

# PERFORMANCE EVALUATION OF A SELF-PROPELLED MINI COMBINE HARVESTER JD12GD ON WHEAT CROP

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## ABSTRACT

*A mini combine harvester is a light duty harvesting machine that simultaneously cuts, threshes and cleans standing crop of grain. Wheat harvesting, which is time consuming and labour intensive, is commonly done manually by peasant farmers in Kano State, Northern Nigeria. A self-propelled mini combine harvester JD12GD purchased by Agricultural and Environmental Engineering Department, Bayero University Kano was evaluated on 200 m by 40 m wheat field at Kano River Irrigation Project in Kura Local Government area of Kano State, Nigeria to ascertain its performance parameters. A randomized complete block design (RCBD) was adopted for this study with three levels of forward speed (S); (S1) 1.8 km/h, (S2) 2.3 km/h and (S3) 2.8 km/h, three levels of grain moisture content (M); (M1) 20.16%, (M2) 15.21% and (M3) 10.35% for Atilla and Norman-Borloug wheat varieties planted adjacent to one another on the field. The results of the experimental research show that the mean theoretical field capacity, effective field capacity, field efficiency, fuel consumption, and cleaning efficiency of the combine harvester on Atilla variety are 0.253 ha/h, 0.181 ha/h, 72.12%, 1.77 L/h, and 80.64% respectively while that on Norman-Borloug are 0.253 ha/h, 0.18 ha/h, 71.68%, 1.79 L/h, and 80.11% respectively. Analysis showed that the combine harvester performed better on Atilla variety with less grain losses during harvesting compared to Norman-Borloug wheat varieties. Further evaluation of the combine harvester under a wide range of grain crops and soil conditions across different agro-ecological zones and economic comparison with manual harvesting is recommended. This would facilitate the adoption of the combine harvester by smallholder farmers so that timeliness in harvesting could be ensured and grain losses minimized.*

**Keywords:** Performance evaluations, wheat varieties, mini combine harvesters, JD12GD

## 1 INTRODUCTION

**W**heat (*Triticum aestivum*) is a staple food and the most widely cultivated cereal in the world [1]. It contributes more calories and proteins to the world diet than any other cereal crops [2]. In Nigeria, Wheat is a crop of major interest as it is the main component of bread and other wheat-based products such as cakes, biscuits, macaroni, spaghetti, pasta, etc. The demand and consumption of wheat in Nigeria is increasing consistently and this can be attributed to increasing population and change in diet pattern. Wheat has been cultivated in Nigeria for several centuries especially, in the northern states. Commercial production in Nigeria is carried out under irrigation mainly in the Sudan and Sahel ecological zones, which include the Chad Basin, Hadejia Jama'are River Basin and Sokoto River Basin. The crop is cultivated during the cold "Harmattan" period between the months of November and March. Wheat harvesting is usually a tedious operation which includes: cutting, transporting, threshing and cleaning. Wheat can be harvested when the moisture content dries to 20 percent w.b and below [3]. Harvesting methods being used are manual harvesting and mechanical harvesting. Most farmers, particularly the smallholder farmers use manual harvesting with sickles to cut, sticks to thresh and trays to winnow or clean. These consumes more time, labour and cost [4]. Timely harvest of the crop is vital to achieve better quality and higher yield of the crops. To overcome these problems, mechanical harvesting is required. Combine harvesters are the greatest applications in this regard. A combine harvester is machine use in harvesting the small grains, soybeans and corns, but these machines are also used for a wide variety of seed crops [5]. The mechanism included in a combine harvester accomplish

five general functions which are: cutting, feeding, threshing, separating and cleaning [6]. The cutting-and-feeding assembly known as the header, includes the reel, the cutter bar, a platform for receiving the cut material, and conveyors for delivering the material to the threshing cylinder [5]. The header is attached through a lateral hinge axis and is adjustable from the operator's station to obtain heights of cut ranging from about 5 cm up to at least 100 cm. The threshing mechanism which detach the grain from the stalks, consists mainly of a revolving cylinder and a concave. Threshing is accomplished with the cylinder working against the concave (a curved, grated sections). Separation operation removes the threshed grain from the mixture of plant parts that comes from the threshing section [7]. Cleaning unit assembly consist of a cleaning shoe which has a combination of two or three cleaning sieves, a damper controlled fan and augers for conveying the tailings and the clean grain to the elevators [8]. Combine harvester comes in different sizes which are mainly categorized as mini and large for light duty and heavy-duty operations respectively. In small holdings, the use of large combine harvester which may be over 4m in width [8] is inappropriate because of the large investment required, issues with maneuverability during field operation and high operational and maintenance cost. So, the use of mini combine harvesters commonly in the range of 1.1 to 2.1 m width is appropriate for small holdings. Meanwhile, the Nigerian farming system is characterizing by small holding and more than 80% of the Nigeria farmers are small holder farmers [9]. Amongst the primary indicators of combine performance is the amount of grain loss during harvesting operation [10] and the harvesting quality i.e. cleaning efficiency of the combine. Combine harvesting can be profitable only if the operator knows how to adjust the combine properly and operate it efficiently with a minimum of losses. Harvesting losses in combine harvesters occur mainly due to the header, thresher and separator activities. Studies have shown that the header loss are the major problems of combine harvesters [11, 12]. Thus, any effort for reducing this loss is economically important [7]. The main objective of the study is to evaluate the performance of a self-propelled mini combine harvester JD12GD on wheat crop. While the specific objectives include: to determine the effect of grain moisture content and combine harvester forward speed on fuel consumption, effective field capacity, field efficiency, cleaning efficiency, header loss, threshing loss, separating loss and total loss in harvesting Atilla and Norman-Borloug wheat varieties and to compare the performance of the combine harvester on Atilla and Norman-Borloug wheat varieties using t-test. Study of the field performance such as field capacity, field efficiency, fuel consumption and grain losses at various operational units of the combine harvester would enhance the drive towards exploiting the further research on the potentials of the machine for farmers and researcher.

## **2 MATERIALS AND METHODS**

The materials used in this research includes; a self- propelled mini combine harvester JD12GD, measuring tape (50 m span), stop watch, fuel measuring cylinder (1000 ml capacity), fuel (diesel), ranging poles (80cm in length), 1m wooden square frame, G & G electronic scale, jj3000Y, 3000g capacity, 0.1 sensitive weighing scale, 150kg capacity, digital tachometer, Sunwa DT836, digital Camera, TECNO P9, grain moisture meter, LSKC-608, laboratory Oven, UNISCOPE SM9023. The self-propelled mini combine harvester mainly composed of the engine, manipulating unit, header, threshing, separating and cleaning unit. The manipulating unit is composed of: The main clutch handle, swing clutch pin, accelerator handle, down cutting elevation handle, gear level handle and leg, steering wheel. Plate I show a Self-Propelled Mini Combine Harvester JD12GD.



Plate I. A Self-Propelled Mini Combine Harvester JD12GD

The reel height was set at constant height of 35 cm from the ground level by adjusting the cutting height level. This is the lowest level attainable on the combine and it's close to the reel height level of 30 cm recommend by [13] for minimum grain loss on wheat. The rasp bar cylinder clearance was un-adjustable at a clearance of 12 mm. Reel rotational speed and cylinder speed were pre-set at 25 rpm and 700 rpm [10] respectively by adjusting the accelerator nob and measuring the output speed using a calibrated tachometer. At this constant level of accelerator nob, preliminary tests were conducted to determine the combine harvester forward speed by varying the gear levels and running the combine through a marked distance and timed. Crop moisture content was monitored from time to time using a calibrated moisture meter (calibrated with the oven drying method) until appropriate wheat crop harvesting moisture content was obtained [14]. The wheat varieties were Atila and Norman-Borloug. These varieties were selected because they are the most cultivated local wheat varieties in Kano state. Atila is locally demanded for making pasta while Norman-Borloug is for Bread making. The combine harvester field performance testing was carried out on farmer's field at Kano River Irrigation Project in Kura Local Government area of Kano State-Nigeria. The area is located along Kaduna-Kano road on latitude  $11^{\circ}77' N$  and longitude  $8^{\circ}42' E$  within Kano State-Nigeria. A 200 m by 40 m wheat crop field was divided into three blocks for the field test. Each of the blocks was subdivided into 1.1m by 20 m length plots to carryout both mechanical harvesting with the self-propelled mini combine harvester JD12GD of 1.1 m width, side by side with the manual harvesting (the use of sickle to cut, sticks to thresh and tray to winnow).

## 2.1 Experimental Design

Wheat moisture content, wheat variety and combine forward speed were used as the independent variables for the field performance of the combine harvester. Randomized Complete Block Design (RCBD) was adopted to study the various effects of combine forward speed (S) (3 levels) and wheat moisture content (M) (3 levels) on effective field capacity, field efficiency, cleaning efficiency and fuel consumption as performance parameters each for Atila (V1) and Norman-Borloug (V2) wheat variety. The 3x3 factorial treatment combination was assigned at random with three replications. The moisture contents ( $M_1$ ,  $M_2$ ,  $M_3$ ) corresponding to 20.16%, 15.21% and 10.35%, forward speed ( $S_1$ ,  $S_2$ ,  $S_3$ ), corresponding to 1.8, 2.3 and 2.8 km/hr were used. The moisture content range were selected to cover high, moderate and low moisture content of wheat during harvesting. Forward speed range of the combine was selected base on the recommendation of forward speed during harvesting from the combine harvester manual i.e. between 1.5 to 3 km/h.

## 2.2 Principle of Operation of the Combine Harvester

When the combine harvester works, the reel separates the crop to be cut at once from the crop awaiting cutting. The cutting operation takes place when the wheat crop passes the cutter bar, they are cut by reciprocating cutter bar; after cutting, the header stirrer sends the crop to the threshing chamber from where the threshing cylinder repeatedly beats the moving crop on screens for threshing and separation. The grain with little debris penetrates through the screen and is gathered by the grain exit stirrer to the right side of the threshing machine (the forward direction of the harvester) where fan repeatedly blows out impurities to the left side. The cleaned grain is thrown through the stirrer grain

board for bagging. In addition, straws are stopped by the screener and thrown outside of the machine at the right side of the roller thus completing the entire process as shown in plate II.



Plate II. The Mini Combine Harvester JD12GD Operation on Wheat Field

### 2.3 Field Test Measurement

Machine and crop parameters were measured on field for evaluating the performance of the combine harvester. Machine parameters refer to measurement related to the machine while crop parameters refer to those measurements related to crop. The procedure and relationships that were adopted for measurement, recording and computations of various parameters are presented below.

#### 2.3.1 Crop parameters

The crop parameters that were determined include; grain moisture content, plant height, plant population, pre-harvest loss and height of cut. To determine the height of wheat crop, nine (9) different plants were selected at random from the field. The height of the plant was obtained by measuring the distance from the soil surface to the tip of the panicle. The collected data were finally averaged. The number of plant present per meter square is known as plant population. It is expressed as number/m<sup>2</sup>. Ranging poles each measuring 80 cm in length was used to mark the sample areas. The ranging poles were placed in standing crops at nine (9) different locations of each field to mark (1 m x 1 m) sample areas. Number of plants enclosed by the ranging poles were noted. Average value of the number of plants per square area of the nine locations was then determined. The pre-harvest losses occur in standing crops due to shattering by insects, birds, animals, wind and rusts etc. It is the grain shed on the ground before any harvesting takes place. Ranging poles each measuring 80cm in length were used instead of steel frame to mark the sample areas. The ranging poles were placed in standing crops at nine (9) different locations of the field to mark (1 m x 1 m) sample areas. Loose grains on the ground and enclosed by the ranging poles were collected to represent grain loss per meter square area then pre-harvest losses determined as follow:

$$PL = \frac{W_p}{Y} \times 100 \quad (1)$$

Where; PL= Pre-harvest loss in %, Y= Field yield in g/m<sup>2</sup>,  $W_p$ = Average weight of shattered grain on the ground enclosed by the sighting poles before harvest (g). To determine the stubble height, nine (9) different plants were selected at random from the field after harvesting operation. The height of cut was obtained by measuring the distance from the soil surface to the top of the cut plant. The data collected were finally averaged.

#### 2.3.2 Machine parameters

##### i. Combine Forward Speed

Forward speed of the self-propelled mini combine harvester was determined by varying the gear levels (1-L, 2-L, 3-L, 1-H, 2-H and 3-H) of the combine at constant acceleration knob and then

running the machine through a marked distance and timed. The forward speeds were then calculated and recorded in km/h [15] as follow:

$$S = \frac{3.6 D}{T} \quad (2)$$

Where: S= forward speed (km/h), D = Harvesting distance (m), T = harvesting time (s). After which 2 L, 3 L and 1 H gear levels corresponding to 1.8, 2.3 and 2.8 km/h respectively were noted and utilized during field operation (As per forward speed range of between 1.5 km/h – 3 km/h recommended in the combine manual during harvesting operation)

#### ii. **Fuel Consumption**

To measure fuel consumption, a procedure provided by [16] was used with some calibrations. Instead of filling the engine fuel tank completely at the start and finish of each time-recorded period and weighing the quantity of fuel added, fuel of known volume was added into the fuel tank and then a meter rule was inserted into the fuel tank after which the graduations on the meter rule were calibrated against the corresponding volume (litres) of diesel [14]. The procedure above was used for the measurement before and after every harvesting operation. Fuel consumption was determined using the relation below:

$$F_c = \frac{q}{t} \quad (3)$$

Where;  $F_c$  = Fuel consumption (L/h),  $q$  = Quantity of fuel consumed (L),  $t$  = consumption time (h)

#### iii. **Field Efficiency**

Field efficiency is the ratio of the useful time to total operating time expressed in percent. Effective time (useful time) was measured by stop watch and the lost time for machine adjustment, turning and refueling was taken during field operation. The sum of useful and loss time gave the total operational time [6].

$$e = \frac{T_e}{T_t} \times 100 \quad (4)$$

Where;  $e$  = field efficiency (%),  $T_e$  = Useful time (h),  $T_t$  = Total operating time (h)

#### iv. **Theoretical Field Capacity**

Theoretical field capacity of machine is the rate of field coverage that would be obtained if the machine is performing its function at 100% of the time at the rated speed and always covered 100% of its rated width. It was calculated based on the operating speed and width of the machine [6] as follow:

$$C_t = \frac{W \times S_o}{10} \quad (5)$$

Where;  $C_t$  = theoretical field capacity (ha/h),  $W$ = cutting width (m),  $S_o$  = Operating speed (km/h)

#### v. **Effective Field Capacity**

The Effective field capacity of the combine is the actual rate of being able to harvest crop in a given time. In order to determine the effective field capacity, the rated width of the equipment (cutting width), forward speed of travel and field efficiency were measured, and effective field capacity determined as given by [6] as follow:

$$C_e = \frac{W \times S_o \times e}{10} \quad (6)$$

Where;  $C_e$  = effective field capacity (ha/h),  $W$ = cutting width (m),  $S_o$  = Operating speed (km/h),  $e$  = Field efficiency (%)

#### vi. **Cleaning Efficiency**

The cleaning efficiency reflects the amount of weed present in a grain sample. To determine the cleaning efficiency, grain sample was collected from the grain tank (sack) and weighed to give the total weight of sample after every harvest. The total sample was further cleaned manually and weighed to

obtain the weight of clean grain. The cleaning efficiency was then calculated by dividing the weight of clean grains by total weight of sample (clean grain + weed) collected per unit time. Cleaning efficiency was calculated as given by [6] as follow:

$$CE = \frac{B}{D} \times 100 \tag{7}$$

Where; CE = cleaning efficiency (%), B = weight of clean grain (g), D = total weight of sample (g)

### 3 RESULTS AND DISCUSSION

#### 3.1 Results

The effect of grain moisture content and combine harvester forward speed on fuel consumption, field efficiency, effective field capacity and cleaning efficiency for Atilla and Norman-Borloug wheat variety are discussed as follow:

##### 3.1.1 Effect of Moisture Content and Forward Speed on Fuel Consumption of the Mini Combine JD12GD Harvester for Atilla and Norman-Borloug Wheat Variety

Results for mean values of fuel consumption for Atilla and Norman-Borloug wheat variety is presented with figure 1a and 1b respectively. The figures show that fuel consumption increases with increase in forward speed. These could be due to the increase in engine speed. More so, the figures show that fuel consumption increases with increase in moisture content. This can be attributed to the fact that at higher moisture content of crop, the crop is heavier, stiffer and requires more energy to cut. Similar trends were reported by [2] and [18].

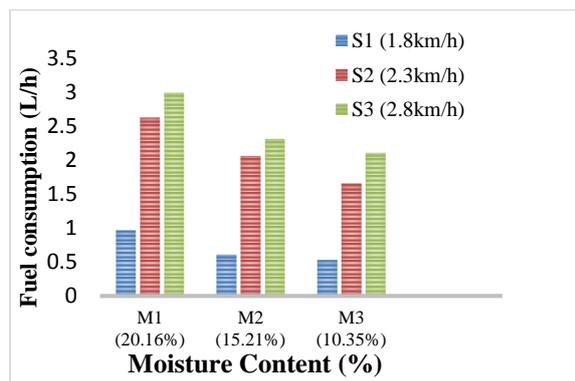


Figure 1a. Effect of Moisture Content and Forward Speed on Fuel Consumption for Atilla (V1)

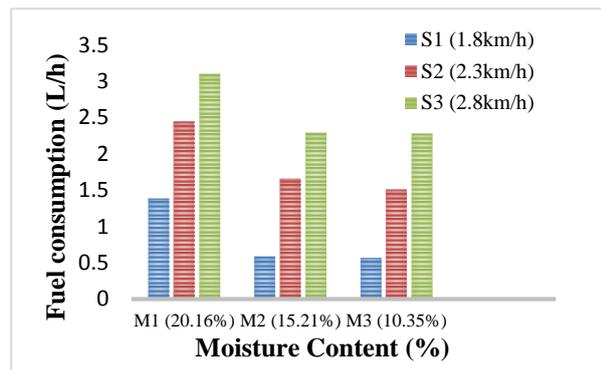


Figure 1b. Effect of Moisture Content and Forward Speed on Fuel Consumption for Norman-Borloug (V2)

The results of the analysis of variance (ANOVA) are presented in Table 1 and 2. The tables show that moisture content and forward speed significantly affected fuel consumption of the combine harvester at 1% probability level for both varieties. While Interaction between moisture content and forward speed have no significant effect on the fuel consumption of the combine harvester for both varieties.

Table 1. Analysis of Variance for Fuel consumption on Atilla (V1)

Source of variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	0.06463	0.03231	0.95
Moisture content, M	2	2.77943	1.38971	41.01**
Speed, S	2	15.73747	7.86874	232.21**
M * S	4	0.27297	0.06824	2.01 <sup>NS</sup>
Error	16	0.54217	0.03389	
Total	26	19.39667		

\*\* - Highly Significant (at 1% probability level); \* - Significant (at 5% probability level)  
NS - Not significant

Table 2: Analysis of Variance for Fuel Consumption on Norman-Borloug (V2)

Source of variation	Degrees of freedom	Sum of squares	Mean of square	F-Value
Replication	2	0.02547	0.01274	0.39
Moisture content, M	2	3.58776	1.79388	54.93**
Speed, S	2	13.88992	6.94496	212.66**
M * S	4	0.00637	0.00159	0.05 <sup>NS</sup>
Error	16	0.52253	0.03266	
Total	26	18.03205		

\*\* - Highly Significant (at 1% probability level); \* - Significant (at 5% probability level); NS - Not significant

### 3.1.2 Effect of Moisture Content and Forward Speed on Field Efficiency of the Combine Harvester for Attila and Norman-Borloug Wheat Variety

Results for mean values of field efficiency at various combinations of moisture content and forward speed is presented in figure 2a and 2b. From the figures, it can be seen that the field efficiency of the combine harvester decreases with increase in forward speed. This may be attributed to the fact that at higher speed, it became difficult to control the combine harvester. Similar observation was reported by [2, 13], but contrary to the findings of [18]. The difference in observations may be attributed to the mode of control of the combine harvesters. More so, field efficiency of the combine harvester was observed to decrease with increasing moisture content. This may be attributed to the fact that at higher moisture content, the grain weight is more with lesser header loss thereby reducing the forward speed of the machine. Similar observation was made by [18].

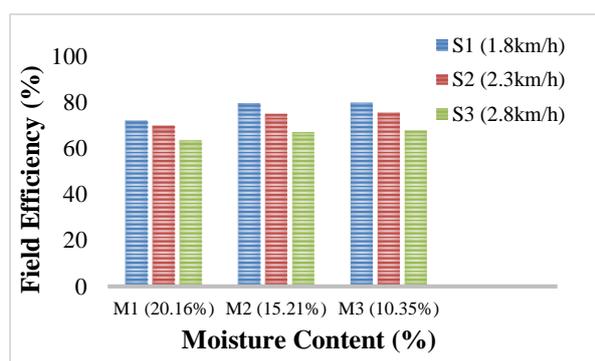


Figure 2a. Effect of Moisture Content and Forward Speed on Field Efficiency for Attila (V1)

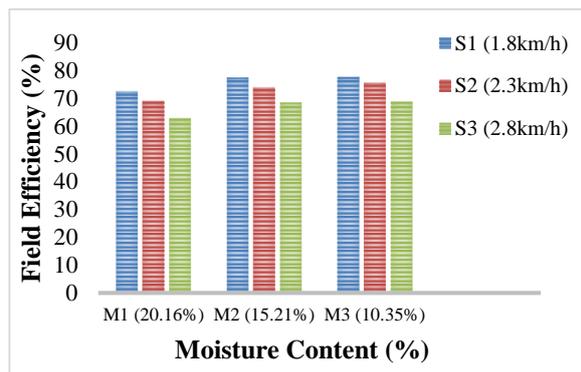


Figure 2b. Effect of Moisture Content and Forward Speed on Field Efficiency for Norman-Borloug (V2)

The result of the analysis of variance (ANOVA) are presented in Table 3 and 4. Results from the Tables show that moisture content and forward speed significantly affected the field efficiency of the combine harvester at 1% probability level for Attila and Norman-Borloug wheat varieties, while interaction between moisture content and forward speed have no significant effect on the field efficiency of the combine harvester for both varieties.

Table 3. Analysis of Variance for Field Efficiency on Attila (V1)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	7.030	3.515	0.01
Moisture content, M	2	175.504	87.752	32.16**
Speed, S	2	521.293	260.647	95.52**
M * S	4	11.389	2.847	1.04 <sup>NS</sup>
Error	16	43.660	2.729	
Total	26	758.876		

\*\* - Highly significant (at 1% probability level); NS - Not significant

Table 4. Analysis of Variance for Field Efficiency on Norman-Borloug (V2)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	0.071	0.035	0.34
Moisture content, M	2	185.731	92.866	35.05**
Speed, S	2	379.446	189.723	71.61**
M * S	4	2.268	0.567	0.21 <sup>NS</sup>
Error	16	42.390	2.649	
Total	26	609.906		

\*\*-Highly significant (at 1% probability level); NS- Not significant

### 3.1.3 Effect of Moisture Content and Forward Speed on Effective Field Capacity of the Combine Harvester for Attila and Norman-Borloug Wheat Variety

Results for the mean values of effective field capacity at various combinations of forward speed and grain moisture content is presented in figure 3a and 3b. The figures show that effective field capacity increases with increase in forward speed and decrease in moisture content for both varieties. Similar trends have been reported by [18].

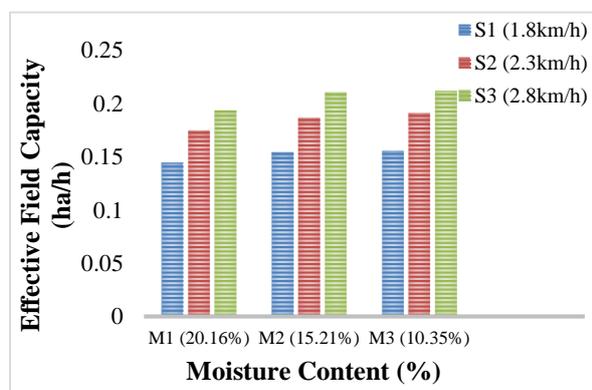


Figure 3a. Effect of Moisture Content and Forward Speed on Effective Field Capacity for Attila (V1)

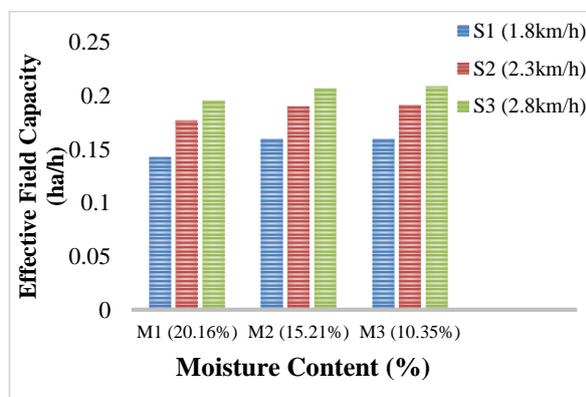


Figure 3b. Effect of Moisture Content and Forward Speed on Effective Field Capacity for Norman-Borloug (V2)

The result of the analysis of variance (ANOVA) are presented in Table 5 and 6. Results from the tables show that moisture content and forward speed significantly affected the effective field capacity of the combine harvester at 1% probability level for Attila and Norman-Borloug wheat variety respectively. While the interaction between moisture content and forward have no significant on the effective field capacity of the combine harvester for both varieties.

Table 5. Analysis of Variance for Effective Field Capacity on Attila (V1)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	0.017267	0.008633	1.95
Moisture content, M	2	4.184067	2.092033	471.89**
Speed, S	2	1.462867	0.731433	164.98**
M * S	4	0.012533	0.003133	0.71 <sup>NS</sup>
Error	16	0.070933	0.00443	
Total	26	5.747667		

\*\*- Highly Significant (at 1% probability level); NS- Not significant

Table 6. Analysis of Variance for Effective Field capacity on Norman-Borloug (V2)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	0.00001798	0.00000899	0.52
Moisture content, M	2	0.00117295	0.000058647	33.94**
Speed, S	2	0.01362286	0.00681143	394.19**
M * S	4	0.00027647	0.000001728	1.23 <sup>NS</sup>
Error	16	0.00027647	0.00001728	
Total	26	0.01517509		

\*\* - Highly Significant (at 1% probability level); NS - Not significant

### 3.1.4 Effect of Moisture Content and Forward Speed on Cleaning Efficiency for Attila and Norman-Borloug Wheat Varieties

Results for the mean values of cleaning efficiency at various combinations of forward speed and grain moisture content is presented in figure 4a and 4b. The figures show that cleaning efficiency decreases with increase in forward speed as well as increase in moisture content.

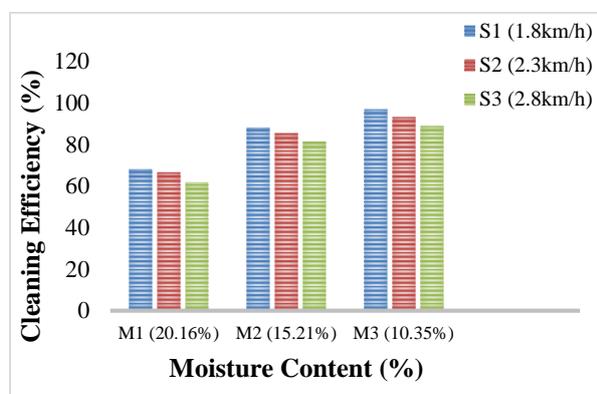


Figure 4a. Effect of Moisture Content and Forward Speed on Cleaning Efficiency for Attila (V1) Attilla (V1)

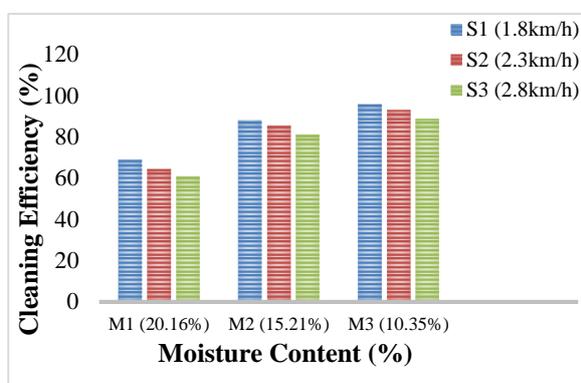


Figure 4a. Effect of Moisture Content and Forward Speed on Cleaning Efficiency for Norman-Borloug (V2) Attilla (V1)

The results from the analysis of variance (ANOVA) are presented in table 7 and 8. Results from the tables show that moisture content and forward speed significantly affected cleaning efficiency of the combine harvester at 1% probability level for both varieties. The interaction between moisture content and forward speed have no significant effect on the cleaning efficiency of the combine harvester for both varieties.

Table 7. Analysis of Variance for Cleaning Efficiency on Attila (V1)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	5.959	2.979	0.67
Moisture content, M	2	3714.103	1857.051	419.90**
Speed, S	2	240.792	120.396	27.22**
M * S	4	3.970	0.993	0.22 <sup>NS</sup>
Error	16	70.761	4.423	
Total	26	4035.585		

\*\* - Highly Significant (at 1% probability level); NS - Not significant

Table 8. Analysis of Variance for Cleaning Efficiency on Norman-Borloug (V2)

Source of Variation	Degrees of freedom	Sum of Squares	Mean of square	F-Value
Replication	2	1.349	0.674	0.23
Moisture content, M	2	3614.116	1807.058	609.23**
Speed, S	2	221.042	110.521	37.26**
M * S	4	4.222	1.056	0.36 <sup>NS</sup>
Error	16	47.458	2.966	
Total	26	3888.187		

\*\* - Highly Significant (at 1% probability level); NS - Not significant

### 3.2 Discussion of results

The results revealed the mean values of the performance parameters of the combine harvester on both varieties that include fuel consumption, field efficiency, field capacity, cleaning efficiency. The fuel consumption was 1.77 L/h at an average forward speed of 2.3 km/h. [2, 19] obtained similar observation of 1.78 L/h and 1.69 L/h respectively. While [4] obtained a higher fuel consumption of 6.8 L/h. This may be attributed to higher cutting width and forward speed of the machine. Field efficiency was obtained as 72%. [2, 20, 21] obtained similar field efficiency of 72%, 72% and 74.3% respectively while [14, 19] obtained lower field efficiency of 60.7% and 54.78% respectively. The lower field efficiency obtained in the later maybe attributed to smaller experimental plot, lower forward speed and presence of weed during operation as compared to the aforementioned. Field capacity of the machine was obtained as 0.181ha/h. [2] obtained almost similar field capacity of 0.195 ha/h. [20, 21, 22] obtained higher field capacity of 1.42 ha/h, 0.81 ha/h and 1.05 ha/h respectively. The higher field capacity obtained by these researchers may be attributed to higher forward speed and cutting width of the machine. The cleaning efficiency of the combine harvester was found to be 80.8% which is smaller than the findings of notable researchers such as and [4, 14] with values of 99.32% and 96.37% respectively. The smaller value obtained in this research may be attributed to the fact that the combine harvester has smaller blower capacity.

## 4 CONCLUSION

Based on the results from the experiment, the following conclusions were made: i) Grain moisture content and forward speed were found to have effects on fuel consumption, field efficiency, effective field capacity and cleaning efficiency of the combine harvester while wheat variety has effects on only header loss and total grain loss. ii) Atilla and Norman-Borloug wheat varieties can be optimally harvested with mini combine harvester JD12GD at 1.8 km/h forward speed and 10.35% moisture content. iii) Mini combine harvester JD12GD performs better with less grain loss on Atilla wheat variety than Norman-Borloug.

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