Preliminary Investigation on the Distribution and Spread Pattern of Cowpea in a Cross Flow Grain Separator

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ABSTRACT

A thresher-cleaner developed at the Federal University of Technology, Akure, Nigeria was used to study the distribution and spread of the threshed cowpea in a cross flow system. Podded cowpea was subjected to insect infestation before threshing to ensure that the grains are with heterogeneous and varied aerodynamic characteristics. Majority of the pods were collected at the exit end of the thresher unit while the grains and a few pods obtained at the discharge end of the thresher unit were channeled into the cleaning chamber. Pod moisture content (PMC) of 14.0%, 18.0%, and 22.0% equivalent to grain moisture content (GMC) of 15.3%, 17.2%, and 18.8% respectively; fan speed of 900 rpm and 1500 rpm and fan angle of inclination of 90^o, 105^o and 120^o to the vertical plane were used for the study.

The spread patterns of the materials recovered in the cleaning chamber were analyzed and evaluated by plotting the percentage frequency distribution curve using the S-Plus and Harvard Professional 3.0 soft wares. The model fitting was done using ordinary least square (OLS) method with a simple program. The effect of pod and grain moisture content, fan speed and the angle of inclination of the fan were observed and studied as they affect the material distribution in the cleaning chamber.

Keywords: Cowpea, Grain size, fractionation, Separation, Material distribution

1. INTRODUCTION

Grain cleaning reduces the problems that occur during storage and handling. Impurities and contaminants are separated from sound grains during cleaning process. Impurities found in grain include light material, foreign material, broken kernel, shrunken kernel/ splits and fine or powdered material (Wang et al, 1994). Clean grains save storage space and increase marketability. Separation and cleaning is conventionally achieved as a result of the differences in the size, density and terminal velocity of the mixed product (Kulkarni, 1989). Cleaning of grains is conventionally done using screen or pneumatic separator. Screen separation is mostly used to separate product on the basis of the differences in their sizes and multi screen separators are used for classifying grains to size grades. Some screen separators incorporate fan to remove light particles (Ogunlowo and Adesuyi, 1999). Screen separator includes the rotary and the reciprocating types (Kulkarni, 1989; Ademosun, 1993).

Pneumatic separation occurs as a result of the differences in the aerodynamic properties of the mixed material to partition them into two major groups. Pneumatic separators/cleaners are basically of two types namely the vertical air stream and horizontal air stream separators (Gorial and O'Callaghan, 1991a & b). In the vertical air stream separator, air stream is flowing vertically against the injected mixed product such that heavy particles (grains) drop through the air (counter current flow) while the light materials (chaff) move upward and are carried along by the air (concurrent flow). In the horizontal air stream separator, air is blown horizontally or at an inclined angle to the horizontal against mixed product injected along the vertical plane. The mixed products are displaced along the horizontal plane at various distances based on their aerodynamic properties (Gorial and O'Callaghan, 1991b, Adewumi, 2006, Adewumi et al., 2006a, b).

Grading and fractionating bulk sample of grain into several fractions with different qualities is a proven step to ensure nutritional quality of food items (Elfverson and Regner, 2000). The physical quality of grain is evaluated by five parameters namely test weight, variety purity, soundness, vitreousness and maximum limits of foreign materials (Majumdar and Jayas, 2000). It has been shown that there are often differences among the different fractions in chemical composition or in germination potential capacity (Regner et al., 1994; Evers et al., 1995; Milberg et al., 1996). These differences clearly show that the size of the kernel is an important characteristic (Andersson et al., 1999). Evers et al (1995) concluded from his studies on wheat that largest kernels had the highest alpha-amylase activity.

Spread pattern is a good tool for evaluating material distribution (Grift, 2000). Studying the spread pattern of grains relative to the distance from the plane at which the materials are discharged was suggested as an approach to investigating the separation of seed from materials other than grain and the grading of seeds in horizontal air stream (Adewumi, 2005). Therefore, the study is aimed at investigating the distribution of grain in a cross flow system in order to ascertain the spread of the various materials in the trays of the cleaning chamber.

2. MATERIAL AND METHODS

A thresher-cleaner developed at the Federal University of Technology, Akure, Nigeria was used for the study. The machine is made up of four (4) main units namely the conveyor, threshing, fan and cleaning units. Harvested pods are loaded into the conveyor hopper. The conveyor regulates the feed rate and transfers the podded materials into the threshing unit. The threshing unit is axial flow type. As the threshing occurs, most of the pods are discharged at the exit port of the threshing unit while majority of the grains and some pods, mostly broken, pass through the screen of the threshing unit and discharge into the cleaning chamber. Primary cleaning of the threshed materials occurred in the threshing unit, where majority of the pods are separated. Further separation of the remaining pods takes place in the cleaning chamber. An electric motor operates both the conveyor and threshing units while the fan unit is operated by another electric motor. Cleaning of grain in the cleaning unit is achieved by the centrifugal fan supplying air perpendicularly or at inclined angle to the materials discharged into the cleaning chamber. Detailed information about the thresher-cleaner is reported (Adewumi, 2005, Adewumi et al. 2006b, c and d). Fig. 1 shows the schematic diagram of the experimental set up and the theoretical flow of materials in the cleaning chamber.

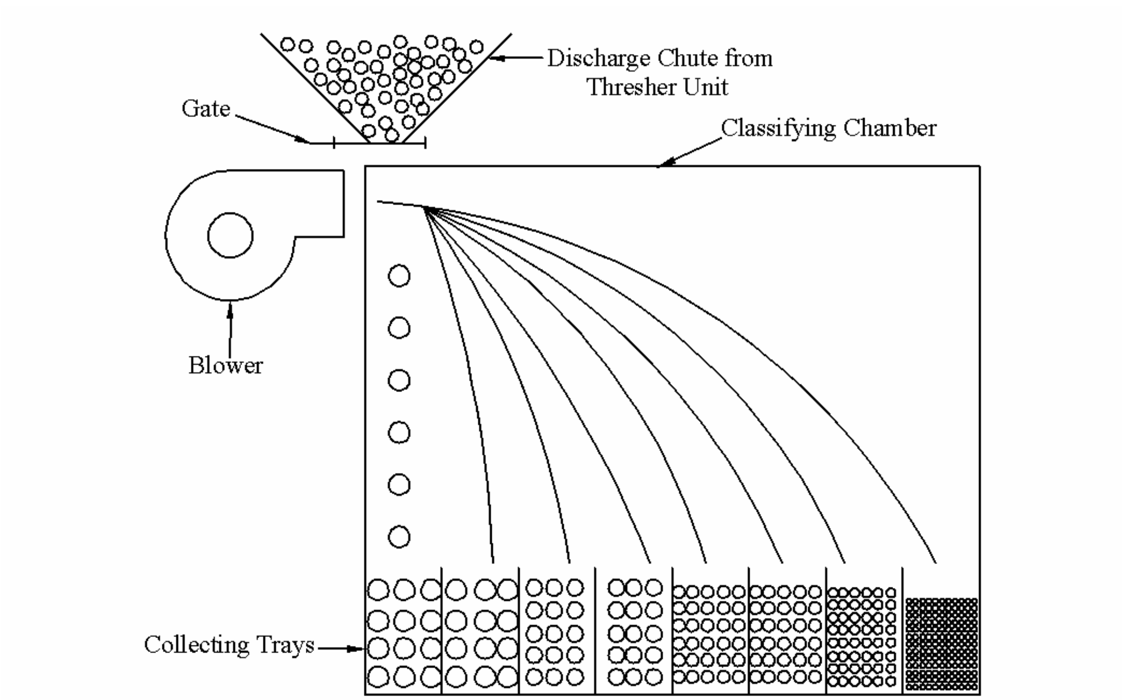

Fig. 1: Sketch of the Experimental Set up and Material Flow in the Classifier

The material loaded into the machine consisted of whole seeds, damaged seeds (infested), threshed pods and unthreshed pods. The unthreshed material used for the study was initially allowed to undergo insect infestations to allow damage on some grains so as to have relatively light weight grains and ensure a fairly heterogeneous grain with varied aerodynamic characteristics. The products from the outlet of threshing unit that passed through the screen with minimum % of unthreshed pods are discharged into the cleaning chamber and materials are recovered and collected in the trays at the lower part of the cleaning chamber. There are seven (7) trays altogether located at the lower part of the cleaning chamber, each with a length, height and width of about 30.0, 30.0 and 12.5 cm. The materials collected in each of the trays were classified as whole seeds, damaged seeds, threshed pods and unthreshed pods and the distribution of the materials in each of the trays is evaluated. The whole grain was classified into big, medium and small size. The threshed pod was also classified as whole medium and small as reported (Adewumi, 2005, Adewumi et al., 2006a). Table 1 shows the size characteristics of the materials loaded into the cleaning chamber. The fan was inclined at angles from 90^0, 105^0 and 120^0 anti clockwise to the vertical plane.

Table 1: Size Characteristics of Materials Loaded into the Cleaner Chamber

Material	Specification	Size range (mm)
Cowpea	*Big size*	*7.00 ≤ x ≤ 10.00*
(Whole seeds)	Medium size	5.00 ≤ x ≤ 7.00
	Small size	*3.80 ≤ x ≤ 4.99*
Cowpea	Broken seeds	< 5.00
(Damaged seeds)	Infested seeds	3 ≤ x ≤ 10.00
	Immature seeds	< 3.00
Pods	*Unthreshed*	*40 ≤ L ≤ 120*
	Threshed whole	*100 ≤ L ≤ 120*
	Threshed medium size	40 < L < 99
	Threshed small size	5 ≤ L ≤ 39

Three levels of pod moisture content - PMC (14.0%, 18.0%, and 22.0%), equivalent to grain moisture content - GMC of (15.3%, 17.2% and 18.8%), were used. These moisture contents (wet basis) correspond to typical storage, processing and harvest moisture levels respectively (Ige 1977 and 1978, Olukunle 2002, Ickikawa and Sugiyama 1991). Moisture content was determined using the electronic moisture meter and oven method as appropriate. The moisture meter was calibrated and found to have a very high correlation, up to 95%, compared with oven method. The moisture meter was preferred for instant measurements of moisture content because of its effectiveness. Fan speed of 900 rpm and 1500 rpm recommended as the lower and higher limits respectively for cowpea separation was used for the study (Ige, 1978, Ige and Ajayi, 1979). The weight of each of the fractions collected in each of the trays was measured using a sensitive electronic balance and the relative percentage of each fraction in each tray was obtained. Each experiment was conducted in triplicate and the mean values were used to determine the spread pattern.

The spread pattern of the materials for each experiment was obtained by plotting the percentage (%) frequency distribution curve using the Excel, S-Plus and Harvard professional soft wares. The original data collected (material weight) were entered and converted to percentages in each tray using Excel, transposed with S-Plus and the spread pattern was plotted using the transposed data obtained with the aid of the Harvard professional. The model was fitted for each of the material group in each tray using the ordinary least squared (OLS) method so as to get the estimate coefficient of the models, R^2, and the corresponding standard error, t-values and significant difference value.

3. RESULTS AND DISCUSSIONS

The spread pattern of materials in the cleaning chamber relative to the distance from the plane at which the materials are discharged was studied in other to investigate the separation of seeds from material other than grains and the grading of seeds in the horizontal air stream. Figs. 2–15 show the spread pattern obtained under specified conditions of pod and grain moisture contents, fan speed and fan angle of inclination using the S-Plus and Harvard professional soft wares.

It was generally observed that majority of the materials recovered in the cleaning chamber have a negligible percentage of pods (whole, medium, small and unthreshed pods). Such materials recovered in the cleaning chamber were relatively small in magnitude, mostly less than 1% of the total materials recovered in the cleaning chamber. They were mostly blown out of the cleaning chamber. This is an indication of the effectiveness of the cleaner to remove pods from bulk material loaded into it.

In most of the cases at fan speed of 900 rpm and for all angles of fan inclination of 90 and 105^o, more than 85% of the whole seeds were recovered within the first three trays, that is, at a distance of 37.5 cm from the entry point (Figs. 2 - 7). As the angle of fan inclination increased, to 120^o at same fan speed of 900 rpm, the trend gradually changed such that the majority of the materials recovered in the cleaning chamber moved beyond the third tray (Figs. 8 - 10). But, this trend was not the same at fan speed of 1,500 rpm and fan angle of inclination of 120^o (Figs. 13-15). The trend observed in Figs. 11 and 12 is similar to that observed in Figs. 8 – 10 but, sizable percentage of whole grains were retained within the first three trays while the highest percentage of the other materials were blown beyond the third tray or outside the cleaning unit.

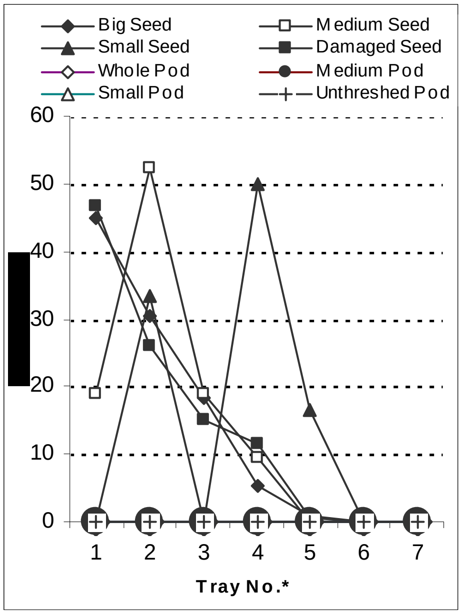

Fig. 2: Spread pattern of material in the trays at $\theta = 90^0$, PMC = 14.0%, GMC= 15.3 % and V = 900 rpm

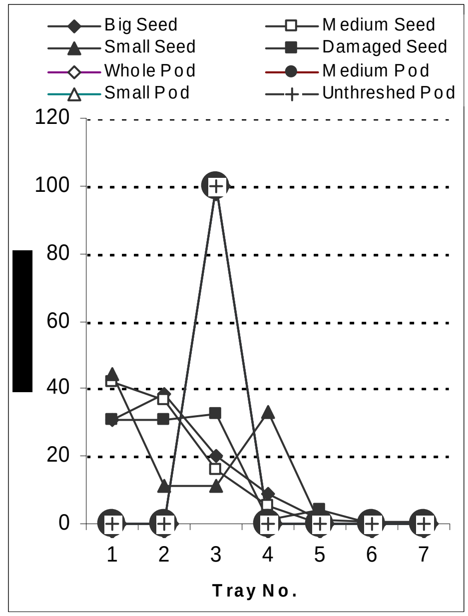

Fig. 3: Spread pattern of material in the trays at $\theta = 90^0$, PMC = 18.0%, GMC=17.2% and V = 900 rpm

* The distance from the entry point or horizontal displacement of materials equivalent to the tray No. 1, 2, 3, 4, 5, 6 and 7 is 12.5, 26.0, 38.0, 50.0, 62.0, 74.5 and 87.0 cm respectively

It should be noted that Figs. 11 and 12 showed the case at fan speed of 1500 rpm and fan inclination of 90 and 105^o respectively (less than 120^o). The trend observed in Figs. 2 – 7 was completely reverse at fan speed of 1500 rpm and fan inclination of 120^o, where 85% and more of the whole seeds were recovered beyond tray No. 3 (Fig. 13 – 15). These changes in trend of material distribution could be associated with the combined effects of the moisture contents of pod and grain, angle of inclination of the fan and magnitude of the drag force generated by the fan at the high speed.

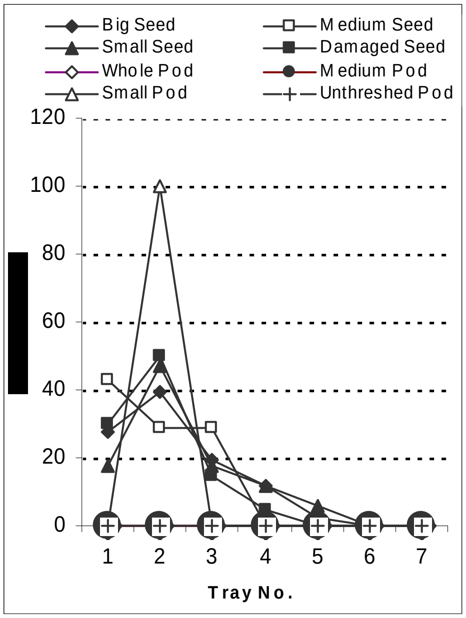

Fig 4: Spread pattern of material in the trays at θ = 90^0, PMC = 22.0%, GMC = 18.8 % and V = 900 rpm

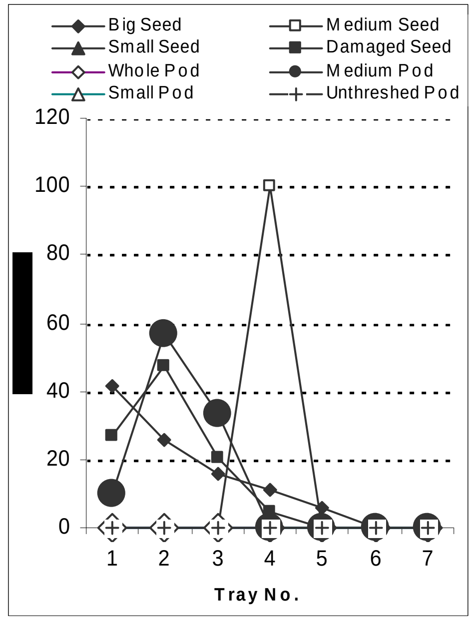

Fig.5: Spread pattern of material in the trays at θ = 105^0 , PMC = 18.0%, GMC = 17.2 % and V = 900 rpm

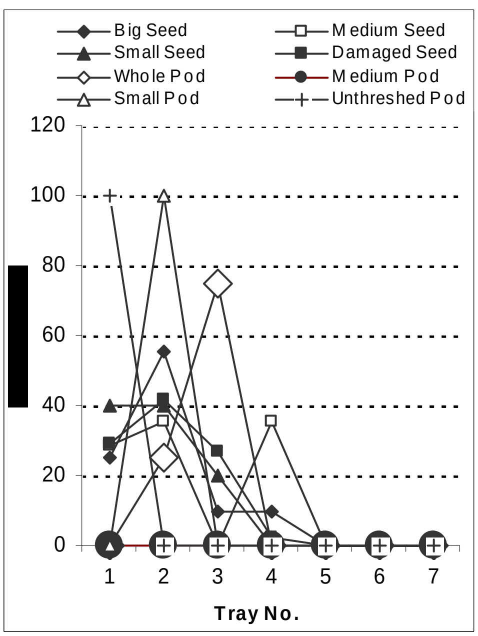

Fig. 6: Spread pattern of material in the trays at θ= 105^0, PMC = 14.0%, GMC=15.3% and V = 900 rpm

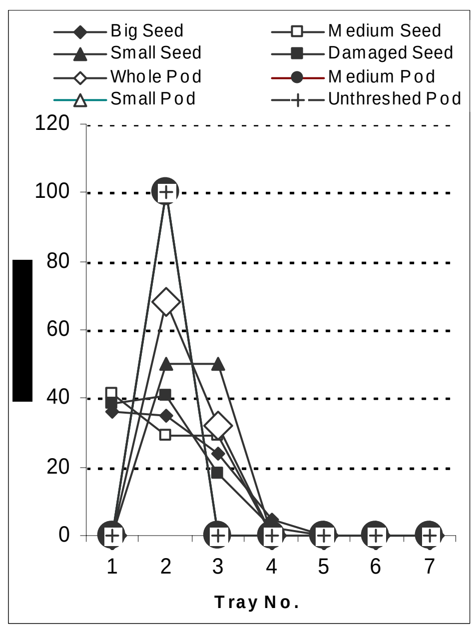

Fig. 7: Spread pattern of material in the trays at θ = 105^0, PMC = 22.0%, GMC = 18.8% and V = 900 rpm

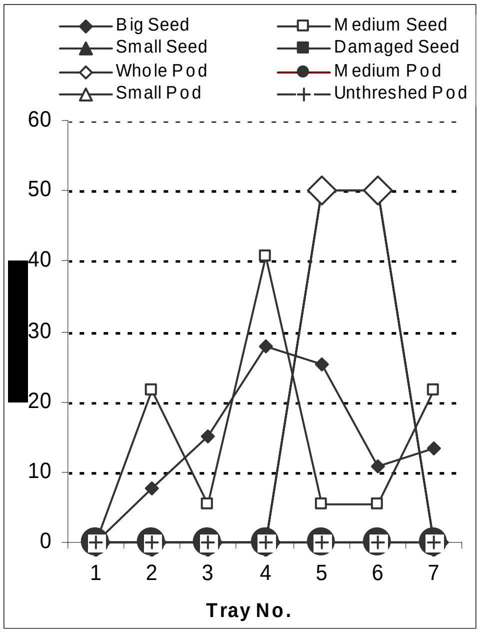

Fig. 8: Spread pattern of material in the trays at θ = 120, PMC = 14.0%, GMC=15.3% and V = 900 rpm

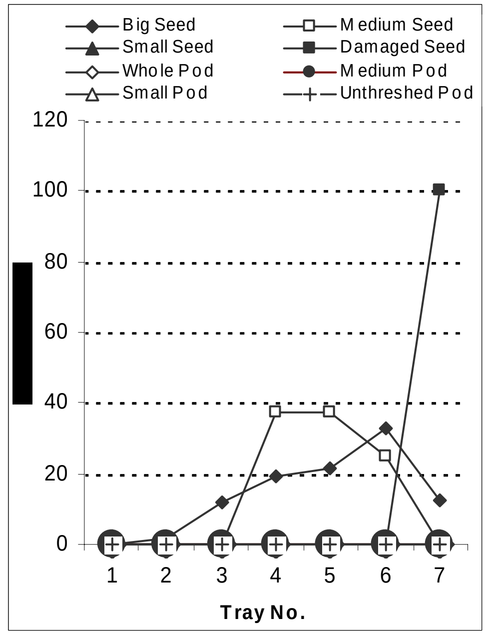

Fig. 9: Spread pattern of material in the trays at θ = 120, PMC = 18.0%, GMC=17.2% and V = 900 rpm

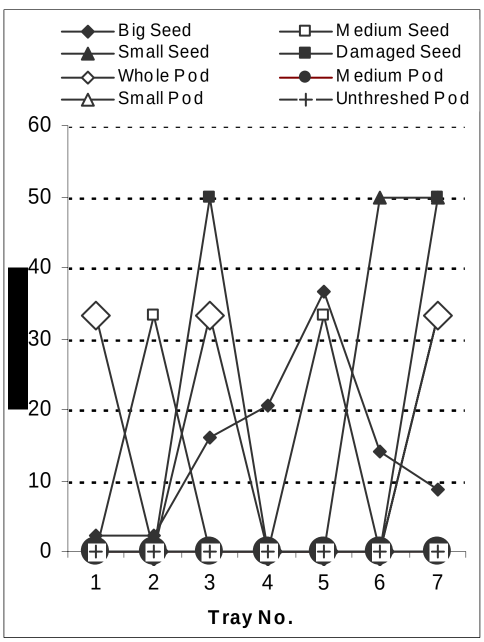

Fig. 10: Spread pattern of material in the trays at θ = 120, PMC = 22.0%, GMC= 18.8% and V = 900 rpm

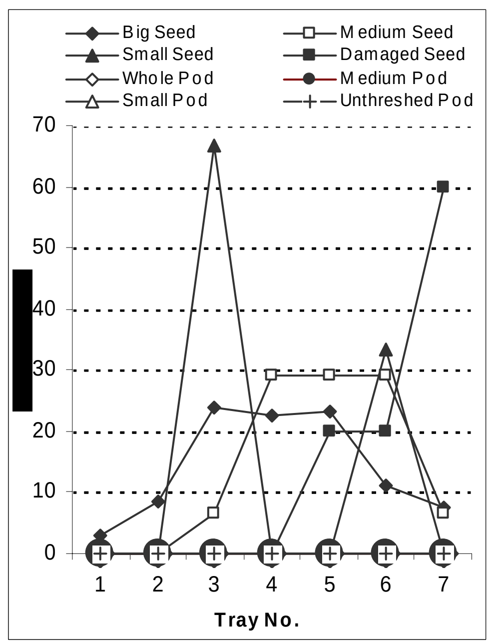

Fig. 11: Spread pattern of material in the trays at θ = 90, PMC = 22.0%, GMC= 18.8 % and V = 1500 rpm

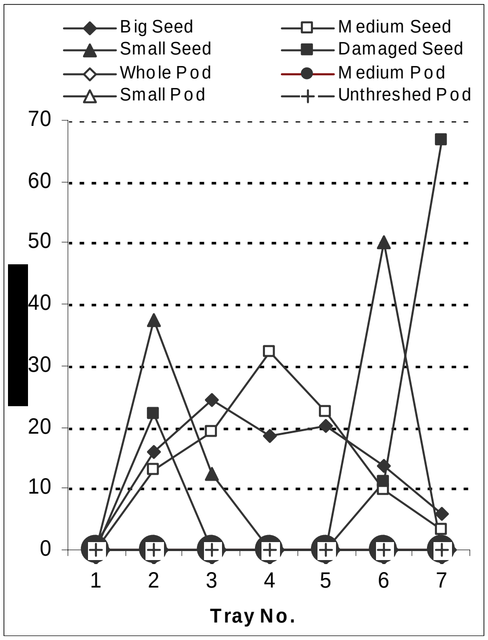

Fig. 12: Spread pattern of material in the trays at θ = 105 , PMC = 14.0%, GMC=15.3% and V =1500rpm

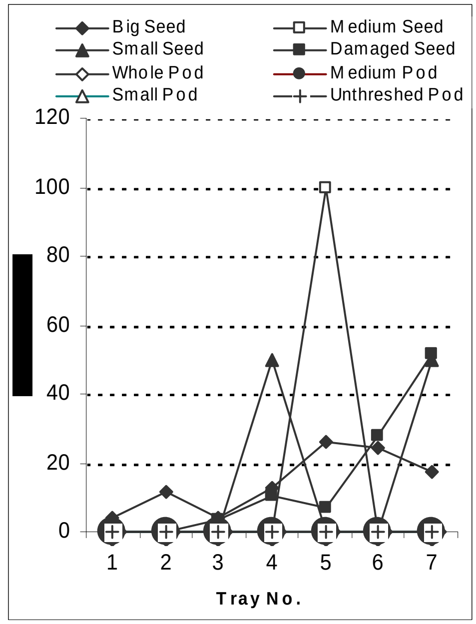

Fig. 13: Spread pattern of material in the trays at θ = 120 , PMC = 14.0%, GMC = 15.3% and V =1500rpm

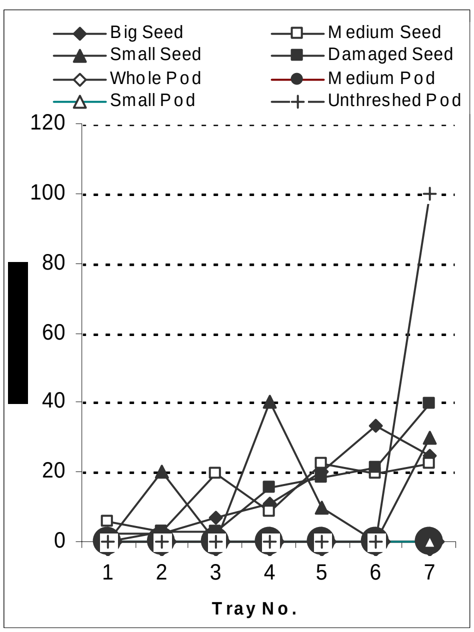

Fig. 14: Spread pattern of material in the trays at θ = 120 , PMC = 18.0%, GMC = 17.2% and V =1500rpm

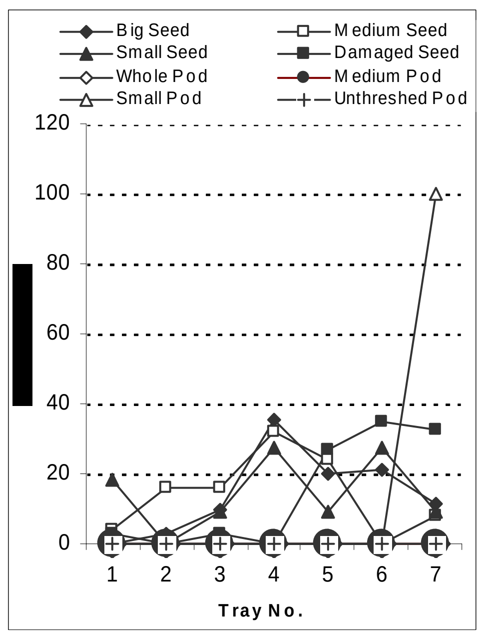

Fig. 15: Spread pattern of material in the trays at θ = 120 , PMC = 22.0%, GMC = 18.8 % and V =1500 rpm

The effect of the angle of inclination could not seriously contribute to increase the drag of material at fan speed of 900 rpm (Figs. 2-10) Also, the effect of fan speed of 1500 rpm could not seriously contribute to increase the drag of material at angles of inclinations of 90 and 105^o (Figs. 11 and 12). But, at high fan speed and high angle of inclination, the change in trend was glaring. Therefore, the combined effect of the high angle of inclination of the fan and the high fan speed would have contributed to the change in trend. A higher drag is expected at higher speed and the approach of air at higher angle of inclination must have resulted in the change in trend. Hence the materials were deposited at further distance for a fan inclination and speed of 120, and 1,500 rpm respectively, compare to the other conditions under experimentation.

This change or shift in trend is suggestive. It is suggested that the fan speed and inclination for optimal performance of the cleaner unit may lie between 900-1500 rpm and $105\text{-}120^o$ respectively. This deduction or suggestion may require further experiments in the nearest future to verify, but the likelihood may be correct because of the shift in trend observed. There is therefore the need to balance the selection of operating and machine parameters to optimize the performance of the machine

It was generally observed that majority of the small sized damaged seeds were recovered at the exit end or outside of the cleaning chamber and the largest proportion of the large sized damaged seeds were obtained in the cleaning unit. These damaged seeds obtained in the cleaning chamber were uniformly mixed with the big, medium and small sized whole seed in the trays. This is because the big sized damaged seeds are presumed to have comparable terminal velocity with the big, medium and small sized whole seeds depending on the extent of damage and were therefore spatially distributed within the whole seeds in the collecting trays in the cleaning chamber. The removal of damaged grain before loading the cleaner will likely improve the effectiveness of the cleaner to grade grains into size grades. It is therefore suggested that insect infection (leading to infested/ damaged seeds) should be minimal for grains loaded into the cleaner. This shall aid the cleaner to further classify grains into size grades, under the operating conditions of the experiments.

4. CONCLUSION

From the study reported, the following conclusions can be deducted:

1. Grain infestations by insect should be minimized for effective performance of the cleaning chamber of the machine. Where insect infestation is minimized, the cleaning chamber would not only separate the pods from the grains but also classify the grains into size grades.

2. The optimum performance of the cleaner unit is likely obtainable with fan speed of 900 – 1500 rpm and fan angle of inclination of $105 – 120^0$.

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6. REFERENCES

Ademosun, O. C. 1993 Development and performance evaluation of a pedal-operated multi-crop cleaner. Journal of Agricultural Engineering and Technology 1: 27 – 37.

Adewumi, B. A. 2005. Development and evaluation of an equipment for threshing /cleaning of legume crops. Unpublished PhD Thesis, Federal University of Technology, Akure, Nigeria.

Adewumi, B. A. 2006. Aerodynamics and particle dynamics: Applications in grain fractionation and classification. Article submitted for publication in Journal of Food Science and Technology, Nepal. 17pp.

Adewumi B. A.; Ademosun, O. C.; Ogunlowo, A. S. 2005. Research contributions to the development of a small/medium scale legume thresher. Paper presented at the International Conference on Science and Technology, Federal University of Technology, Akure, Nigeria. 10pp.

Adewumi, B. A.; Ogunlowo, A. S.; Ademosun, O. C. 2006a. Classification of material in cross flow system. Proceeding of the 1st International Conference on Advances in Engineering and Technology, Makerere University, Uganda. Published by Elsevier Publishers. Pp 321-325.

Adewumi, B. A., Ogunlowo, A. S. and Ademosun, O. C. 2006b. Investigating particle trajectory as a parameter for selecting the dimensions of cross flow classifier. CIGR Ejournal Vol VII, pp19.

Adewumi B A, O. C. Ademosun and A. S. Ogunlowo. 2006c. Design, fabrication and preliminary testing of a thresher-cleaner for legume. Article accepted for publication. Journal of Food Science and Technology, India. 22pp.

Adewumi, B. A., Ogunlowo, A. S. and Ademosun, O. C. 2006d. Particle dynamics research initiatives at the Federal University of Technology, Akure, Nigeria. Proceeding of the 1st International Conference on Advances in Engineering and Technology, Makerere University, Uganda. Published by Elsevier Publishers. Pp 315-320.

Andersson, A., Elfverson, C., Andersson, R., Regner, S., and Aman, P. 1999. Chemical and physical characteristics of different barley samples. J. Sci Food & Agric 79(3): 979 – 986.

Elfverson, C and Regner, S. 2000. Comparative precision of grain sieve and pneumatic classification on a kernel level. Applied Engineering in Agriculture 16 (5): 537 – 541.

Evers, A. D., Flintham, J and Kotecha, K. 1995. Alpha-amylase and grain size in wheat. J. Cereal Sci. 21(1): 1 – 3.

Gorial, B. Y. and O'Callaghan, J. R. 1991a. Separation of grain from straw in a vertical air stream. Journal Agricultural Engineering Research 48: 111 – 122.
Glorial, B. Y. and O'Callaghan, J. R. 1991b. Separation of particles in a horizontal air stream. Journal of Agricultural Engineering Research. 49(4): 273 – 284.
Grift, T. E. 2000. Spread pattern analysis tool (SPAT) 1. Development and theoretical examples. Trans of American Society of Agricultural Engineers 43(6): 1341 -1350.
Ichikawa, T., Sugiyama, T. 1991. Soybean thresher in Japan and development of a new thresher. Journal of Agricultural Research Quarterly 16(2): 87 – 93.
Ige, M. T. 1977. Measurement of some parameters affecting the handling loses of some varieties of cowpea. Journal Agricultural Engineering Research 22: 127 – 133
Ige, M. T. 1978. Threshing and separation performance of a locally built cowpea thresher. Journal Agricultural Engineering Research 23(1): 45 - 51.
Ige, M. T., and Ajayi, O. A. 1979. The development of a low cost cowpea thresher. Journal of Agricultural Engineering Research 24(1): 45 – 51.
Kulkarni, S. D. (1989). Pulse processing machinery in India. Agricultural Mechanization in Asia, Africa and Latin America 20 (2): 42 – 48.
Majumdar, S and Jayas, D. S. 2000. Classification of cereal grains using machine vision 1: Morphology models. ASAE Trans. 43(6): 1669 – 1675.
Milberg, P., Andersson, L., Elfverson, C and Regner, S. 1996. Germination characteristics of seeds differing in mass. Seed Sci. Res. 6: 191 – 197.
Ogunlowo, A. S, and Adesuyi, A. S. (1999). A low cost rice cleaning/ destoning machine. Agricultural Mechanization in Asia, Africa and Latin America 30(1): 20 – 24
Olukunle OJ 2002. Grain damage and threshing efficiency of indigenous combine harvester. Agricultural Engineering Journal 10(1): 51 – 58.
Regner, S., Schunurer, J., and Jansson, A. 1994. Ergosterol content in relation to grain kernel weight. Cereal Chem. 71(1): 55 – 58.
Wang, Y. J., Chung, D. S., Spillman, S. R., Eckhoff, S. R., Rhee, C., and Converse, H. H. 1994. Evaluation of laboratory grain cleaning and separating equipment – Part 1. Trans of American Society of Agricultural Engineers 37(2): 507-513.