



EVALUATION AND OPTIMIZATION OF CUTTING EFFICIENCY OF MOTORIZED SOYBEAN HARVESTER

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ABSTRACT

A motorized soybean harvester was designed and evaluated on a soybean farm to determine its cutting efficiency. Three independent factors at five levels were used. Moisture content (9, 14, 18, 22, and 26 %), clearance between the cutting blades (0.4, 2, 4, 6 and 8 mm). The experimental design was carried using Design of Expert version 13.0. The total number runs were 36, and each plot measured 4 m by 4 m. In each plot, the variation the factors were established on the machine before cutting soybeans. After cutting each plot, the harvester was stopped, and the number cut and uncut soybean stem were counted and recorded. Thereafter, the data generated was subjected to statistical analysis. The ANOVA results showed that moisture content and cutter bar speed had significant effect of 0.0001 each on the cutting efficiency at 5 % confidence interval. Further analysis with 3D response surface graph, and 2D contour plot revealed that optimum cutting efficiency was achieved at 18 % moisture content, 4 mm clearance between the cutting blades, and 850 rpm cutter bar speed. In addition, numerical optimization alongside with ramp function graph and desirability bar chart were used to optimize the harvester, and it revealed that cutting efficiency of 77.302 % can be achieved if the moisture content was set at 14 %, clearance between the cutting blades at 4.17 mm, and cutter bar speed at 1200 rpm. In essence, the cutting efficiency of the motorized soybean harvester is above average.

Keywords: Moisture content, 3D, Efficiency, Experimental, Desirability

INTRODUCTION

Harvester is a machine used for harvesting crops like maize, rice, soybean, carrot, cabbage, cocoyam, groundnut, sorghum and wheat. Some harvesters like combine harvester perform five operations like harvesting, gathering, threshing, cleaning and bagging in a single operation, while some harvesters harvest and gather the crop on one side of the field. The use of mechanical harvester to harvest crops like soybean, and rice reduces qualitative and quantitative loss, because during the peak of harvest, farmers always encounter shortage labourers which prolong the stay of soybean on the field thereby leading to high level of shattering losses. Using mechanical harvester to harvest soybean helped to actualize labour and land productivity, minimizes losses and maximizes profit. Due to peculiar nature of soybean, it is important to harvest it ones it matures, otherwise high level of losses may be incurred. When harvesting of soybean is delayed, the shattering losses may be as high as 4.75 % of total yield per hectare which exceeded the 3 % stipulated by the American Society of Agricultural and Bioresources Engineering (ASABE) for any crop (Liu et al., 2023). The cost of harvesting soybean manually, is expensive and accounted for about 58.3 % of cost of labour /ha of soybean (Ko, 2010). Harvesting soybeans with a machine ensure timeliness of operation, reduces drudgery associated with manual harvesting, saves time and energy and low harvesting cost per ha (Musoni et al., 2013). Dugje et al. (2009) stated that due to the peculiar nature of soybeans, harvesting is one of the critical stages in soybeans production because any undue delay in harvesting matured soybeans leads to high percentage of losses. Soybean matures within 3 – 4 months after planting and requires timely harvesting to check excessive yield losses. It was recommended that soybeans should be harvested when 85 % of pods have turned brown for non-shattering varieties but 80 % for the shattering varieties. Soybeans can be harvested when the seeds' moisture content is between 14 to 16 % (Dugje et al., 2009), and mechanized harvester is the

solution to timely harvesting of soybeans. For instance, a combine harvester with a 6 m wide cutter bar moving at a ground speed of 1.3 m/s can harvest 2 ha of soybeans per hour, while human power requires a minimum of 100 hrs per ha. It is obvious that harvesting soybeans with machines has many benefits but the cost of purchasing it is beyond the reach of small and medium scales farmers.

To ensure that small scale farmers harvest their soybeans timely and affordable and portable motorized soybean harvester was developed at the workshop of Agricultural and Bioresources Engineering, Ahmadu Bello University Zaria. Due to the fact many factors like moisture content of crop, cutter bar speed, reel height, forward speed, clearance between the cutting blades, operators experience, and crop factors affect the overall performance of a harvester (Ahad et al., 2025), this developed Motorized Soybean Harvester was evaluated and the factors considered were the moisture content, clearance between the cutting blades, and the cutter speed, while response investigated was cutting efficiency. Cutting efficiency of a harvester is an important performance indicator of a harvesting machine and if the cutting efficiency of a harvester is not optimum, the effective field capacity of a harvester, shattering losses, field efficiency of harvester are always poor (Al-Mashhadani, 2023)

The objective of this research is to investigate how moisture content of soybean, clearance between the cutting blades, and cutter bar speed affect the cutting efficiency of motorized soybean harvester, and consequently recommend the appropriate combination of factors that can enhance its cutting efficiency, and possibly the overall performance of this harvester.

MATERIALS AND METHODS

Experimental Site

The motorized soybean harvester was designed and fabricated at the department of Agricultural and Bioresources Engineering, Ahmadu Bello University Zaria. Its

performance evaluation was carried out at Institute of Agricultural Research (IAR) farm, Ahmadu Bello University Zaria, situated between Area C staff quarters and Bomo town with the latitude and longitude of 11.1766 ° N, 007.6337 ° E, respectively, and 690 m above the sea level, Kaduna state in the northern guinea savannah of Nigeria. The size of the plots was 40 m by 40 m. Randomization approach was used to generate 36 runs, and each sub-plot's dimension was 4 m by 4 m.

Composite Design (CCD) was used to design the experiment which has three factors, and each factor has five levels, which later gave rise to 36 runs. These 36 runs were established in the plot measuring 40 m by 40 m, where each run measured 4 m by 4m.

Experimental Design

The statistical tool Design Expert version 13.0 in conjunction with Response Surface Methodology (RSM) based on Central

Developed Motorized Soybean Harvester

The pictorial view, isometric and orthographic view of the motorized soybean harvester were presented in Figure 1, 2.2, 2.3, respectively.



Figure 1: The Pictorial View of the Motorized Soybean Harvester

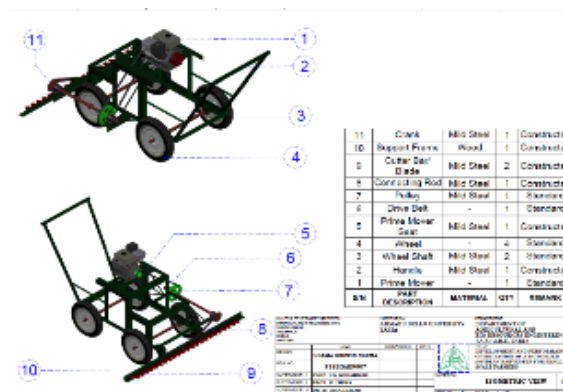


Figure 2: The Isometric View of Motorized Soybean Harvester

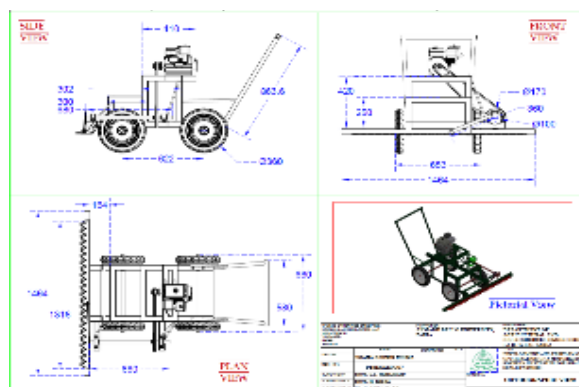


Figure 3: The Orthographic View of Motorized Soybean Harvester

Performance Evaluation of Motorized Soybean Harvester

A prime mover of 5 hp was used to power the Motorized Soybean harvester. During the field evaluation, three

independent factors were used to evaluate the Cutting Efficiency of a Motorized Soybean Harvester. The field evaluation of the harvester was demonstrated in figure 4.



Figure 4: Field Evaluation of Motorized Soybean Harvester

The cutting efficiency of the harvester was determined by using the harvester to harvest each plot. After harvesting, the number of soybean stem successfully cut were counted and recorded, as well as the number soybean stems that were not cut. Then the cutting efficiency (%) was calculated using equation 2.1 (Gana *et al.*, 2025).

$$CE = \frac{C_2}{C_1} \times 100 \% \quad 2.1$$

Where:

CE = cutting efficiency, %

C_2 = Total number of soybean stem cut

C_1 = Total number of soybean stems on the plot before harvest

RESULTS AND DISCUSSIONS

Analysis of Variance (ANOVA) Results

After the generation of cutting efficiency data, the data was subjected statistical analysis whereby the statistical software suggested that data fits quadratic model, and the model is significant, while the lack of fit is not significant. The Analysis of Variance (ANOVA) result is presented in table 1.

Table 1: Anova Results of The Effect of Moisture Content, Clearance Between the Cutting Blades, and the Cutting Speed on the Cutting Efficiency of Motorized Soybean Harvester

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	638.74	9	70.97	22.02	< 0.0001	significant
A-Moisture Content	103.74	1	103.74	32.18	< 0.0001	
B-Clearance between the cutting blades	1.48	1	1.48	0.4589	0.5041	
C-Cutter bar speed	370.88	1	370.88	115.05	< 0.0001	
AB	9.38	1	9.38	2.91	0.1000	
AC	22.04	1	22.04	6.84	0.0147	
BC	1.04	1	1.04	0.3231	0.5746	
A ²	0.0701	1	0.0701	0.0217	0.8839	
B ²	103.15	1	103.15	32.00	< 0.0001	
C ²	2.26	1	2.26	0.6999	0.4104	
Residual	83.81	26	3.22			
Lack of Fit	19.81	5	3.96	1.30	0.3015	not significant
Pure Error	64.00	21	3.05			
Cor Total	722.56	35				

From table 1, it was obvious that moisture content, cutter bar speed, the interaction between the moisture content and cutter bar speed, and quadratic effect of cutter bar speed had significant effect on the cutting efficiency of motorized soybean harvester.

The adjusted coefficient of determination (R^2), and predicted coefficient of determination (R^2), adequate precision were 0.8439, 0.7217, 20.0934, respectively. These suggested the closeness between the observed values and the predicted values of cutting efficiency of motorized soybean harvester. And coefficient of variation is 2.58 % which is highly acceptable because it showed high level of consistency and reliability between the data. Also. the variance inflation

factors (VIFs) are within unity (1) which signified the variation is not extreme. The optimum cutting efficiency of 71.667 % was achieved at moisture content of 18 %, 4 mm clearance between the cutting blades, and 850 rpm cutter bar speed.

Findings in this research were similar with results reported by other researchers. Like the results reported by Jin *et al.* (2025), where they reported that increase in cutting speed of reciprocating blades resulted in increase in cutting efficiency/rate of a harvester. Jin *et al.* (2025) reported that when the cutting of a harvester was reduced from 800 rpm to 600 rpm, the cutting efficiency/rate reduced by 24.46 %, and the speed was further reduced to 400 rpm, the cutting

efficiency decreased by 48.32 %. This observation revealed that crank speed of a cutter bar had influence on the cutting efficiency, because when the crank speed is low, the reciprocating commutation speed of cutter bar is low, thus given rise to repeated cutting of a soybean stem, and inability to cut soybean stem in one complete oscillation of cutter bar. Comparably, Maruf *et al.* (2025) evaluated the impact of cutting speed (1750rpm, 1950 rpm, and 2000 rpm) on the cutting efficiency of rice harvester, and reported that 2000 rpm achieved the highest cutting efficiency of 94.4 %. In similar case, Gana and Yusuf (2022) investigated the effect of forward speed, cutter bar speed, and moisture content on the cutting efficiency of forage harvester, and concluded that moisture content and cutter bar speed played significant role in cutting efficiency of a harvester. In the experiment, Gana and Yusuf (2022) varied their moisture content from 25 to 65 %, cutting speed from 15 to 65 m/min, and forward speed from 1.3 to 2.4 km/hr, and reported that high cutting efficiency of 94.4 % was achieved at forward speed of 2.4 km/hr, moisture content of 55 %, and cutting speed of 55 m/min. From the work of Gana and Yusuf (2022), lower moisture and higher moisture content of plants materials affect the cutting efficiency of a harvester, because it lower moisture content the shatters and the cutting blades hardly grip them, and at high moisture content, the stem offers higher resistance to the cutting blades, and in essence, the moisture

content of crops/plants need to be moderate. Relatedly, Kiran *et al.* (2017) achieved cutting efficiency of 98.24 % at forward speed of 2.17 km/hr, and cutting speed of 48 m/min (35 m/min to 51 m/min). Their results were in agreement with the findings of Shital *et al.* (2025) in which they reported that increase in cutter bar speed (1200 rpm, 900 rpm, 600 rpm) led to increase in cutting efficiency as follows 86.69 %, 82.67 %, and 77.76 %, respectively, as well as with the finding of (Kiran *et al.*, 2017; Yiljep and Mohammed,2005). In addition, Elyamani *et al.* (2024) carried investigation on the effect of cutter bar speed (2.28 m/s, 3.18m/s, 3.78m/s) and forward speed (3.20, 3.45, 3.78, and 4.32 m/s) on the cutting efficiency of Alfafa reaper, and achieved maximum cutting efficiency of 98.6 % at forward speed of 3.2 km/hr, and cutting speed of 3.78 m/s. From my results, and in reference to other authors' findings, it can be concluded that cutting speed of a harvester played major in harvesters' cutting efficiency, followed moisture content of the plants/crops, and the forward speed.

Graphical Interpretation of Effect of Independent Factors on the Cutting Efficiency

The effect of moisture content, clearance between the cutting blades, and cutter bar speed on the cutting efficiency is presented in Figure 5, 6, 7, 8, 9 and 10, respectively.

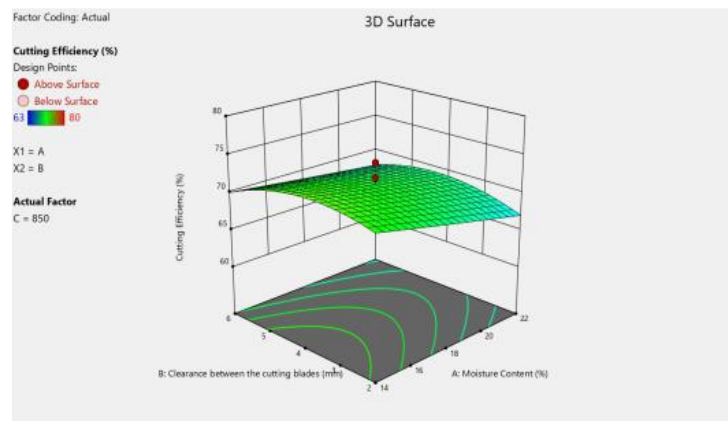


Figure 5: 3D Response Surface of Effect of A and B on the Cutting Efficiency

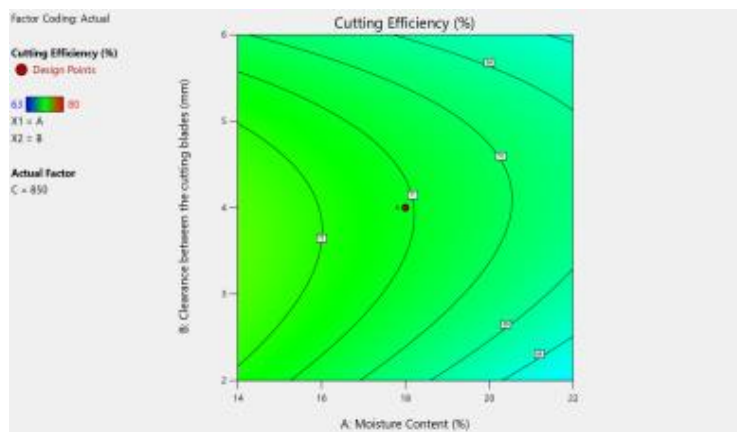


Figure 6: 2D Contour Plot of Effect of A and B on the Cutting Efficiency

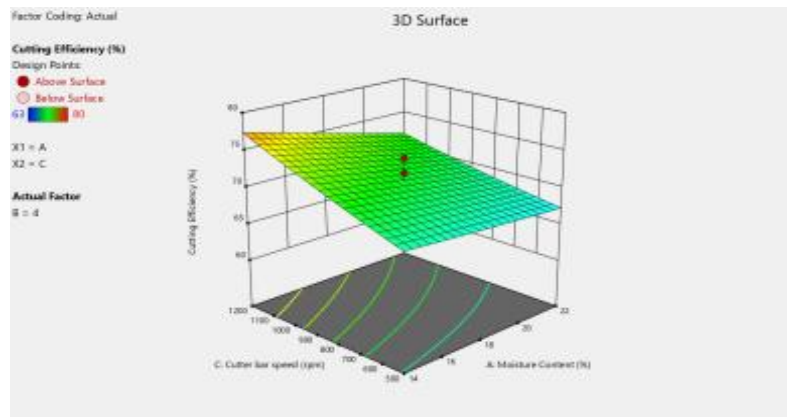


Figure 7: 3D Response Surface Plot of Effect of A and C on the Cutting Efficiency

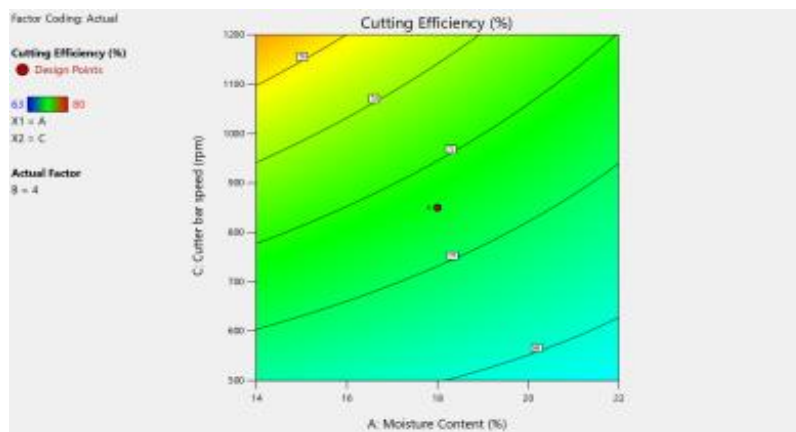


Figure 8: 2D Contour Plot on the Effect of A and C on the Cutting Efficiency

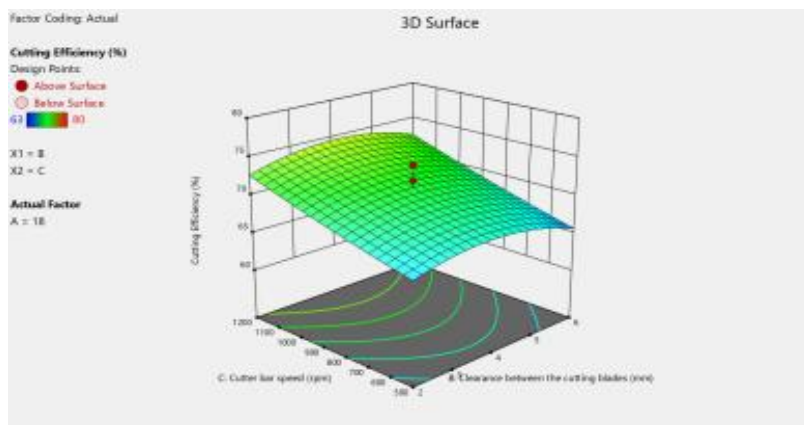


Figure 9: 3D Response Surface Plot of Effect of B and C on the Cutting Efficiency

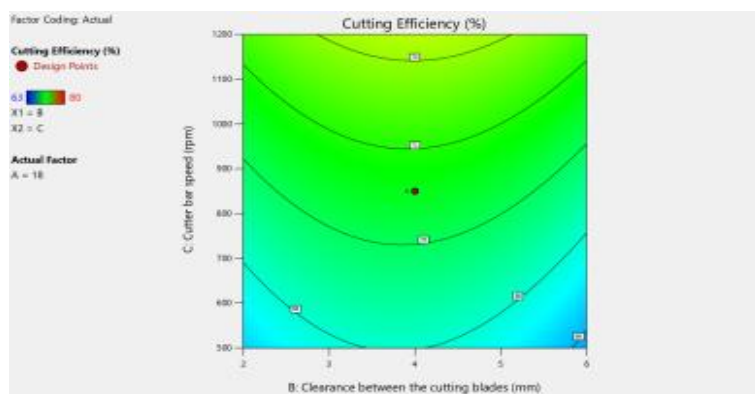


Figure 10: 2D Contour Plot of Effect of B and C on the Cutting Efficiency

Through the inspection of the graphs presented above, the optimum cutting efficiency was achieved at 18 % moisture content, clearance between the cutting blades (4 mm), and at 850 rpm cutter bar speed. The maximum predicted cutting efficiency of 74 % was achieved at 18 % moisture content, 3.99 mm clearance between the cutting blades, and 1159 rpm cutter bar speed. The minimum predicted cutting efficiency of 68 % was achieved at 21.27 % moisture content, 2.33 mm of clearance between the cutting blades, and 568 rpm cutter bar speed.

Optimization of Motorized Soybean Harvester

Numerical optimization was carried in order to determine the optimum combination of independent factors that can yield optimum cutting efficiency. The optimization indicated that high cutting efficiency of 77.305 % can be achieved by setting the moisture content, clearance between the cutting blades, and cutter bar speed at 14 %, 4.166 mm, and 1200 rpm respectively. The ramp function graph, 2D contour plot, and bar chart of desirability were presented in figure 11, 12, and 13, respectively.

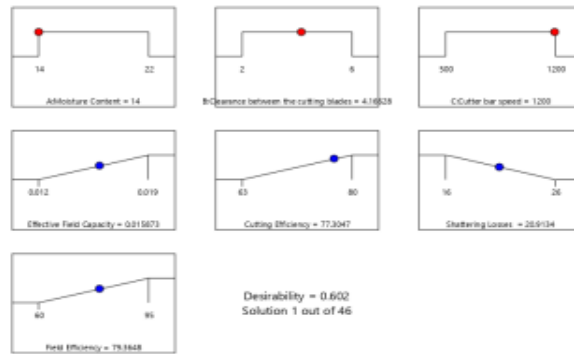


Figure 11: Ramp Function Graph of Independent Factors, and Response Variable (Cutting Efficiency)

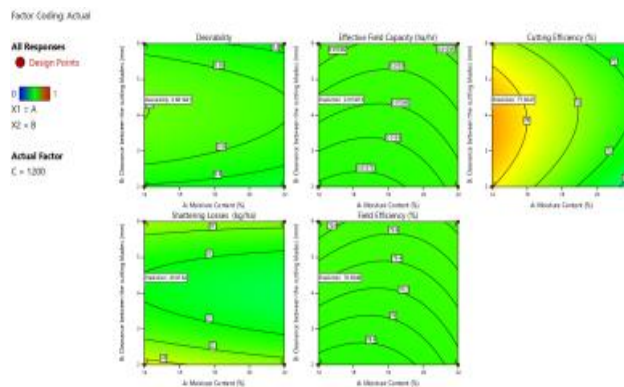


Figure 12: 2D Contour Plot Cutting Efficiency

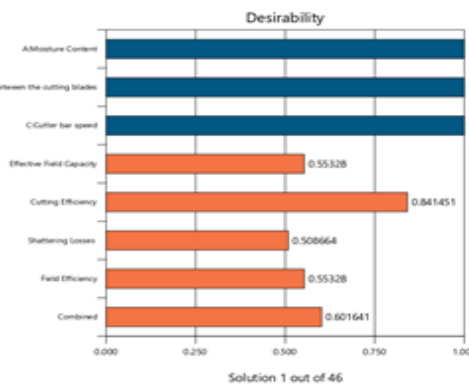


Figure 13: Bar Graph of Desirability of Cutting Efficiency

The desirability of cutting efficiency is 0.841 as shown in Figure 7. This value is close to 1, which implied that the cutting efficiency is optimum.

CONCLUSION

The developed motorized soybean harvester was evaluated and its cutting efficiency was determined. The out of the three

factors investigated, cutter speed played significant role in cutting efficiency of the harvester. As the cutter bar increased, the cutting efficiency increased, but as the moisture content increased, the cutting efficiency decreased. On the case of clearance between the cutting blades, it exhibited increase and decrease effect on the cutting efficiency. As the clearance between the cutting blades increased, the cutting efficiency

increase, and reached a certain point it became constant, and after that particular point, further increase in clearance value led to decrease in cutting efficiency.

The challenges encountered during the field evaluation were high rate of vibration, high percentage (28 %) of uncut stem, excess wear and tear of the cutting blades. These shortfalls can be addressed by incorporating damper, using high carbon steel to produce cutting blades, and overall reduction of the harvester's weight by 50 %.

REFERENCES

- Ahad Assad Yasser., Assad Yousif Khudher and Majed Saleh Hammoud (2025). Impact of Mechanical Process and Forward Speed in Cutting and Collecting Green Fodder. IOP Conf. Ser.: Earth Environ. Sci. 1487 012218. doi: <https://doi.org/10.1088/1755-1315/1487/1/01221>
- Al-Mashhadani, Abdul Rahman Hussein Ahmed (2023). Modification of the cutting knife angle of Murray-15hp driven grass cutter and its field testing under three levels of forward speed. Master's thesis in Agricultural Machinery and Equipment, College of Agricultural Engineering Sciences, University of Baghdad.
- Dugje IY., Omoigui. L.O., Ekeleme. F., Bandyupadhyay. R. L., Kumar. P and Kamara. A.Y (2009). Guide to soybean production in Northern Nigeria. International Institute of Tropical Agriculture (IITA), Ibadan Nigeria.
- Gana IM, Gbabo A, Hassan A M (2023). Effects of operating speed, cutter bar cutting speed and forage plant moisture content on performance of a forage harvester. MOJ Food Process Technol ;11(1):1-7. doi: <https://doi.org/10.15406/mojfpt.2023.11.00271>
- Jin, Y., Wang, J., Song, Z., Zhang, R (2025). Design and Parameter Optimization of a Reciprocating In-Soil Cutting Device in a Green Leafy Vegetable Orderly Harvester. Appl. Sci.15, 7326. doi: <https://doi.org/10.3390/app15137326>.
- Kiran, I. K. M., Awal .M. A., Ali .M. R. (2017). development and performance evaluation of a battery operated small-scale reaper. Agricultural Engineering International: CIGR Journal, 19(2): 217-223
- Ko, J. M. (2010). A study on soybean supply, demand trends, breeding and industrial utilization. In: Strategy symposium for globalization and policy support for soybean industry; Rural development administration. National Institute of Crop Science: 19-30.
- Liu (2023). Research progress on mechanized technology and equipment for soybean and corn Strip compound planting. Chin. J. Agric. Mech. 44(1), 39-47. doi: <https://doi.org/10.13733/j.jcam.issn.2095-5553.2023.01.006>
- Maruf O. Ajenifuja., Maiwada L. Suleiman., Moshood Isiaka., Ogijo I. Samuel (2025). Effects of Speed and Energy Sources on the Performance of a Developed Solar-Powered Rice Harvester for Small-Scale Farming. FUOYE Journal of Engineering and Technology, Volume. doi: <https://dx.doi.org/10.4314/fuoyejet.v10i3.3> 10, Issue
- Musoni. S., Raymond. M. N and Leonard. M (2013). Mechanization of Soybean Harvesting for Small and Medium Scale Farmers in Zimbabwe. IOSR Journal of Agriculture and Veterinary, Volume 4(1), pp 51-57
- Shital Sonawane., Abhay Kumar Mehta., Rohit Dilip Nalawade., Somnath P. Sonawane1, Mohit Kumar and Mehdi Rahimi (2025). Design, development and performance evaluation of henna harvester. doi: www.nature.com/scientificreports
- Yiljep, Y. D. and Mohammed, U. S (2005). Effect of knife velocity on cutting energy and efficiency during impact cutting of sorghum stalk. Agric. Eng. Int. CIGR EJournal 7, 1-10.



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