

## An Evaluation of Field Efficiency of a Developed Petrol Engine Powered Rice Harvester

<sup>1</sup>Timothy, Y. J., <sup>2</sup>Yusuf, D. D., <sup>3</sup>Mohammed, U. S., <sup>4</sup>Isiaka, M.

<sup>1</sup>Department of Agricultural Education,  
Federal College of Education, Zaria

<sup>123</sup> Department of Agricultural And Bio-Resources Engineering,  
Faculty of Engineering, Ahmadu Bello University, Zaria.

### ABSTRACT

To address the recurring issue of time-consuming and tedious rice harvesting faced by small-scale farmers in Northern Nigeria, this work aimed to develop a locally fabricated rice harvester to improve efficiency and reduce drudgery and losses. The existing options, manual methods using sickles and knives and the costly importation of mechanical harvesters, were not ideal. A self-propelled petrol engine rice harvester was developed and fabricated in the workshop of the Department of Agricultural and Bio-resources engineering at ABU Zaria. Performance evaluation of the harvester was conducted at the Institute of Agriculture Research farm for the 2020 and 2021 wet seasons, considering three independent variables (speed, moisture, and height) in relation to the dependent variable (field efficiency). Statistical analysis using SAS 2009 software was performed on the data collected for 2020, 2021, and the pooled results. The findings showed that speed, moisture, and height significantly influenced the actual field capacity (FCA). The highest FCA (0.224 ha/hr) was achieved at a height of 15cm and moisture of 27% with a speed of 4m/s during the 2021 wet season. Speed had a significant effect on field efficiency (FE), and the highest FE (91.1%) was obtained at a speed of 3m/s, moisture of 13%, and height of 20cm. The study suggests using a high torque prime mover to drive the harvester and replacing belt mechanisms with chains to eliminate belt slippage issues during harvesting. Overall, the machine is recommended for use by small-scale farmers in Northern Nigeria. In conclusion, this work successfully developed and evaluated a locally fabricated rice harvester, offering an efficient solution to the challenges faced by small-scale farmers during rice harvesting in the region.

### ARTICLE INFO

Article History

Received: March, 2023

Received in revised form: April, 2023

Accepted: May, 2023

Published online: June, 2023

### KEYWORDS

Petrol Engine, Rice harvester

### INTRODUCTION

Rice (*Oryza sativa*) is a cereal belonging to the family *Gramineae* (Ajala and Gana, 2015). The world rice production, had risen to 648 million metric tons. India and China account for the highest production of 141 million metric tons (MMT) and 187 MMT, respectively (FAO, 2020). In Nigeria, 1.1 million metric tons (MMT) was produced in 2019 and for Nigeria to be self-sufficient in rice consumption, additional 3.2 MMT

would be needed, (Akinwunmi, 2021). WARDA (2004) reported that Nigeria is the highest rice productions country in West Africa and the third largest in Africa, after Egypt and Madagascar. Ajala and Gana (2015) reported the most popular lowland and upland varieties as the *faro 44, 52, 59 and 61* respectively.

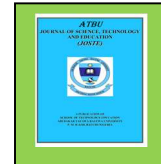
Harvesting constitutes a major and labour intensive operations in rice cultivation (Rangasamy and Kathirve, 2012). The harvesting

Corresponding author: Timothy, Y. J.

✉ [timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



is still based on using sickle, which is laborious, time wasting and uneconomical (Olukunle, 2010). Solving these problems, the choice of mechanical harvesting, like a combine harvester was made. But the high cost, complexity, land fragmentation, spare parts facilities for repairing and maintenance affects its acceptability (Imrul *et al.*, 2017). To solve the challenges affecting combine harvesters, the development of reapers and binders was done (Kato, 2013). However, these machines too have their shortcomings; the difficulties in importing reapers, their application in our local farm setting, much labour for gathering and transferring the panicles along with the straws, have reduced their acceptability. (UNAPCEAM. 2010). Therefore, Handaka and Pitoyo (2011) says that the development of local rice harvesters is the best alternative, but their evaluations have proven low performance, hence additional challenges. To these effects, Berhe and Somado, (2013) stated that there is the need to further develop harvester from local materials that is affordable and can be available to solve the harvesting challenges for the small scales' farmers in this Nigeria

The aim is to improve rice harvesting, reduce drudgery, save time and losses, while the main objectives of this study is to develop and optimize the performance of a rice harvester. And the specific objectives are to; design rice harvesting machine, construct the components and assemble the machine, and conduct the performance evaluation of the machine

## MATERIALS AND METHODS

### **Materials Selection**

The selected materials were; angle pipes, cast iron, mild steel flat bars, flat bar panel, bolts and nuts, based on their strength, toughness, brittleness, malleability, and affordability.

### **Design Considerations**

1. The rice stalks were vertically standing.
2. The thickness of the stalk adopted for the blade penetrating was 5mm.
3. Length of rice stalks to be cut was 400mm.
4. Translational motion was limited to 20mm.
5. The ultimate shear strength of rice stalk was 14N/mm<sup>2</sup> (Tavakoli *et al.*, 2010).
6. Minimum efficiencies of belt drive, chain and bevel gears were 95%, 98% and 97% (Grainer, 2019) and toothed wheel external diameter of 280mm

### **Machine Description and Working Principle**

The Rice harvester as seen in (Plate .1) comprises of power source from a petrol engine, power transmission by belts and chains, cutting components among others. Double-groove belt drive transmits power from the source to the gear box input shaft while a chain drive transmits power from the gearbox input shaft to the front axial spiked wheels for locomotion. Within the central gear box were two equal bevel gears for input and output torque concurrently. Thus, the output shaft was connected to a lower parallel shaft; as the actuation source for the cutting blade through a connecting crank link, such that a constant translational motion was obtained between the lower and upper cutting blade thus, result to cutting actions



Plate 1. The Developed Rice Harvester.

## DESIGN THEORY AND CALCULATION

### Cutting force:

The magnitude of cutting force which is also called shearing force is depends upon the area to be cut and mechanical properties of stock material. The force required to shear the blank or slug is calculated by following formula (Singh, 2020).

$$F_{sh} = lt\tau_{max} \quad 1$$

where:

$F_{sh}$  is the shearing force (N),  $l$  is the length of cut / perimeter of the stalks of rice (mm)  
 $t$  is the thickness of stalks material (mm),  $\tau_{max}$  is the ultimate shear strength of rice stalk ( $N/mm^2$ )

### Cutting power required:

Considering that the blades will slide across each other in a translational manner, the cutting power was calculated thus according to (Khurmi and Gupti, 2005) as

$$P_{sh} = F_{sh}v_{sh} \quad 2$$

where,

$P_{sh}$  is the shearing power required (W),  $v_{sh}$  is the adopted shearing velocity (m/s)

### Selecting the petrol engine:

The petrol engine for the machine was selected based on power requirement of the

machine for its operation as well as its motion given by (Khurmi and Gupti, 2005)

$$P_{pm} = P_{sh}\eta_b\eta_{ch}\eta_{bg}\eta_{ch} \quad 3$$

where,

$P_{pm}$  is the power requirement of the petrol engine prime mover (W),  $P_{sh}$  is the shearing power requirement for cutting the rice stalks (W),  $\eta_b$  is the efficiency of the belt drive (%),  $\eta_{ch}$  is the efficiency of the chain drive (%),  $\eta_{bg}$  is the efficiency of the bevel drive (%)

### Length of belt:

The belt drive was obtained using the relation given by (Khurmi and Gupti, 2005)

$$l_b = \frac{\pi}{2}(d_{is} + d_{pm}) + 2x + \frac{(d_{is} - d_{pm})^2}{4x} \quad 4$$

where,

$l_b$  is the length of the belt (mm),  $d_{is}$  is the diameter of the pulley on the gearbox input shaft (mm)

$d_{pm}$  is the diameter of the pulley on the prime mover output input shaft (mm),  $x$  is the centre distance between the prime mover output shaft and gearbox input shaft (m)

Corresponding author: Timothy, Y. J.

✉ [timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved

### Shaft diameter:

The shaft diameter was obtained by using the ASME shaft design code given by (Khurmi and Gupta, 2005)

$$d_{sw} = \sqrt[3]{\frac{16}{\pi\tau} \sqrt{(K_m M)^2 + (K_t T)^2}} \quad 5$$

where,

$d_{sw}$  is the safe diameter for the wheel axial shaft (mm),  $M$  is the maximum bending moment upon the shaft (Nm),  $K_m$  is the combined shock and fatigue factor for bending (1.75),  $K_t$  is the combined shock and fatigue factor for Torsion (1.75),  $T$  is the maximum torque transmitted by the shaft (Nm),  $\tau$  is the maximum allowable shear stress on the shaft material ( $N/m^2$ )

### Machine Design:

Design process included conceptual stage, embodiment stage and detail stage (Godfrey, 2013) As in Appendix D the design was made in third angle projection showing the orthographic projection of the plan, front and the end elevation and the isometric drawing having the following features;

The frame of the rice harvester, spike wheel with ball bearing within, back castor wheel bearing, front wheel bracket with ball bearing, gearbox/ clutch, Cutting blade crank link and cutting blade.

### Development/ Fabrication Process:

The harvester's components were made from MS angles iron, MS rod, MS flat bar, angle iron and square bar consisting of the frame and the shafts; whose functions were support and the transmission of power from one point to another. Other parts include slider crank and cutter bar made of cast iron mild steel flat bar of thickness 5mm. While the Spike wheel with ball bearing were constructed from mild steel flat sheet of 3mm thickness and serrated with spikes to withstand slippage and provides rolling resistance. And the gearbox/ clutch: were constructed from 5mm flat bar as a housing for gear oil and the two bevel gears and to withstand pressure and fatigue. Other transmission and coupling parts: consist of sprocket, chain, pulleys, bevel gears

### PERFORMANCE EVALUATION INDICATORS

#### Actual field capacity

$$FC_A = \frac{A_T}{T_o} \left( \frac{ha}{h} \right) \quad 6$$

where,

$FC_A$  = actual field capacity, ha/h.,  $A_T$  = area covered, ha.  $T_o$  = total operating time, h.

#### Theoretical field capacity:

$$FC_T = \frac{W_c \times S_o}{10} \quad 7$$

where:

$FC_T$  = Theoretical field capacity, ha/h,  $W_c$  = Cutting width, m,  $S_o$  = Operating speed, km/h

#### Field efficiency:

$$E = \frac{FC_A}{FC_T} \times 100 \quad (\%) \quad 8$$

where:

$E$  = Field Efficiency, %,  $FC_A$  = Actual field capacity, ha/h,  $FC_T$  = Theoretical field capacity, ha/h

### PERFORMANCE INDICES

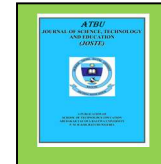
The effect of speed, moisture and height on the actual field capacity and field efficiency of rice harvester.

#### Field Preparation.

The field located at IAR (Institute of Agricultural Research) farm, Bomo area of Samaru, Zaria, was planted with faro 44 using spot method. The planting was done on a level ground of sandy loam soil during raining season, on average plant to plant spacing of 25cm in the 2020 and 2021 wet seasons respectively.

#### Experimental Design and Layout:

The effect on combinations of machine height (H) 3 levels (H<sub>1</sub>-15cm, H<sub>2</sub>-20cm, H<sub>3</sub>-25cm) above the ground, machine forward speed (S) 3 levels (S<sub>1</sub> 3m/s, S<sub>2</sub> 4m/s, S<sub>3</sub> 5m/s) and crop moisture content (M) 3 levels (M<sub>1</sub>-13%, M<sub>2</sub>-20%, M<sub>3</sub>-27%) on field performance of the rice harvester. A Randomized Complete Block (RCBD) design with three replications. The 3 x 3 x 3 factorial treatment combination was used from Gupta and Khurmi (2005)



## RESULT AND DISCUSSION

### Effect of Height, Speed and Moisture Content on Actual Field Capacity.

From appendix. A below, the heights show no significant difference ( $P \geq 0.05$ ) on Actual field capacity ( $FC_A$ ) for machine operation in 2020 season although from the mean, the highest  $FC_A$  (0.210 ha/hr.) and the lowest  $FC_A$  (0.206 ha/hr.) were obtained at 15cm and 25cm machine height respectively. However, in 2021 season, height indicates significantly ( $P \leq 0.01$ ) difference on the AFC, with highest  $FC_A$  (0.266 ha/hr.) and the lowest ( $FC_A$ ) (0.234 ha/hr.) obtained at 20cm, and 15cm height of machine respectively from the mean table for the same period. This implies that  $FC_A$  of machine increased with decreased in machine height and decreased with increased in machine height respectively.

However, the effect of speed as observed in the same Appendix A shows significant ( $P \leq 0.01$ ) difference on  $FC_A$  with the highest mean value of (0.224ha/hr.) in 2020 and (0.251ha/hr.) in 2021 at the speed of 3m/s. While the lower  $FC_A$  (0.198 ha/hr and 0.217 ha/hr.) were recorded at the speed of 4m/s in 2020 and 2021 season respectively. In both seasons the  $FC_A$  were observed to be similar to the  $FC_A$  0.20 and 0.25ha/hr for chine self-propelled reaper and BRRRI reported by Zami *et al.*, (2014) and similar to the field capacity of Korean and Vietnan reaper 0.15ha/hr and 0.23ha/hr respectively Nipal (2016). It was also observed that the  $FC_A$  tend to be higher than that of Nipa 2016 (0.22ha/h) and lower than that of Korean reaper (0.33ha/h), China reaper (0.25ha/h) respectively, (Elsaied *et al.*, 2015), Imrul *et al.*, 2017). This implies that  $FC_A$  of machine can be affected by speed, soil condition, crop condition and operator skill (Nipa, 2016). Finally, moisture does not show any significance difference ( $P \geq 0.05$ ) on the  $FC_A$  of the machine in 2020 and 2021 wet season, but the highest  $FC_A$  (0.216 ha/hr. and 0.247 ha/hr.) and the lowest  $FC_A$  (0.206 ha/hr.) were recorded at the moisture of 27% and 20% respectively in 2021 wet season.

### The Effect of Interaction of Height and Moisture Content on the Actual Field Capacity.

Appendix B shows the highest Actual Field Capacity (0.224 ha/hr) at the machine height and moisture content of 15cm and 27% respectively, while the lowest  $FC_A$  (0.195 ha/hr.) was recorded at the height and moisture of 25cm and 13%, respectively. These are higher than the Actual Field capacity (0.0525ha/hr) recorded by Ogunlowo and Olaoye (2017) at 1400rpm. But similar to the  $FC_A$  (0.20ha/h) and (0.25ha/hr) for chine self-propelled reaper and BRRRI reported by Zami *et al.*, (2014) and Korean and Vietnan reaper (0.15ha/hr) and (0.23ha/hr) Nipal (2016). It was also observed that the  $FC_A$  tend to be higher than that of Nipa 2016 (0.22ha/h) and lower than that of Korean reaper (0.33ha/h), China reaper (0.25ha/h) respectively, (Elsaied *et al.*, and 2015), Imrul *et al.*, 2017). This implies that  $FC_A$  of machine can be affected by speed, soil condition, crop condition and operator skill (Nipa, 2016).

### The Pooled ANOVA Result of the Effect of Height, Speed and Moisture Content on the Actual Field Capacity.

The pooled ANOVA result shows that speed significantly ( $P \leq 0.05$ ) have effect on the Actual Field Capacity of machine, while moisture and height shows no significance ( $P \geq 0.05$ ) effect on the dependent variable. Also both the replication within the table and the variables themselves did not show a significance difference ( $P \geq 0.05$ ). This implies that speed is essential for the actual field capacity.

### Regression of Height and Speed on Actual Field Capacity of Machine.

From figure 1, the graph shows the effect of height and speed on the actual field capacity of machine at three different crop moisture level (13%, 20% and 27%) respectively. The highest  $r^2$  value of 0.75 was obtained at the height and crop moisture content of 20cm and 27% respectively, while the lowest  $r^2$  0.072 was realized at the height and crop moisture of 20cm and 20% respectively.

Corresponding author: Timothy, Y. J.

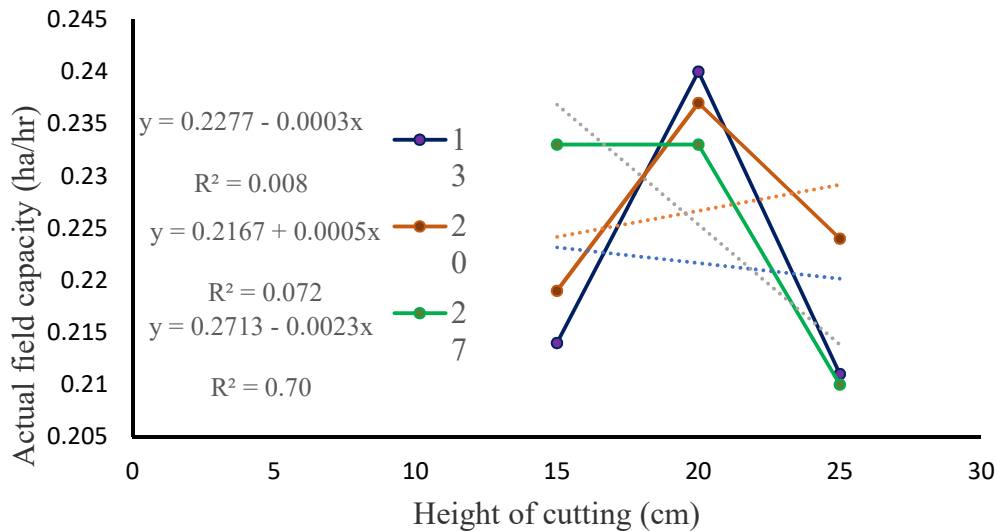
[timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

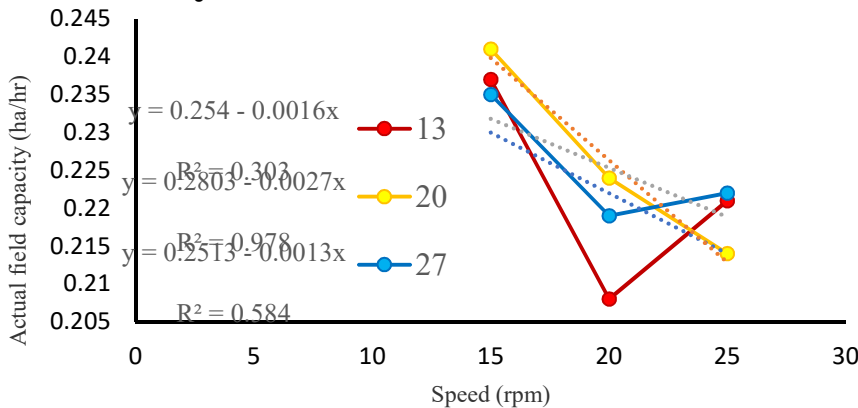
© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved

Similarly, figure .2 shows the highest  $r^2$  value of 0.97 at the speed of 15rpm and moisture level of 20% while lowest  $R^2$  value of 0.30 was

obtained at the speed of 15rpm and moisture level of 13% respectively.



**Figure 1:** Regression of Height on Actual Field Capacity of Machine Operated Rice Harvester at various Moisture Level during 2020/2021 Combined Season



**Figure 2:** Regression of Speed on Actual Field Capacity of Machine Operated Rice Harvester at Various Moisture Level during 2020/2021 Combined Seasons

**Effect of Height, Speed and Moisture Content on Field Efficiency of Machine.**

From Appendix C, the result shows that height, and moisture does not have significant ( $p \geq 0.05$ ) effects on field efficiency (FE) of machine

during the two wet season. However, speed shows a significant different on the field efficiency in 2021 wet season. It was observed from the mean results, that the highest FE (91.5% and 90.5%) were obtained at the height of 20cm and

Corresponding author: Timothy, Y. J.

[timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved

15cm for 2020 and 2021 seasons, while the lowest FE (89.6% and 84.3%) were obtained at 15cm height of 15cm and 27cm respectively for the 2020 and 2021 season respectively.

In term of speed, from the mean result, the highest FE (90.9% and 87.5%) and lowest FE (90.1% and 87.6%) were recorded at the speed of 3m/s and 5m/s in the two wet seasons respectively during the machine harvest. The FE obtained was higher than the FE reported by Asrafal, *et al.*, (2018) on Korean reaper (50.1%) and Vietnam reaper (64%). Also higher than Kalsirislip and Singh (1999) reapers' field efficiency of 74% for standing crop and 72% for lodged crop and Manjunatha *et al.* (2009) field efficiency of 73% at the average speed of 3.2km/h.

However, moisture content indicated highest FE (91.3% and 85.0%), and lowest FE (74.2% and 85.0%), at the moisture content of 13% and 27% wet basis for machine harvest. These are higher than the FE (86.53%) recorded by Wagiman *et al.*, (2019) but similar to the FE (86.53%) reported by Hanna (2016), The machine records of highest field efficiency depending on time, types and agronomic characteristics of rice, plot sizes, operator's skill, time losses for turning and adjustment (Alizadeth and Allameh, 2013).

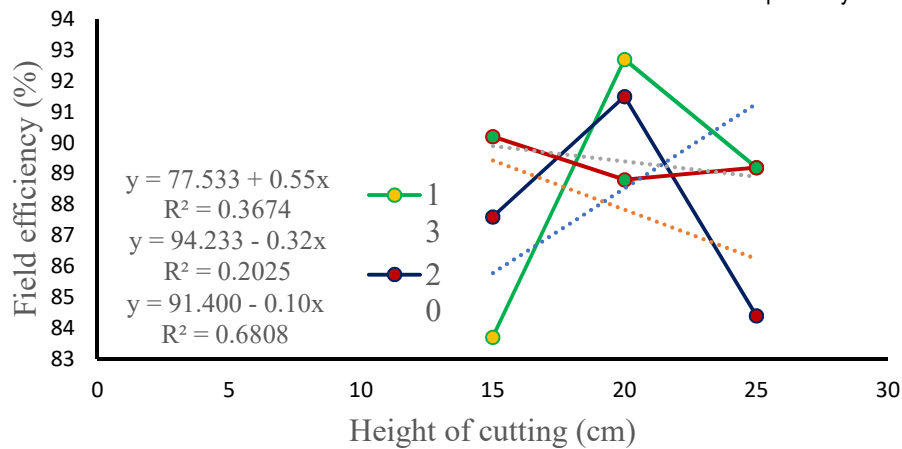
### The Pooled ANOVA Result of the Effect of Height, Speed and Moisture on Field Efficiency.

The Pooled ANOVA Result shows the replications not significance in either ( $p \geq 0.05$ ) or ( $p \geq 0.01$ ). It implies that since there were not significance differences between test, average values can be accepted for the variables.

### Regression of height and speed on field efficiency of machine

From the figure 3 and 4 below, the graph shows the effect of height and speed on the field efficiency of machine for the 2020/2021 combined season at three different crop moisture levels (13%, 20% and 27% wet basis) respectively. Figure 3 shows the highest  $r^2$  value of 0.68 which was obtained at the height and crop moisture level 15cm and 27%, while the lowest  $r^2$  value of 0.20 was realized at the height of 20cm and crop moisture level of 20% respectively.

In addition, however, figure 4 which is the effect of speed on the field efficiency at different moisture levels indicated the highest  $r^2$  value of 0.62 at the speed of 25rpm and moisture level of 13% wet basis while the lowest  $r^2$  value of 0.39 was identified at the speed of 15rpm and moisture level of 20% wet basis respectively.



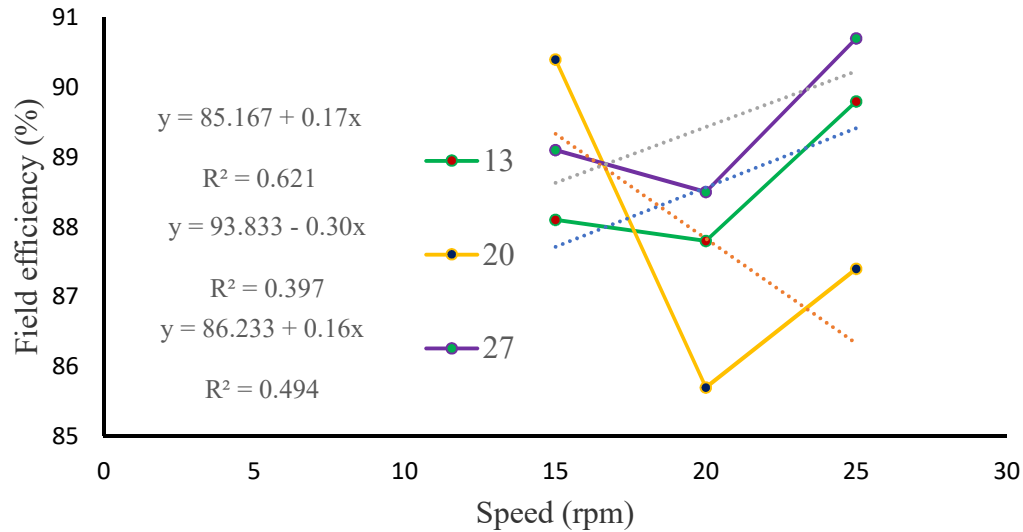
**Figure 3:** Regression of height on Field Efficiency of Machine Operated Rice Harvester at Various Moisture Level during 2020/2021 Combined Season

Corresponding author: Timothy, Y. J.

[timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



**Figure 4:** Regression of Speed on Field Efficiency of Machine Operated Rice Harvester at Various Moisture Level during 2020/2021 Combined Season

**CONCLUSION**

Speed show a significant different ( $p \leq 0.01$ ) on Actual Field Capacity ( $FC_A$ ), moisture and height does not show a significant different ( $p \geq 0.05$ ) but the highest  $FC_A$  of 0.224ha/hr, was obtained at the height and moisture of 15cm and 27%. The highest  $r^2$  value of 0.75 was obtained at the height and crop moisture content of 20cm and 27% respectively, for the field efficiency, Speed, moisture and height does not show significant different ( $p \leq 0.05$ ) on the field efficiency (FE) in 2020, but in 2021 speed show a significant different ( $p \leq 0.01$ ) on the field efficiency and the highest FE (91.1%) was obtained at the speed, moisture and height. of 3m/s, 13% and 20cm respectively. With the high field efficiency exhibited by the machine, therefore the machine has satisfied the desire objectives and is recommended to be tested by the small scale farmers in Nigeria.

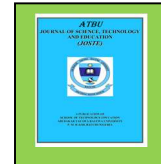
**REFERENCES**

Ajala, A. S and Gana, A. (2015). *Analysis of Challenges Facing Rice Processing in*

*Nigeria (An Unpublished Thesis)* Submitted to the Department of Food Science and Engineering, Ladok Akintola University of Technology, Ogbomoso, Nigeria. pp 34.  
 Akinwunmi, A. (2021). Rice Smugglers Still on the Prowl. *The National Mirror*. Retrieved from <http://www.nationalmirroronline.net/new/rice-smugglers-still-on-the-prowl/>. (Date Accessed: April , 2021)  
 Alizadeh, M.R and Allameh, A. (2013). Evaluating Rice Losses in Various Harvesting Practices. *International Research Journal of Applied and Basic Science* 4 (4): 894-901  
 Ashraful Alam, M.D, Anwar H.M.D, Saiful Islam A.K.M, and Monjurul-Alam, M.D (2018) Performance Evaluation of Power-Operated Reapers for Harvesting Rice at Farmers' field. *Journal of Bangladesh Agricultural University* 16 (1): 144-150.

Corresponding author: Timothy, Y. J.  
 ✉ [timmyyus@gmail.com](mailto:timmyyus@gmail.com)  
 Department of Agricultural Education, Federal College of Education, Zaria.  
 © 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved





- Berhe, T. and Somado, E.A. (2013). Harvest and Post-Harvest Operations. [[www.africanrice.org](http://www.africanrice.org)] site visited on 05/09/2018.
- El-Sharabasy, M. M. (2019), *Selecting the Proper System for Mechanizing Grain Crops Harvesting in the Small Holdings*. M. Sc. Thesis. Agric. Eng. Dept., Faculty of Agric., Zagazig Univ. Egypt. pp 33.
- Food and Agriculture Organization (FAO), (2019). *Sustainable Rice Based Production and People's Livelihood, International Rice Commission Newsletter (Special Edition) 52*, International Rice Commission, FAO, Rome, Italy. pp. 38.
- Grainger. (2019). Types of Belt Drives and How They Improve Efficiency. Retrieved from Grainger Know How: <https://www.grainger.com/know-how/equipment-information/kh-types-of-belt-drives-efficiency>
- Handaka, Y and Pitoyo, J (2011) Modification of a Grass Cutter in to a Small Rice Harvester, Indonesian, *Journal of Agriculture 4(1)*: 40-45.
- Imrul, M.D., Abdul-Awal, M.D and Rostom, A. (2017) Development and Performance Evaluation of a Battery Operated Small-Scale Reaper. *Agricultural Engineering International: CIGR Journal 17 (2)*:217-223.
- Kato, F. (2013). *Development of Major Rice Cultivation area in the Kilombero Valley, Tanzania*. Kyoto University, Japan. Pp. 18.
- Kalsirislip, R and Singh, G (2001) Adoption of a Stripper Header for Thai -Made Rice Combine Harvester. *Journal of Agriculture Engineering Research 80 (2)*: 23-40-251.
- Khurmi, R. S. Gupta, J. K, (2005). *A textbook of Machine Design*. Ram Nagar, New Delhi: Euresia Publishing House.pp34
- Nipa, J.F. (2016) Study on performance evaluation of self-propelled reaper. *Proceedings of the International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia, March 8–10, 2016*.
- Ogunlowo, Q. O. And J. O. Olaoye (2017), Development and Performance Evaluation of a Guided Horizontal Conveyor Rice Harvester. *Agro-search 17 (1)*: 66–88.
- Olukunle, O. T. (2013), Developments in Grain Harvesting Mechanization. *Journal of Agricultural Engineering and Technology 18(1)*:3-12.
- Rangasamy, R. M. and Kathirve, K. (2012), Philological Cost Analysis for the Operation of Knapsack Cotton Picker in India, M Muthmilsalvan, *Karnataka Journal of Agric. Sci.* 19(3):622-627.
- Tavakoli, M., Tavakoli, H., Azizi, M., & Haghayegh, G. (2010). Comparison of Mechanical Properties between Two Varieties of Rice Straw. *Advance Journal of Food Science and Technology, 2(1)*, 50-54.
- West Africa Rice Development Association (WARDA) (2004) *Growing Lowland Rice*. A Production Handbook, Africa Rice center, Abidjan, Côte d'Ivoire. Pp.23

#### **Acknowledgement**

The researcher acknowledged the efforts of the Technical Staff in the Work Shop of the Department of Agricultural and Bio- Resources Engineering, A.B.U., Zaria.

---

Corresponding author: Timothy, Y. J.

✉ [timmyyus@gmail.com](mailto:timmyyus@gmail.com)

Department of Agricultural Education, Federal College of Education, Zaria.

© 2023. Faculty of Tech. Education, ATBU Bauchi. All rights reserved