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Performance Evaluation of Deutz-Fahr M1202 Combine Harvester on Rice Crop in Kano State- Nigeria

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Abstract

On-farm research to evaluate the performance of Deutz-Fahr (M1202) combine harvester on rice crop was conducted on Agricultural Engineering Department research and demonstration field, Bayero University, Kano. The experiment was run in a completely randomized block design based on three independent variables which include: forward speed of the machine, 3 levels each of moisture content of the crop and clearance. Field experiments were conducted at 1.70 km/hr constant speed, 11, 13 and 15% grain moisture content (MC) and 12, 20 and 26 mm cylinder-concave clearances. The results show that theoretical field capacity, effective field capacity, field efficiency and mean fuel consumption were 0.77 ha/hr, 0.68 ha/hr, 88 % and 45 L/ha respectively. Analysis of variance shows that there was highly significant difference in the mean values of grain breakages, cleaning efficiency and shaker losses at different MC and concave clearances. The mean values for grain breakages, cleaning efficiency and shaker losses were highest at 11% MC with values standing at 2.78%, 96.37% and 41.17 kg/ha respectively. Mean values for grain breakages, cleaning efficiency and shaker losses at 13 and 15% MC are statistically similar but lower than those at 11%. Grain breakages and cleaning efficiency values were highest at 12 mm clearance and lowest at 26 mm. But mean values for shaker losses were highest at 26 mm clearance and lowest at 12mm.

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Keywords: combine harvester, moisture content, concave clearance, shaker losses

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Introduction

Man power Development in Agricultural Engineering profession is of vital importance. Universities and other institutions of higher learning are trying to meet the requirements of equipment for effective teaching and research. Agricultural Engineering Department, Bayero University, Kano has newly acquired a Deutz-Fahr model M1202 combine harvester for teaching and research. The evaluation of the performance of the newly acquired combine would set the pace for other researchers who are going into the field of harvest and post harvest Engineering. It would guide farmers/researchers on the appropriate time, condition and machine setting for effective combine operation, and also serve as a basis for future students' work on the machine.

The greatest applications of combines are in harvesting the small grains, soy beans and corns, but these machines are also used for a wide variety of seed crops (Kepner *et al*., 1978). Direct combining, which means cutting and threshing in one operation, is the most common harvesting method. Windrowing permits the curing of green weeds and unevenly ripened crops before threshing. The weather hazard to the standing crop is reduced because windrowing can be started several days earlier than direct combining (Kepner *et al.*, 1978). The cutting-and-conveying assembly known as the header, includes the reel, the cutterbar, a platform or conveyor for receiving the cut material, and conveyors for delivering the material to the cylinder (Kepner *et al.*, 1978). 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 grain ordinarily is cut just low enough to recover all or nearly all of the heads. If the straw is to be saved, cutting may be at a lower height even though more material must be handled by the machine (Kepner *et al.*, 1978). The reel consists of number of wide wooden slats to feed the crop to the cutting platform and is driven by shafts and gears. Its height and speed are adjustable. A clearance of about 12.5 to 25cm between the reel and cutter bar is suitable for all purposes. The canvas carrier runs very close to the knife and receives the harvested crop to feed the threshing unit. Canvas may also be provided with narrow wooden slats across the width, to avoid slippage of the grain stalks on the canvas. The size of a combine is indicated by the width of cut it makes. The small size self propelled combines ranging from 1.5 to 2.1 m are common. However, large size machines may be over 4 m in width (Ojha and Michael, 2011).

The threshing mechanism, which separates the grain from the stalks, consists mainly of a revolving cylinder and concave. A feeder beater is usually located in front of the cylinder and at the upper end of the elevator-feeder to assist the elevator-feeder in feeding the grain to the threshing mechanism (Smith, 1965). Cylinders may be spike tooth cylinder, peg-tooth cylinder, rasp bar cylinder or angle bar cylinder (Ojha and Michael, 2011). Most combines are provided with the rasp-bar- type cylinder and concave (Smith, 1965). The main separation of the grain from the straw is through concaves (Smith, 1965). The beater also beats the heads of the grain as they come from the cylinder. In addition, it helps to loosen further the grain in the head so that it will fall out (Ojha and Michael, 2011). The loose grains which are mixed with the straw as it leaves the cylinder are separated by oscillating straw racks(Smith, 1965). The straw racks are oscillated at 200 to 300 strokes per minute so as to throw the straw slightly upwards and backwards (Ojha and Michael, 2011). These racks may consist either of one piece or several sections which alternately move with a slight elliptical action to pitch the straw rear ward with each movement. A revolving crankshaft is used to operate them. The pitch action of the straw racks shifts the loose grain from the straw and let it fall onto a grain pan underneath (Smith, 1965). The function of the cleaning unit is to remove chaff and other foreign matter from the grain (Smith, 1965). The 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. The grains and chaff falling on the uppermost sieve and through other sieves, are generally winnowed by the evenly distributed blast from the fan. The air blast from the fan is directed upward at an angle to blow the chaff to the rear side. The grain fall through sieves on to the pan which is inclined.

El-Haddad (2000) stated that the threshing efficiency increased with increasing of drum speed and decreasing of feed rate. The maximum threshing efficiency was 99.761% at drum speed 21.25 m/s (1400 r.p.m.), feed rate 15 kg/min. El-Behiry *et al*., (2000) found that the feeding rate increases linearly by increasing drum speed. The straw sizes decreased by increasing the drum speed, while the grain losses increasing. Also, the straw sizes decreased at lowest moisture content under all threshing process. Combine adjustment is very important to reduction of wheat losses during harvesting. Although the mean of combine losses is about 4-5% in advanced countries, unfortunately in Iran is about 20% and higher (Moghaddam, 2007). In a rasp bar cylinder, threshing is achieved between corrugated cylinder bars and stationary bars of the concave. The rotating cylinder rubs the seed out from the head as it is drawn over the bars on the concave. Cylinder are generally 1.4 to 1.5 m long, 55 to 65 cm in diameter and generally have 6 to 8 bars which may be spirally fixed on the cylinder. The bars are generally channels or angle irons with corrugated or ridged rubber facings. Similarly, concaves are also rubber faced. The clearance between the cylinder and concave at the entrance is about 19 to 13 mm and it reduces to about 9 to 6 mm at the exit (Ojha and Michael, 2011). The peg tooth cylinder and concave is adaptable for threshing a variety of crops. The teeth on the concave and cylinder are arranged that the cylinder teeth pass midway between the staggered teeth on the concave. The clearance between cylinder and concave can be adjusted. As the grain stalks are allowed to pass through the unit, grain get separated from the head due to impact between the teeth. The peripheral speed of the cylinder varies between 1500 and 1800 m per minute. It is changed by means of adjustable pitch V-belt sheaves (Ojha and Michael, 2011).

The most significant qualitative indices of the estimation of operation of the threshing apparatus of combine harvesters were the grain threshing loss, grain damage and the part of the trash in the grain (Rademacher, 2007). They are closely related and depend on the design characteristics of the threshing apparatus, the cereal flow fed into the threshing apparatus, and technological parameters, such as drum rasp bars speed and the clearance between the drum and the concave (Shipokas, 2005). Crop flow at the beginning of the concave is by 1.1 m s^{-1} slower than at its end thus when a greater number of grains is threshed from the ears, they are separated through the concave more quickly and are less damaged. Estimates of the impact of the combine design on the operation qualitative indices, Feiffer *et al*., (2005) concluded that technological parameters of the threshing apparatus had the greatest impact on the grain damage. Proper operation of the reel is critical to minimize header losses, which include shatter losses and cutter bar losses. Shatter losses are grain heads or pods that fall to the ground due to the action of the reel. Cutter bar losses are grain heads or pods that are cut by the cutter bar but fall to the ground (Behroozi-Lar and Mobli, 2006). Tahir *et al*., (2003) showed that header losses mostly occur due to shattering of crop by cutter bar-moisture contact of crop at the time of harvest plays major role in containing these losses. Grain losses in stripper harvesting occur at the gathering/stripping operation which are shattering (grains spilled on the ground), stubble (grains left on the standing stalks) and lodging (grain left on the lodged stalks) losses. These losses can be reduced by resetting the machine and changing the harvesting technique. The losses should be assessed so that corrective measure can be taken to minimize the loss which is the main purpose of this study for rice harvesting with a self-propelled prototype stripping harvester developed in Nigeria, Adisa (2009).Agricultural Engineering Department, Bayero University, Kano has purchased a fairly used Deutz-Fahr model M1202 combine harvester for teaching and research. Evaluation reports (IAR, 1994) have indicated that information given by manufacturer manuals usually differ from evaluation indices obtained locally. Therefore, there is need to conduct some primary performance evaluation studies locally on the machine. The objective of this study was to measure selected performance parameters of the Deutz-Fahr (M1202) combine harvester and to establish some specifications for its operation on rice.

Materials and Methods / Methodology

The equipment used in this study was a Deutz-Fahr (M1202) combine harvester (Plate 1). The study parameters include moisture content, cylinder-concave clearance, forward speed, theoretical field capacity, effective field capacity, field efficiency, cleaning efficiency, grain breakages, shaker losses and mean fuel consumption. Jamila local rice variety was selected for the study.

The experiment was carried out on a 1.5 acre Agricultural Engineering Department research and demonstration field, Bayero University, Kano. The experiment was run in a completely randomized block design. The experimental plot which is 1.5 acre i.e. (100 × 60m) was divided in such a way as to have three (3) replications for each of the nine (9) treatments. The calibration of the combine as stated earlier was based on three independent variables which include: forward speed of the machine, 3 levels each of moisture content of the crop and clearance. The forward speed of the machine was kept constant throughout the experiment. The moisture content of the crop was taken at three different levels. The clearance was adjusted using the knob provided at the side of the operator. The procedures applied in field measurement of performance evaluation of combine by (Kepner *et al.*, 1978) were adopted in this study.

For a field-performance evaluation of the functional components, simultaneous collections were made of the material discharged from the straw walkers, the material from the shoe, and the seed into the grain tank. These collections were made while the machine was travelling at a constant speed over a measured and timed distance in a uniform crop condition. The combine was allowed to reach a stable operating condition at a constant feed rate before the collections were started. A running length of 25 meters was used for all measurements and determinations.

The theoretical field capacity of the combine harvester was evaluated using the relationship provided by (Kepner *et al.*,1978):

$$F_c = \frac{W \times S}{10} \qquad (1)$$

Where:

F_c = field capacity (ha/hr)

w= width of the machine (m)

s = speed of travel of the machine (km/hr)

A constant forward speed of 1.77 km/hr was maintained throughout the experiment. The effective field capacity was evaluated using the following equation (ASAE, 1979):

$$C = \frac{SWe}{10} \qquad (2)$$

Where C = effective field capacity (ha/h), S= speed (km/h), W= machine width (m) and e= field efficiency (decimal).

Based on time losses for turning and uploading, all other time losses were negligible. The efficiency was computed thus:

$$Eff = \frac{T_0}{T_t} x\, 100 \qquad (3)$$

Where:

T_o= operating time per hectare, h

T_t = total time, h

The moisture was determined using laboratory procedure provided by (FAO, 1994). Moisture content on a wet basis, M, (%) was calculated.

$$M\ (\%) = \frac{W_W - W_d}{W_W} \quad (4)$$

Where

W_W = mass of wet sample, g

W_d = mass of dry sample, g

The grain breakages was determined using the relation provided by (FAO, 1994).

$$\text{Damaged grain, } (\%) = \frac{W_{Dg}}{W_T} \quad (5)$$

Where

W_{Dg} = mass of damaged grain, g

W_T = Total mass of sample, g

The cleaning efficiency reflects the amount of weeds present in the grain sample (Tahir *et al*, 2003). The cleaning efficiency was then calculated by dividing the weight of clean grains by total weight of sample (clean grain + weeds) collected per unit time.

$$CE = \frac{B}{D}\ x\ 100,\ \% \quad (6)$$

Where

CE= cleaning efficiency (%)

B = weight of clean grain (g)

D = total weight of sample (g)

Shaker loss is the loose grain passing from the combine with the straw (FAO, 1994). The procedures outlined in (FAO, 1994) for the determination of shaker losses were adopted.

Fuel consumption was also measured using the procedure provided by FAO (1994) with some calibrations.

Results and Discussion

The results for mean values of grain breakages, GB, cleaning efficiency, CE and shaker losses, ShL are presented in table I. Analysis of variance in table II shows that grain breakages, cleaning efficiency and shaker losses at 11, 13 and 15 % moisture content, MC, are highly significant (1% level). Comparison using LSD in table III shows that grain breakage at 11 % moisture content is higher. Values at 15 % and 13 % moisture content are statistically similar but lower than 11%. Similar values of breakages were obtained by Veerangouda *et al.*, (2010) who reported 1.41, 1.10 and 1.35 %. Alizadeh and Khodabakhshipour (2010) reported mean grain breakages of 0.338, 0.247 and 0.167 % at 17.0, 20.0 and 23.0 % moisture content respectively. AMRI (2014) reported grain breakages of 1.1-3.6% The results obtained from this study and those reported by Alizadeh and Khodabakhshipour (2010) show that grain breakages increases as the moisture content is reduced which also agree with both reports from Kepner *et al.*, (1978) and Tahir *et al.*, (2003) which stated that seed damage increase as the seed moisture content is reduced. Analysis of variance shows that breakages at 12, 20, 26 mm concave clearance, CL, are highly significant (at 1 % level). LSD shows that clearance of 12mm has the highest breakages of 2.72 % while clearance of 26 mm has the lowest. It was observed from the result that grain breakage increases as the concave clearance is reduced. This results agrees with report of (Arvier, 1983) that, smaller clearance increases grain breakages.

Comparison using LSD in Table III shows that moisture content (MC) of 11 % has the highest cleaning efficiency of 96.37 % while MC of 15 % has the lowest with 94.65%. The results show that cleaning is higher at lower moisture content. The values obtained for the cleaning efficiency are close to 92.72, 93.50 and 94.00 % reported by Veerangouda *et al*., (2010) for tractor mounted combine but lower compared to 98.8 and 99.5% reported by Tahir *et al.*, (2003) for class denominator combine. Lower cleaning efficiency in this study could be accounted due to the presence of weeds in the fields because cleaning efficiency reflects the amount of weeds in the grain sample as reported by Tahir *et al.,* (2003). Therefore, proper weed control measures should be adopted in order to have good cleaning efficiency. Analysis of variance shows that at 12, 20, 26 mm concave clearance cleaning efficiencies are highly significant (at 1% level). Comparison using LSD shows that clearance of 12 mm has the highest cleaning efficiency of 96.29% while clearance of 26 mm has the lowest with 94.77%. It was observed from the result that cleaning is more efficient at lower concave clearance. Statistical analysis carried out shows no significant interaction between moisture content and concave clearance.

Comparison using LSD in table III shows that moisture content (MC) of 11% has the highest shaker losses of 41.17 kg/ha while moisture content of 13 and 15% are statistically similar but lower than that at 11%. The result shows that shaker losses increase with decrease in moisture content. Analysis of variance shows that at 12, 20, 26 mm concave clearance, shaker losses are highly significant (at 1% level). Comparison using LSD shows that clearance of 12 mm has the lowest shaker losses of 21.92 kg/ha while clearance of 26 mm has the highest with 49.20 kg/ha. The results obtained shows that shaker losses increases with increase in concave clearance.

Table IV presents the values of speed, field capacity, effective field capacity, field efficiency and mean fuel consumption of the combine harvester as measured during the field tests. The field capacity was 0.77 ha/h at constant speed of 1.7 km/h. Elsaied *et al.*, (2009) reported similar values: field capacity of 0.25 and 0.57 ha/hr at 1.6 and 3.6 km/h respectively. Tahir *et al.*, (2003) also reported similar field capacity of 2.5 and 3.0 acre/hr(1 and 1.2 ha/h). Attanda *et al.*,(2014) reported field capacity of 1.95 acre/hr(0.78 ha/h) which was almost equal to 0.77 ha/h obtained from the study. The effective field capacity was 0.68 ha/h which was close to 0.64 ha/hr reported by Veerangouda *et al.*, (2010).

The field efficiency was 88%. (Elsaied *et al.*, 2009 and Veerangouda *et al.*, 2010) reported field efficiencies of 67.6 to 78.4 % and 67.02 to 76.83 % respectively. The higher field efficiency in this study may be due to the low hectarage of the trial plot. With larger areas, the efficiency may be lower. The mean fuel consumption was 45 L/hr which is higher than 15 L/acr e(37.5 L/ha) reported by Tahir *et al.*, (2003). The relatively higher fuel consumption may be attributed to the make (model) of the combine.

Conclusions

On the basis of results obtained from the laboratory and field experiments, the following conclusions were drawn:

i. Performance specifications for the operation of the Deutz-Fahr M1202 combine harvester on rice crop based on selected performance parameters were established.

ii. Grain breakages, cleaning efficiency, shaker losses of the combine harvester are affected by moisture content of the crop and machine cylinder-concave clearance.

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Plate 1: Deutz-Fahr M1202 Combine

Table I: Mean Values of Grain Breakages, Cleaning Efficiency and Shaker Losses

MC %,	CL mm	GB %,	CE %,	ShL %.
11	12	3.14	97.36	26.60
	20	2.82	96.39	35.37
	26	2.38	95.37	61.53
13	12	2.67	96.01	22.30
	20	2.35	95.52	27.60
	26	2.01	95.15	46.70
15	12	2.35	95.51	16.87
	20	2.03	94.64	27.27
	26	1.68	93.80	39.40

MC= Moisture Content %, CL= Concave clearance mm, GB= Grain Breakages %, CE= Cleaning Efficiency %, ShL= Shaker Losses, %.

Table II: ANOVA for Cleaning Efficiency, Grain Breakages and Shaker Losses.

source	DF	F value		
		GB	CE	ShL
R	2	3.16*	44.09**	1.24ns
M	2	13.54**	25.48**	13.81**
C	2	11.27**	19.80**	58.72**
M*C	4	0.03ns	1.0ns	0.20ns
Err	16			
T	26			

*, **, ns indicates significant at 5 %, highly significant at 1 % , and not significant respectively.

Table III: t-test of LSD on Grain Breakages, Cleaning Efficiency and Shaker Losses

MC	Treatments		
	GB	CE	ShL
11	2.78a	96.37a	41.17a
13	2.34b	95.56b	32.20b
15	2.02b	94.65c	27.84b
LSD	0.43	0.71	7.55
CL	Treatments		
	GB	CE	ShL
12	2.72a	96.29a	21.92c
20	2.40a	95.52b	30.08b
26	2.02b	94.77c	49.21a
LSD	0.43	0.71	7.55

Means with same letter are not significantly different

Table IV: Machine Parameters

Parameter	Value
Constant speed (km/hr)	1.70
Field capacity (ha/hr)	0.77
Effective field capacity (ha/hr)	0.68
Field efficiency (%)	88
Mean fuel consumption (L/ha)	45