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Effects Of Variety And Some Machine Parameters On Threshability Of Okra Pod

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***Abstract*—Okra pod threshing has been mainly traditional with consequent losses and damage to `the seeds. Effects of machine properties (drum speed and concave clearance) of a developed okra threshing machine were studied on NHAe47-4, V-35, LD88, and 'Elesoagbinrin' okra varieties. The machine was evaluated using Nigerian Standard Test Code for Grain Threshers at drum speed of 4, 5, 6 and 7 m/s; concave clearance of 45, 55, 65 and 75 mm and germination tests were carried out. The mean threshing efficiency, cleaning efficiency, damage seed, blown seed, seed loss, threshing recovery and output capacity were 88.24 %, 99.45 %, 0.40 %, 49.14 %, 62.21 %, 37.89 % and 49.64 kg/hr respectively. Okra pods were best threshed in terms of variety, drum speed and concave clearance combination as NHAe47-4, 6 m/s, 65 mm; V-35, 7 m/s, 55 mm; LD88, 5 m/s, 75 mm; and 'Elesoagbonrin', 5 m/s, 55 mm; considering energy conservation and damage to seeds at 7 to 28% moisture content. The result of seed germination percentage studied shows that seed germination increased with increase in speed and concave clearance. The grand mean seed germination percentage was 77.22 ± 1.62 %.**

Keywords— Okra, variety, drum speed, concave clearance, efficiency.

I. INTRODUCTION

Okra (*Abelmoschus esculentus(L)Moench*) is one of the most important vegetable crops in the tropical and sub-tropical regions of the world for its tender fruit, young shoots, leaves and seeds. Okra is commonly known as okra, lady's finger in English, *Gombo* in French, *Quimbambo* in Africana [1,2]. In Nigeria, it is called *Ila* among the Yoruba's, *Kubewa* among the Hausas and *Okwuru* among the Igbos. Okra seed (dry seed) is a good source of high quality oil and protein for both the temperate regions and tropics. In Nigeria, okra is widely grown as vegetable for its tender fruits and young leaves covering 1.5 million hectare of land area annually [3]. Okra can be found in almost every market in Africa. In Nigeria, okra is ranked second best vegetable in order of importance, in Ghana, it is the fourth most popular vegetable, in Cameroon, it is the second most important vegetable in the market after tomatoes, in Sudan, it is the third most popular vegetable [4,5]. The seed is free from undesirable components such as protease inhibitors in soybean. Like other plant protein (i.e. such as pulses, seeds and cereals) it's cheap and of high calorie. In Nigeria like other developing countries, where protein deficiencies are endemic due to the cost of conventional animal protein source, okra oil and protein could be used to help bridging or solving country's food deficiency problem as well as other plant protein seeds.

Okra is harvested fresh or dried depending on the end use of the crop. The fruit (pod) is plucked by hand or cut with harvesting tools. For seed utilization, the pod is harvested dried on the plant or well matured pods are harvested and dried prior to threshing. In a developing country like Nigeria battling with hunger and malnutrition, it is most desirable that vegetable protein for the preparation of processed food be obtained from local sources of which dry okra seed protein is one. The seed is also a good source of oil and essential vitamin needed for healthy growth of the populace. Okra is a good source of calcium and the amino acids found in okra seed compare favourably with those in poultry, eggs and soy beans [5].

[6], reported that plant foods are generally subjected to fermentation processing prior to consumption, which is generally used either as meat substitutes or as condiments, such as okra seed is fermented to produce condiment known as *Owoh* in Nigeria Delta Area.

In order that the economic value of okra be multiplied, it is necessary that it be processed of which threshing the dry pod is an important stage. Traditionally, okra pods are opened by hand, beating with sticks in sacks on hard surfaces like (rocks, concrete, tarpaulin, mat and so on) or trampling by animal. The first method is tedious and time consuming while the last two methods cause severe damage to the seed resulting in low germination and quality reduction in industrial usage. In Nigeria, mechanical threshing of okra has not been given adequate attention. Although, mechanically assisted threshing of grain and seed crop has been utilized for many centuries all over the world and many developments have been made in this process. In Nigeria, okra threshers are rear. [7] develop an okra thresher based on physical properties [8,9] mechanical properties [10] and obtained a threshing efficiency of 98 %, cleaning efficiency of 88 % seed damage of 35 % and seed loss of 23 % on the machine test run. [11], utilized a 3-dimensional solid modeling feature of Auto CAD 2000 to design a multi-crop thresher. Evaluation of the designed and constructed, machine using cowpea and sorghum gave 87 % and 95 % threshing efficiencies respectively. [12], commended that threshing whether done manually or mechanically, inevitable leads to some of the grain splitting and breaking, therefore, adequate care is necessary to ensure that the processes or instrument used cause as little damage as possible. [13], evaluated the performance of a locally developed Grain Thresher-II on cowpea and found out that the threshing, shelling efficiency of the thresher varied from 71 % to 95.6 % for the Laboratory and field performance; the rate of shelling increased as the speed was increased, grain losses decreased as the speed was increased, while more breakages was recorded at high speed. [14], modified concave, soil particles sieve, seed sieve, aspirator fan pulley etc which affect groundnut threshing operation of a grain thresher and obtained its field capacity of about 41 % in comparison with Lilliston combine thresher capacity. [15], recommended some acceptable limits of wheat threshers as threshing efficiency greater than 99 %, cleaning efficiency greater than 96 %, grain breakage less than 20 % and total grain loss less than 5 %.

In spite of okra abundance, popularity, high protein and oil content of its seed, the potential of the seed as a new source of vegetable protein and oil is yet to be fully exploited in Nigeria due to poor processing of the crop. Therefore, the objective of this study was to investigate the effect of some machine parameters such as drum speed and concave clearance on the performance of the developed dry okra threshing machine using four okra varieties.

II. MATERIALS AND METHODS

A. Materials

Okra seeds NH47-4 and LD88 were obtained from seed processing units of National Horticultural Research Institute, Idi-shin; V35 form the Institute of Agricultural Research and Training, Moor Plantation; and 'Elesoagbonrin' (Yoruba) from a farmer at Akufo farm settlement, all in Ibadan, Nigeria. The seeds were planted mid April on four separate plots far from each other of about 250 m on Federal College of Agriculture, Moor Plantation, Ibadan farm in accordance with [16], that okra seeds field should be isolated from all other fields of okra by a minimum distance of 200 m and from fields of species with similar seed size by a distance adequate to prevent mixture. Matured and dried pods were harvested manually middle of July to the first week of August, sun-dried three days and stored in bulks in an exclusive store for the experiment. Initial moisture contents of samples were determined by the oven method [17]. Methods developed by [18], were used to obtain the desired moisture contents.

B. Evaluation

Evaluation of the developed okra thresher was carried out on yield and quality of the threshed seed on mass bases. The quality of these seeds was determined in terms of visible damage and germination ability of the seeds. Dependent variables viz: threshing efficiency, clearing efficiency, percentage of damaged grains, percentage of blown grain, percentage of grain loss, threshing recovery and output capacity were determined using National Agricultural Technology Information Centre, INDIA [15,19] test codes.

The independent variables were calculated as:

i. Percentage of un-threshed seed (Gt) = $^{J}/_{GT}$ x 100 (1)

Where, J = Weight of un-threshed seed at all outlets per unit time (kg) and GT = Total seed input (kg)

ii. Threshing efficiency (η_{Thr}) = 100 - Gt (2)

iii. Cleaning efficiency (η_{Cl}) = $^{K}/_{WG}$ x 100 (3)

Where, K = Weight of whole seed at main seed outlet per unit time (kg)and W_G = Weight of whole seed at all seed outlet per unit time (kg)

iv. Percentage of damage seed (D_{GD}) $^{E}/_{GT}$ x 100 - F (4)

Where, E = Weight of damage seed collected at all outlet per unit time (kg)and F = Percentage of damage of seed in all total input before threshing (%)

v. Percentage of blown seed (B_G) = $^{G}/_{A}$ x 100 (5)

Where, G = Weight of whole seed collected at chaff outlet per unit time (kg) and A = Weight of whole seed collected at seed outlet per unit time (kg)

vi Percentage of seed loss (G_L) = $^{Gt}/_{GT}$ x 100 (6)

Where, G_T = weight of all seeds (whole, damage and unthreshed at chaff and other outlet per unit time (kg)

vii Threshing recovery (T_R) = $^{B}/_{GT}$ x 100 (7)

Where, B = Weight of threshed seed at main outlet per unit time (kg)

viii Output capacity (OP_c) = $^{B}/_{t}$ x 60 (8)

Where, t = Time of test run (s)

C. Statistical experimental design and analysis

A – 3 x 4 x 3 factorial in Complete Randomized Block Design, (CBBD)experimental design was used with a total of 192 observation (4 variety x 4 concave clearance x 4 speed x 3 replications).

D. Testing

The electric motor was switched on, and allowed to idle run for half a minute, while a tachometer was attached to the cylinder shaft and noted. A known mass of dry okra pods were poured into the hopper and the threshing time recorded using stop watch (Plate 1). The threshed product from the seed outlet, those blown from the sieve and other outlets were collected separately and each sample separated manually into threshed, unthreshed, damage, chaff and their weights taken using an electric weighing machine (±0.01 g). The operation was repeated for the other speeds and on every variety. Twenty seeds from each run were selected randomly and plated in four spots per row, for seed germination evaluation.

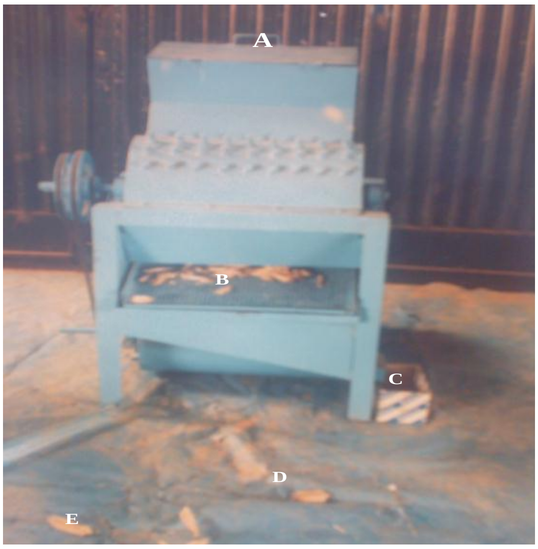

Plate 1:The Developed Okra Pod Thresher in Operation

A - Hopper
B - Threshed Okra Seeds and Chaff
C - Threshed Seeds
D - Blown Okra Seeds
E - Blown Okra Chaff

III. RESULTS AND DISCUSSION

The results of the performance operational tests carried out on the developed okra thresher are given in Tables 1 to 4 and Figure 1 to 14.

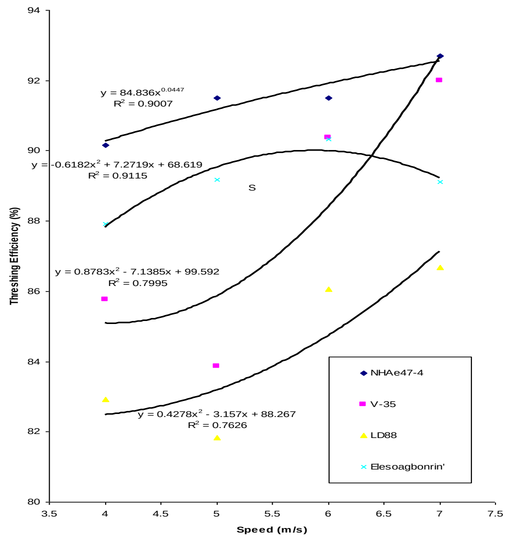

Fig. 1. *Effects of Speeds on Threshing Efficiencies of Okra Varieties*

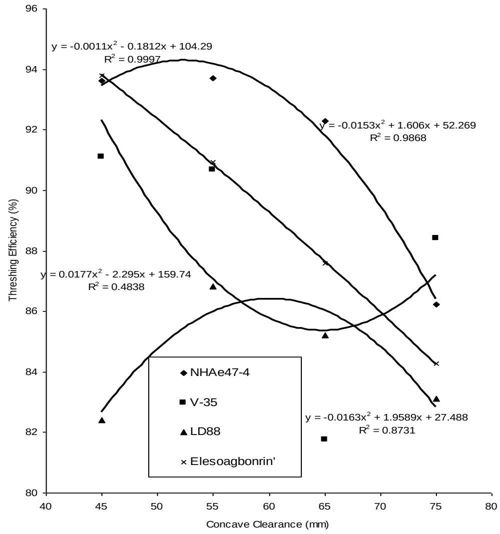

Fig. 2. *Effects of Concave Clearance on Threshing Efficiencies of Okra Varieties*

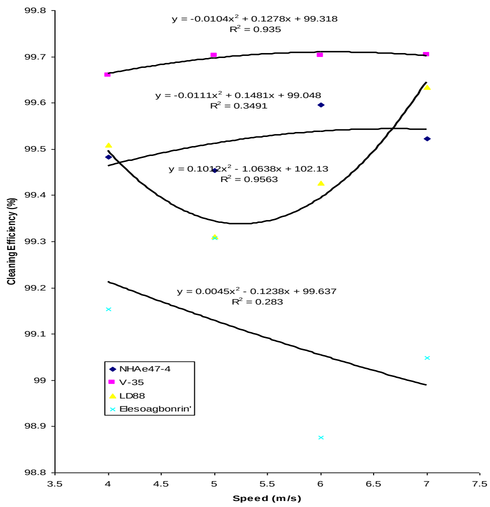

Fig. 3. *Effects of Speeds on Cleaning Efficiencies of Okra Varieties*

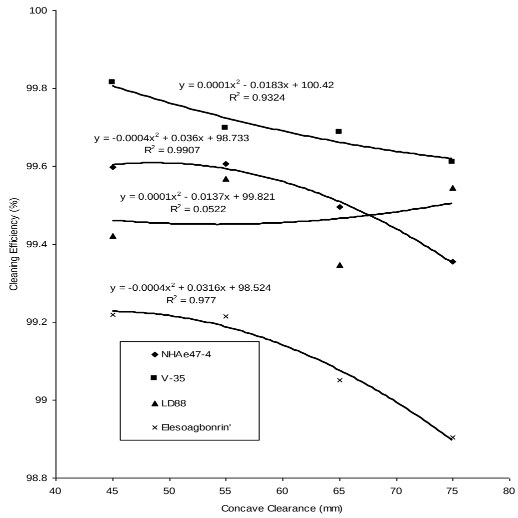

Fig. 3. *Effects of Concave Clearances on Cleaning Efficiencies of Okra Varieties*

TABLE I. GRAND MEAN OF THRESHING PARAMETERS

Dependent Variable	Mean	Std. Dev.	Minimum	Maximum
Threshing Efficiency %	88.24	8.86	49.66	100
Cleaning Efficiency%	99.45	0.55	99.63	100
Damaged Seed %	0.40	0.38	0.00	3.50
Blown Seed %	49.14	10.5	23.03	80.82
Seed Loss %	62.11	10.40	33.50	84.34
Threshing Recovery %	37.89	10.40	15.66	66.50
Output Capacity Kg/Hr	49.64	19.41	14.38	135.16

95 % confidence interval

TABLE II. SPEED EFFECT ON THRESHING PARAMETERS

Speed	Threshing Efficiencies %	Cleaning Efficiency %	Damaged Seed %	Blown Seed %	Seed Loss %	Threshing Recovery %	Output Capacity. Kg/Hr
4 m/s	86.69^{b}	99.45^{a}	0.38^{a}	39.12^{d}	53.33^{d}	46.67^{a}	51.68a
5 m/s	86.59^{b}	99.44^{a}	0.41^{a}	45.16^{c}	59.66^{c}	40.34^{b}	50.26a
6 m/s	89.56^{a}	99.40^{a}	0.40^{a}	54.94^{b}	66.78^{b}	33.22^{c}	45.16b
7 m/s	90.13^{a}	99.48^{a}	0.38^{a}	57.36^{a}	68..65^{a}	31.35^{d}	50.45a
Se	0.22	0.03	0.01	0.19	0.19	0.17	7.58

TABLE III. CONCAVE CLEARANCE EFFECT ON THRESHING PARAMETERS

Concave Clearance	Threshing Efficiencies %	Cleaning Efficiency %	Damaged Seed %	Blown Seed %	Seed Loss %	Threshing Recovery %	Output Capacity. Kg/Hr
45mm	90.23^{a}	99.51^{a}	0.33^{b}	46.56^{c}	57.38^{c}	42.62^{a}	53.39a
55mm	90.53^{a}	99.52^{a}	0.37^{ab}	48.91^{b}	59.65^{b}	40.35^{b}	53.64a
65mm	86.71^{b}	99.39^{b}	0.43^{a}	50.42^{a}	65.03^{a}	34.97^{c}	47.43b
75mm	85.50^{c}	99.35^{b}	0.44a	50.69^{a}	66.37^{a}	33.63^{c}	44.08b
Se	0.22	0.03	0.01	0.19	0.19	0.17	0.76

TABLE IV. EFFECTS OF VARIETY, SPEED AND CONCAVE CLEARANCE ON THRESHING PARAMETERS (ANOVA)

Source of Variance	df	Threshing Efficiency %	Cleaning Efficiency %	Damaged Seed %	Blown Seed %	Seed Loss %	Threshing Recovery %	Output Capacity Kg/Hr
Concave	3	17.08*	4.93*	3.87*	13.82*	63.49*	63.49*	11.81*
Clearance(C_{cl})	3	9.35*	0.84 ^{Ns}	0.37 ^{Ns}	279.62*	170.29*	170.29*	3.10*
Speed (N)	9	15.61*	2.79*	3.72*	7.22*	14.72*	14.72*	7.94*
V* C_{cl}	9	4.88*	5.55*	5.20*	9.36*	3.12*	3.12*	3.01*
V*N	762							
Error								
Total	767							

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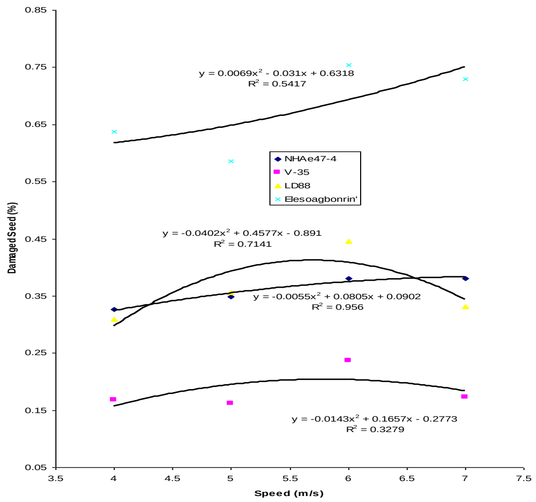

Fig. 5. *Effects of Speeds on Damage Seeds of Okra Pods*

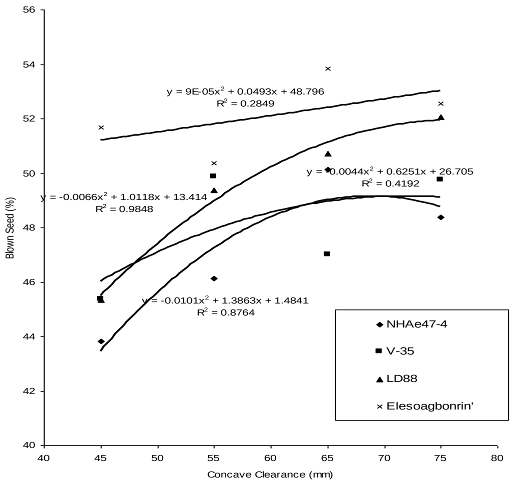

Fig. 8. *Effects of Concave Clearances on Blown Seeds of Okra Pods*

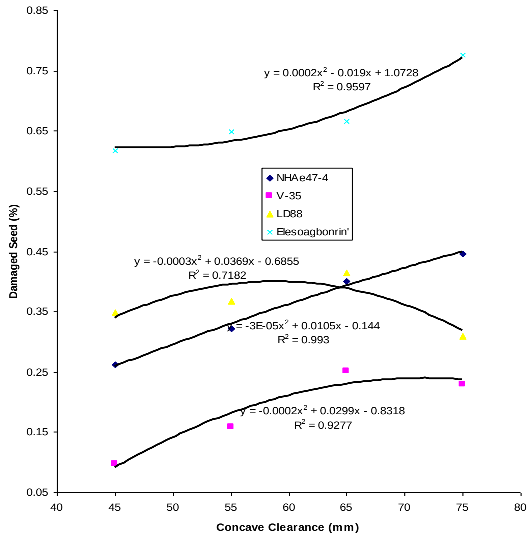

Fig. 6. *Effects of Concave Clearances on Damage Seeds of Okra Pods*

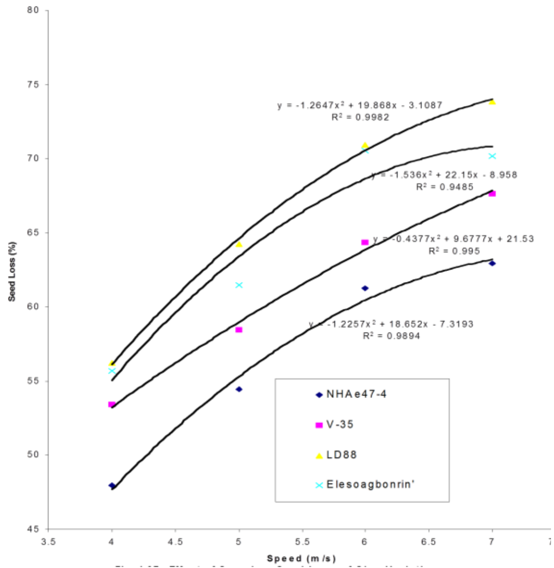

Fig. 9. Effects of Speeds on Seed loss of Okra Pods

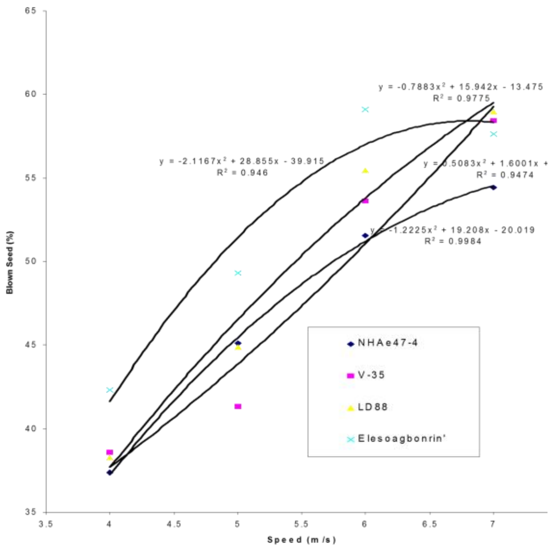

Fig. 7. *Effects of Speeds on Blown Seeds of Okra Pods*

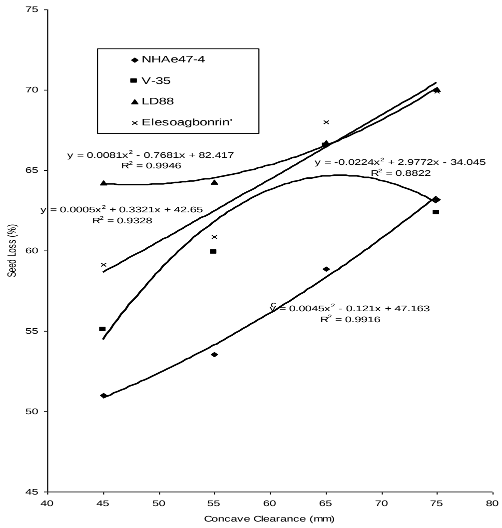

Fig. 10. *Effects of Concave Clearances on Seed loss of Okra Pods*

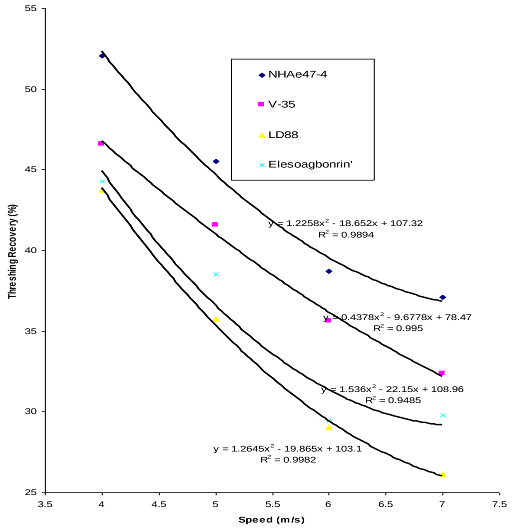

Fig. 11. *Effects of Speeds on Threshing Recovery of Okra Pods*

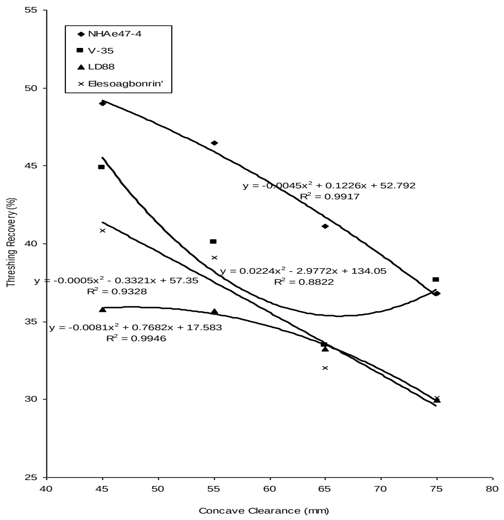

Fig. 12. *Effects of Concave Clearance on Threshing Recovery of Okra Pods*

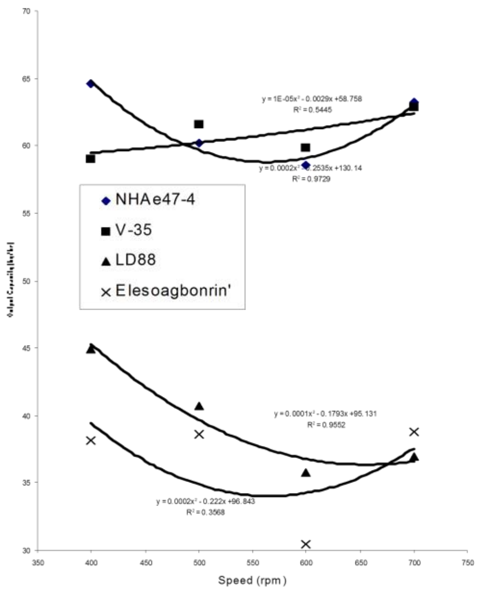

Fig. 13. *Effects of Speeds on Output Capacity of Okra Pods*

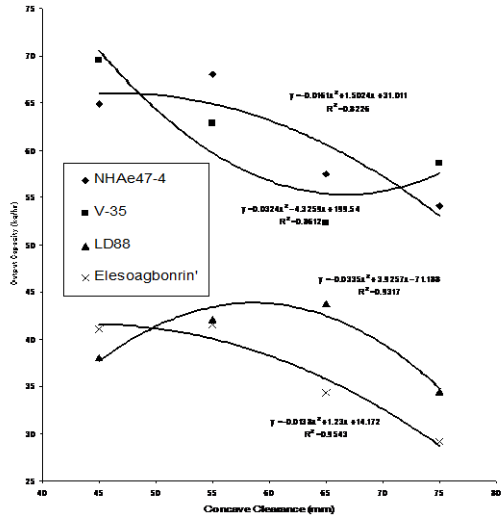

Fig. 14. *Effects of Concave Clearance on Output Capacity of Okra Pods*

A. Threshing efficiency

The machine threshing efficiency on the four varieties at different moisture levels, concave clearances and speeds are given in Tables 1 to 4. The effect of speed on the machine threshing efficiency is as presented in Figure 1. It is observed that threshing efficiency increased with increase in speed (4 to 7 m/s of drum). Threshing efficiency for variety NHAe47-4 increased from 90.2 to 92.7 %, V-35 from 85.8 to 92 %, LD88 from 82.9 to 86.7 % and 'Elesoagbonrin' from 87.9 to 89.1 % respectively**.** The relationships among the dimensions and speed were logarithmic with R^2 0.76 – 0.91. Table 2 shows that there is no significant difference between means of threshing efficiency at 4 and 5, 6 and 7 m/s at P ≤ 0.5.

The effect of concave clearance on threshing efficiency of okra varieties is as presented in Figure 2. It is observed that threshing efficiency does not behave uniformly save 'Elesoagbonrin' which decreased from 93.8 to 84.2 % with increase in concave clearance (45 to 75 mm). NHAe47-4 increased from 93.6 % at 45 mm to 93.7 % at 55 mm, therewith, decreased to 82.2 % at 75 mm. V-35 decreased from 91.1 % at 45 mm to 81.8 % at 65 mm and increased to 88.4 % at 75 mm. And LD88 increased from 82.4 % 45 mm to 86.5 % at 55 mm and decreased to 83.1 % at 75 mm. All their relationships were logarithmic with R^2 0.48 – 1.

The effects of drum speed, concave clearance and variety on the machine cleaning efficiency are as presented in Tables 1 to 4. The machine cleaning efficiency increases with increase in drum speed for variety NHAe47-4 and V-35 (Fig.3). NHAe47-4 increased from 99.5 to 99.5 % and V-35 from 99.7 to 99.7 %. LD88 decreased from 99.5 % at speed 400 rpm (4 m/s) to 99.3 % at 500 rpm (4m/s) and increased to 99.6 % at 700 rpm (7 m/s). 'Elesoagbonrin' decreased from 99.2 % to 99.1 %. The relationships are all quadratic (R^2 = 0.28 – 0.96). Table 2 shows that there is no significant difference (at 5 % level) between the means of cleaning efficiency at all speed levels.

The effect of concave clearance on the machine cleaning efficiency is as represented in Figure 4. The result shows that cleaning efficiency decreases as concave clearance increases except for variety LD88 that increased with increase in concave clearance. Variety NHAe47-4 decreased from 99.6 to 99.4 %, V-35 from 99.8 to 99.6 %, 'Elesoagbonrin' from 99.2 to 98.9 % and LD88 from 99.4 to 99.5 %. All the relationships were quadratic with R^2 0.05 – 0.99.

It can be seen in Table 3 that the mean of concave clearance effect on cleaning efficiency is not significantly different between 45 mm and 55 mm concave clearance; also between 65 mm and 75 mm concave clearance at 5 % levels. Both have very high clearing efficiencies.

As indicated in Tables 1 to 4, the highest cleaning efficiency was at drum speed of 7 m/s, but not significantly different from other speeds at 5 % level. Concave clearance 55 mm produced the highest cleaning efficiency but not significantly different from 45 mm, while the least is at 75 mm but not significantly different from 65 mm.

Analysis of variance (Table 4) shows that drum speed has no significant effect on the mean cleaning efficiency, while concave clearance and variety are significantly different (5 % level).The observed that cleaning efficiency was found higher than the recommended minimum value (96 %) cleaning efficiency for wheat threshers [15].The observation is due to the fact that as the drum speed increases, the fan speed also increases, thus, more air is delivered to blow off the chaff. And as the moisture content and concave clearance increases, less particles are gotten from the fibres which become elastic rather than brittle; thus only the seeds pass through the sieve for effective cleaning leading to high cleaning efficiency.

The effect of drum speed of the machine on percentage of damage seed is as represented in Figure 5. It was observed that there was increased in damage of seed with increased threshing speed for all varieties. Variety NHAe47-4 increased from 0.3 to 0.4 %, V-35 from 0.16 to 0.17, LD88 from 0.31 to 0.33 % and 'Elesoagbonrin' from 0.6 to 0.7 %. All the relationships are quadratics with R^2 0.33 – 0.96. Table 2 shows that there is no difference between the means at all speed levels.

The effect of concave clearance on percentage of damage seed is as represented in Figure 6. Damage seed was observed to be on the increase as concave clearance increased except for LD88 variety that increased to maximum value at 65 mm then, decreased to minimum at 75 mm concave clearance. Variety NHAe47-4 increased from 0.3 % to 0.5 %, V-35 from 0.1 to 0.2 %, 'Elesoagbonrin' from 0.6 to 0.8 % while LD88 increased from 0.3 % at 45mm to 0.4 % at 65 mm, then decreased to 0.3 % at 75 mm concave clearance. All the relationships were quadratic with R^2 0.72 – 0.99. As presented in Table 3, there is no significant difference (at 5 % level) between the means of damaged seed at 65 mm and 75 mm concave clearance. Speed 6 m/s produce the highest damaged seed but not significantly different from other speeds at 5 % level. Concave clearance of 75 mm produced the highest damaged seed, but not significantly different from 65 mm, followed by 55 mm; and 45 mm which gave the least.

The result obtained was below the maximum value (2 %) recommended by [15] for wheat, The result is also in agreement with [12], who commented that breakage of grain is inevitable in threshing, [13] who observed more breakages at high speeds for a locally developed grain thresher. The observation may not be unconnected with varietal effect, NHAe47-4 that has the largest mean diameter produced the least grain damage, but not different from that for LD88 and 'Elesoagbonrin' with least mean diameter produced the highest damaged seed. Increase in concave clearance increases the force of impact that results in more damage of the seed.

The effect of speed on blown seed of okra for the four varieties is as represented in Figure 7. It was observed that blown seed increased with increase in cylinder speed for the varieties. NHAe47-4 increased from 37.4 to 54.5 %, V-35 from 38.6 to 58.4 %, LD88 from 38.2 to 58.9 % and 'Elesoagbonrin' from 42.3 to 57.6 %. The relationships between blown seed and cylinder speeds were quadratic with R^2 0.95 – 1. Table 2 shows that there is significant difference between the four speeds at 5 % level.

The effect of concave clearance on blown seed of okra varieties is as represented in Figure 8. The Figure shows that the blown grain increased with increase in concave clearance. NHAe47-4 increased from 43.8 to 48.4 %, V-35 from 45.4 to 49.8 %, LD88 from 45.4 to 52.1 % and 'Elesoagbonrin' from 51.7 to 52.6 %. The relationships were quadratic with R^2 0.28 – 0.98. Table 3 shows that there is no difference between 65 mm and 75 mm concave clearance at 5 % levels.

The observed percentage of blown seed increases with increase in drum speed, concave clearance. Speed 7 m/s produced the highest blown seed (57.4%), while speed 4 m/s gave the least (39.1%); likewise concave clearance 75 mm produced the highest (50.7%) and 45 mm gave the least (46.6 %). Analysis of variance shows that the effects of speed and concave clearance were significant at 5 % level. The result may be due to the fact that at higher speeds, more volume of air is delivered on the sieve, thus, more seeds and chaff are blown away as the air velocity exceeds that of terminal velocity of the seed.

.The effect of drum speed on the machine seed loss is represented in Figure 9. It is observed that seed loss increases with increase in cylinder speed. Variety NHAe47-4 seed loss increased from 50 to 62.9 %, V-35 from 53.4 to 67.7 %, LD88 from 56.3 to 73.9 % and 'Elesoagbonrin' from 55.7 to 70.2 %. All the relationships are quadratic with R^2 0.95 to 1. Table 2 shows that there is difference between means at all speed levels.

The effects of concave clearance on seed loss of the thresher for the four okra varieties are presented in Figure 10. Seed loss increases with increase in concave clearance. For variety NHAe47-4, it increased from 51 to 63.2 %, V-35 from 55.1 to 66.5 % at 65 mm and decreased to 62.3 % at 75 mm. LD88 increased from 64.2 to 70 % and 'Elesoagbonrin' from 59.2 to 69.9 %. The relationships are quadratic with R^2 0.88 to 0.99.

Table 3 shows that there is no significant difference between the means of 65 mm and 75 mm concave clearance. At the drum speed 7 m/s, the machine attained highest seed loss (68.7 %) and the least 53.3 % at 4 m/s. Also 75 mm concave clearance produced the highest seed loss (66.4 %) and the least by 45 mm concave clearance (57.4 %). Analysis of variance shows that the effect of speed, concave clearance, variety and their interaction are significantly different at 5 %.

The result obtained is observed to be higher than that of chickpea (9.1 %), using a legume thresher (AGAO model C) by [20], and the recommended < 5 % for wheat by [15]. The trend of the obtained result is not in agreement with the result for cowpea observed by [13], that grain loss decreased as speed increased for Grain Thresher -II. However, [21], observed that concave clearance and the type of concave have direct effect on the seed losses in accordance with the studied result, as percentage of seed loss increased with increase in concave clearance. The studied result might not be unconnected with the fact that as the speed and concave clearance increases there was increase in impact force on pods; this result in higher speed of escape of the seeds and chaff from the threshing chamber. The seeds bounce off the sieve rather than rolling on it. Moreover, the high percentage of seed loss may be due to the batch process of the machine evaluated which enhanced free seed and chaff out flow from the threshing unit rather than homogenous mixture.

The effect of speed on threshing recovery of the thresher is represented in Figure 11. It is observed that threshing recovery decreases with increase in drum speed. Variety NHAe47-4 decreased from 52.1 to 37.1 %, V-35 from 46.6 to 32.4 %, LD88 from 43.8 to 26.1 % and 'Elesoagbonrin' from 44.3 to 29.8 %. The relationships are with R^2 0.95 to 0.99; Table 2 shows that there are differences between means at all speed levels.

The effect of concave clearance on threshing recovery of the machine is as given in Figure 12. The threshing recovery decreased generally with increase in concave clearance. Variety NHAe47-4 decreased from 49 to 36.8 %, V-35 decreased from 44.9 to 33.5 % at 65 mm and increased to 37.7 % at 75 mm concave clearance. LD88 decreased from 35.8 to 30 % and 'Elesoagbonrin' from 40.8 to 30.1 %. The relationships s were quadratic with R^2 0.88 – 0.99. Table 3 shows that there is no difference between means of threshing recovery at 65 mm and 75 mm concave clearance. The result is much lower than that observed by [22], for evaluated votex Rice fan thresher (91.28 %). This is due to the machine high blown seed percentage that is a factor in threshing recovery.

The effects of drum speed on the machine output capacity is represented in Figures 13. It is observed that output capacity increased with increase in speed for variety V-35 and 'Elesoagbonrin', while NHAe47-4 decreased to minimum at 6m/s and increased thereafter and LD88 decreased with increase in speed. The output capacity for variety V-35 increased from 59.01 to 62.84 kg/hr and 'Elesoagbonrin' from 38.17 to 38.80 kg/hr. Variety NHAe47-4 output capacity decreased from 64.38 to 58.57 kg/hr at 6m/s and increased to 63.19 kg/hr at 7 m/s while LD88 decreased from 44.95 to 36.96 kg/hr. The relationships were quadratic with R^2 0.36 – 0.97. Table 2 shows that there is no significant different between means of output capacity at 4 m/s, 5 m/s and 7 m/s at 5 % level.

The effect of concave clearance on the machine output and corrected output capacities are presented in Figures 14. It is observed that output capacity decreased with increase in concave clearance for NHAe47-4 and 'Elesoagbonrin' varieties, while that for V-35 variety decreased to minimum at 65mm, thereafter increased, and variety LD88 increased to maximum at 65 mm and decreased thereafter (45 to 75 mm concave clearance). Variety NHAe47-4 output capacity decreased from 64.93 to 54.11 kg/hr and 'Elesoagbonrin' from 41.07 to 29.21 kg/hr. V-35 decreased from 69.51 to 52.26 kg/hr at 65 mm concave clearance, then increased to 58.60 kg/hr at 75 mm concave clearance but LD88 increased from 38.07 to 43.74 kg/hr at 65 mm concave clearance and decreased to 34.41 kg/hr.

Speed 4 m/s produced the highest output capacity (51.49 kg/hr), though not significantly different from 5 m/s and 7 m/s, speed 6 m/s produced the least (45.97 kg/hr). 55 mm Concave clearance produced the highest output capacity (53.45 kg/hr) but, not significantly different from 45 mm at 5 % level, followed by 65 mm concave clearance and 75 mm concave clearance produced the least (43.85 kg/hr). Analysis of variance shows that effect of speed, concave clearance, variety and their interaction are significant at all levels (5 %). The mean of output capacity is in the range of 48.69 to 50.18 kg/hr. The obtained result values were observed lower than that reported by [22], for vetex rice fan thresher (1026.44 kg/hr).

B. Germination percentage

Germination of the seed after threshing suggests to a large extent the quality of the threshed seed. Regeneration of plant is one of the most important uses of threshed seeds apart from industrial utilization. Mechanically, damage seed have disturbed composition thus are not likely to germinate. The germination percentages of the threshed seeds were as given in Table 5. Analysis of variance presented in Table 6. It is observed that 'Elesoagbonrin' gave the best germination (80.28 %), though not significantly different from NHAe47-4 and LD88 (at 5 % level) and the least (71.53 %) was from

V-35 variety. Concave clearance 65 mm gave the best while 55 mm gave the least. Speed 7 m/s which is not significantly from 6 m/s gave the best and the least by 4 m/s. The interaction of variety, concave clearance and speed at 7 to 28 % moisture content, shows that 34 interactions out of 192 gave 100 percent germination and 15 interactions out 192 gave least germination percentage 40 to 49 %.

TABLE V. SEED GERMINATION PERCENTAGE

Item	Mean	Std. Error	Lower Bound	Upper Bound
Grand Mean	77.222	0.822	75.607	78.838
Variety				
Nhae-47-4	78.19^{a}	1.643	74.963	81.426
V 35	71.53^{b}	1.643	68.297	74.759
Ld88	78.89^{a}	1.643	75.658	82.120
"Elesaoagbonrin"	80.28^{a}	1.643	77.047	83.509
Moisture Content				
14%	74.38^{b}	1.423	71.577	77.173
21%	78.23^{ab}	1.423	75.431	81.027
30%	79.06^{a}	1.423	76.264	81.861
Concave Clearance				
35mm	77.50^{ab}	1.643	74.269	80.731
45mm	76.36^{ab}	1.643	73.158	79.620
55mm	74.31^{b}	1.643	71.074	77.537
65mm	80.69^{a}	1.643	77.463	83.926
Speed 4 m/s	67.50^{c}	1.643	64.269	70.731
5 m/s	76.81^{b}	1.643	73.574	80.037
6 m/s	82.08^{a}	1.643	78.852	85.314
6 m/s	82.50	1.643	79.269	85.731

TABLE VI. *ANALYSIS OF VARIANCE FOR THE EFFECTS OF PARAMETERS ON SEED GERMINATION*

Source of Variation	Df	F- Calculated
Variety (V)	3	5.614**
Moisture Content (Mc)	2	3.088*
Concave Clearance (C_{cl})	3	2.33^{ns}
Speed (N)	3	18.043***
V* C_{cl}*N	27	1.675*
V*Mc* C_{cl}*N	54	1.605**
Error	384	
	575	

The result of seed germination percentage studied shows that seed germination increased with increase in speed and concave clearance. Analysis of variance shows that effect of speed and variety are significantly different at 5 % level. The grand mean seed germination percentage is 77.22 ± 1.62 %. The result is observed to be above the minimum 60 % germination recommended by [16], which suggests that the machine design suit the threshing of okra in term of seed quality.

CONCLUSIONS

From the results obtained in this study, the following conclusions are drawn;

i Threshing efficiency increased with increase in cylinder speed, but concave clearance varied with levels and variety. The mean threshing efficiency of the developed thresher was 88.24 ± 8.86 %.

ii The mean machine cleaning efficiency range from 99.42 to 99.47 %, percentage of blown seed from 23.01 to 80.82 %, percentage of seed loss from 33.50 to 84.34 %, threshing recovery from 15.66 to 66.50 % and output capacity from 14.38 to 135.16 kg/hr at moisture content 7 to 28 % (w.b).

iii The percentage of damaged seed increased from 0.02 to 0.78 % and seed percentage germination is from 75.61 to 78.34 % these shows that the threshed seeds from the machine are of good quality.

iv Okra pods were best threshed in terms of variety, concave clearance and drum speed combination as NHAe47-4, 65 mm, 6 m/s; V-35, 55 mm, 7 m/s; LD88, 75 mm, 5 m/s; and 'Elesoagbonrin', 55 mm, 5 m/s; considering energy conservation and damage to seeds at moisture content 7 to 28 % (w.b).

v Seed germination increased with increase in speed and concave clearance. The grand mean seed germination percentage was 77.22 ± 1.62 %.

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