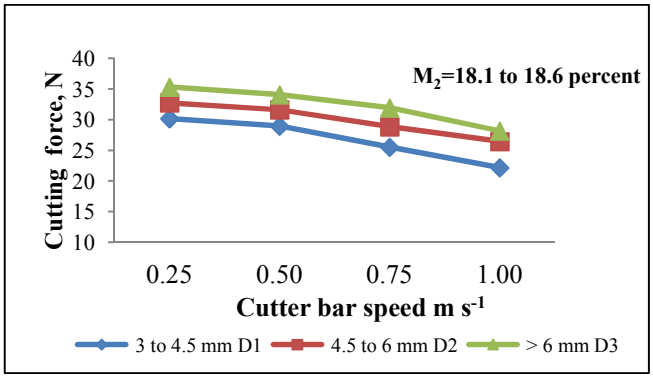

Fig. 2b. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_2) of Bengal gram crop for 50 mm stroke length of cutter bar (L_1)

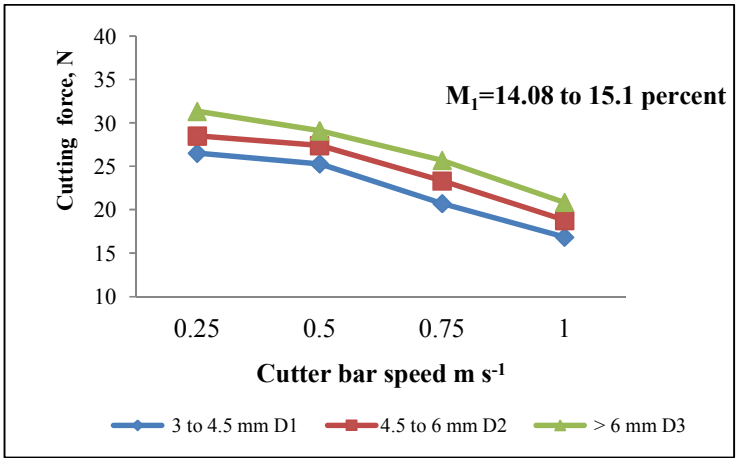

Fig. 2c. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_3) of Bengal gram crop for 50 mm stroke length of cutter bar (L_1)

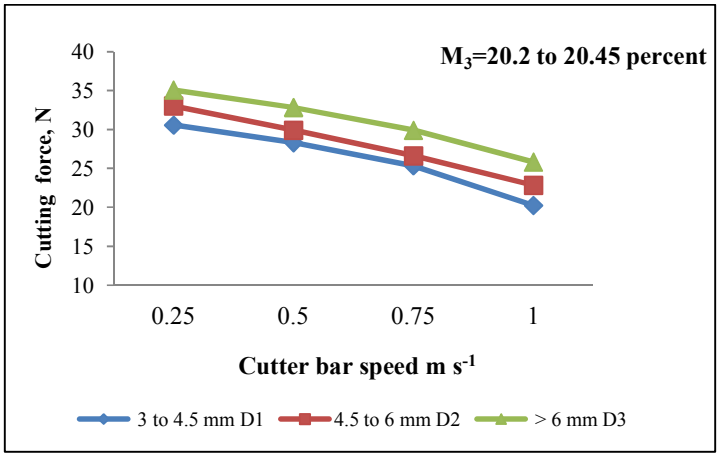

Fig. 3a. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_1) of Bengal gram crop for 76.2 mm stroke length of cutter bar (L_2)

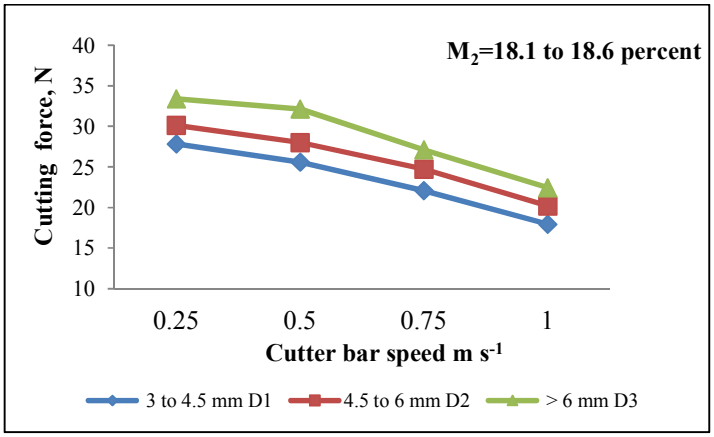

Fig. 3b. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_2) of Bengal gram crop for 76.2 mm stroke length of cutter bar (L_2)

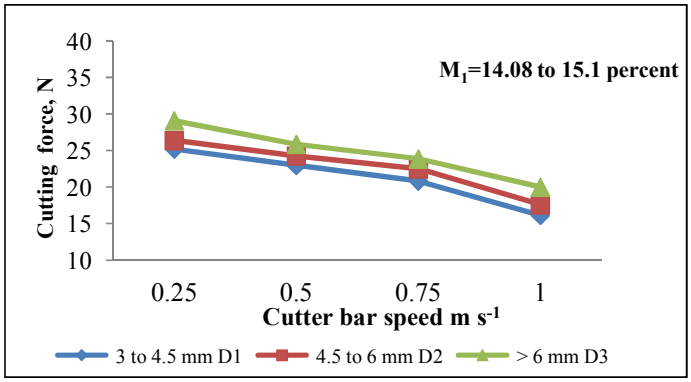

Fig. 3c. Effect of cutter bar speed on cutting force at selected levels of diameter and moisture content (M_3) of Bengal gram crop for 76.2 mm stroke length of cutter bar (L_2)

4. CONCLUSIONS

The power requirement for designing of harvesters was calculated using measured values. The cutting speed and moisture content showed a negative correlation with cutting force. It was observed that stem diameter shows a positive correlation with cutting force. It was concluded that the force required for cutting Bengal gram crop was operated at minimum double knife cutter bar speed of 1 ms^{-1}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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