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Effectiveness of Redesigned Larger Grain Stripping Tools on Stripping *Sorghum Bicolor*Grains off the Panicles

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Abstract*:* An experimental rotational grain-stripping rig device was fabricated to study the effect of using the larger re-designed stripping tools as compared toconventional smaller existing stripping tools to strip sorghum grain off the grain panicles. The redesigning of the stripping tools involved increasing their sizes by a scale factor of 1.5X and 2X over the current commercially available stripping tool. The stripping tools are attached to the drum such that they lean in the direction of the drum rotation at advance angles of 15° which is as in the current commercial machines setting. The three re-designed larger stripping tools, 1.5X*20deg, 1.5X*30deg and 2X*20deg yielded mean un-stripped grain loss of 0.3%, 1.0% and 0.8% respectively which was a significantimproved performance than the 1X*30deg which had 4.5% mean un-stripped grain loss. The study therefore shows that sorghum strip harvesting can be improved with appropriately designed stripping tools.

Keywords: Grain stripping tool, sorghum varieties, Botswana, panicles

I. INTRODUCTION

Studies and understanding of how stripping tools perform in detaching sorghum grain from grain bearing panicles can be useful in designing new machinery for small to medium scale sorghum harvesting and also in improving the current stripper-comb design to overcome the inefficiencies that are encountered when harvesting sorghum[1]. Despite being relatively new to the market it is quite an old technology that was trialled as far back as 1843 in Australia [2]. Reports in USA state that the stripper harvesters are used on various crops like wheat, rice, barley, oilseed rape, camelina (a biofuel seed crop) and peas[1]. Current development and advances of the current stripper harvester technology have been driven and biased and fairly so towards small grains like wheat and barley[3],[4]-[5], rice[6],[7],[8],[9]-[10and even on non-traditional crops like pasture grass seeds[11]and lavender flowers,[12]To datethere is no awareness of any research on the suitability of the technology on grain sorghum. Hence the aim of this study was to

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evaluate the performance of three different redesigned larger stripping tools on stripping sorghum and wheat grain off the grain-bearing panicles as compared with the current commercially-available smaller stripping tools.

II. MATERIALS AND METHODS

A. PLANT MATERIAL

This study was conducted using three sorghum varieties namely Mr Buster Thiram – Botswana (MBT-B), Mr Buster Thiram – United Kingdom (MBT-UK) and Prime Silo (PS) at full grain stage and one wheat variety (Claire) at full grain stage. The variety MBT-B was grown in the field in Botswana with the purpose of investigating the similarities of the sorghum grown in Botswana and the one grown in the UK. Varieties MBT-UK and PS were grown in a glasshouse at Harper Adams University (HAU). The wheat variety was grown in the fields at HAU and used as a comparative control in the study.

B. STRIPPING TOOL DESIGN

This study sought to evaluate the effect of varying the size and geometry of stripping tools. The original design (1X*30deg) (Fig. 1 and Table 1) is based on the current stripping tool used to harvest cereals commercially. The coding 1X means multiplying the current size scale by unit (1) scale factor while 30deg means 30° angle enclosed between V-shaped stripping edges. To modify the current stripper design, two step-up scale factors of 1:1.5 (1.5X) and 1:2 (2X) were used to scale up from the original size by 50 and 100% respectively, whilst two angles of 20 and 30° enclosed by V-stripping edges were used in combination with the scale factors above. The stepping up of the current smaller original design to larger new designs was based on the fact that sorghum has larger panicles with a mean length of 269mm[13] as compared to wheat. It therefore, could be difficult for larger sorghum panicles to slot into the smaller original stripping tools with narrower front gaps and shorter stripping edges which are effective at stripping wheat hence the 1X may not be as effective on larger sorghum panicles. The design combination of size scale factors and angles were; 1.5X*20deg, 2X*20deg and 2X*30deg (Table 1). These four designs were evaluated for their capability to strip the grain off the sorghum and wheat panicles. These sets of stripping tools are interchangeable on the stripper drum.A 1.6mm mild steel plate was used to manufacture the stripping tools to achieve relatively light tool but stronger than the high density plastic used in the previous commercial stripping tools.

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Table 1:Stripping Tool Design Schedule

Stripping tool design	1X*30deg.	1.5X*20deg.	1.5X*30deg.	2X*20deg
A° (Angle Enclosed)(degrees)	30°	20°	30°	20°
Stripper blade Height(mm)	125	180	180	240
Relative size to original (times)	1	1.5	1.5	2

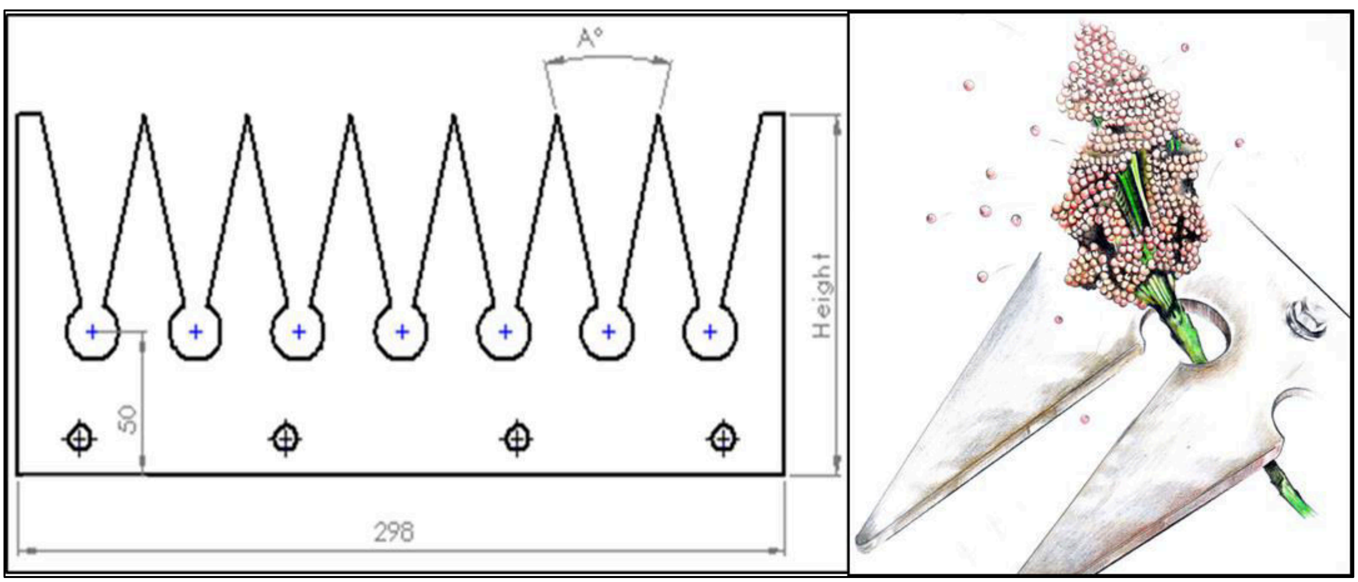

Fig. 1:Typical stripping tool design used in this study(left). And illustration of a stripping tool in action stripping sorghum grain(right)

C. EXPERIMENTAL HARDWARE

A 540mm diameter stripper drum was mounted with eight rows of stripping tools. The stripping tools were bolted to the brackets which were mount-welded on the periphery of the stripper drum. The rotational drum had a single axle running through its centre. The stripping drum was powered by a 0.75 kW Brown Pastellelectric motor (model number SK20-80L/4 and serial number IV/19283 - 4/88) and CUB8A-1(IMO Precision Control Ltdcontrol unit,). The control unit and the motor were powered by the single phase mains supply of 240 volts and the power transfer from the motor to the drum was achieved through a pair of pulleys and timing belt. The step-up speed ratio between the driving and the driven pulley used was 1:6 whilst the drum achieved a variable

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speed range of 120 to 200 rpm in this section; this speed was limited due to the rotational speed of the motor used and the belt-pulley system used. For this experiment two speeds were used (i.e 120 and 200 rpm) with the aim of investigating the effectiveness of slower drum rotational speeds in stripping sorghum grain in comparison to high speeds used in commercial grain stripping. A digital tachometer: AirflowTM TA4 anemometer (serial number 098198) was used to determine the rotational speed of the drum in rpm (resolution of 1rpm)

D. EXPERIMENTAL DESIGN

This study determined the effect of four different designs of the stripping tools on stripping three different sorghum varieties and on one wheat variety at two different stripper drum rotational speed. Statistical analysis was completed using Genstat Release 13.1. A 4*4*2 factorial design analysis of Variance (ANOVA) (Table 2)was completed with a level of probability of 5% ($P<0.05$).

Table 2: Research plan to study the effect of stripping tool design

Factor	
Stripping tool Designs(4 levels)	1X*30deg(control), 1.5X*20deg,1.5X*30deg and 2X*20deg
Crop/Variety (4 levels)	Wheat (control), MBT-B, MBT-UK and PS
Rotational speed (2 levels)	120rpm and 200rpm

E. DETERMINATION OF UN-DETACHED GRAIN LOSSES

A procedure to determine the rate of un-detached material losses was developed. The un-detached grain losses (stripping losses) are the mass of grain which remain still attached to the sorghum or wheat panicles after the process of stripping is complete. When the process of stripping is complete the remaining grain on the panicle was manually stripped and weighed (Fig. 2and Fig. 3). The manual stripping involved removal of grain together with non-grain material as when stripping takes place. Manually-stripped grain as a proportion of the total grain mass of the whole panicle was termed percentage un-stripped grain loss. The stripped material (Fig. 3) was collected in the box below the stripping rig.

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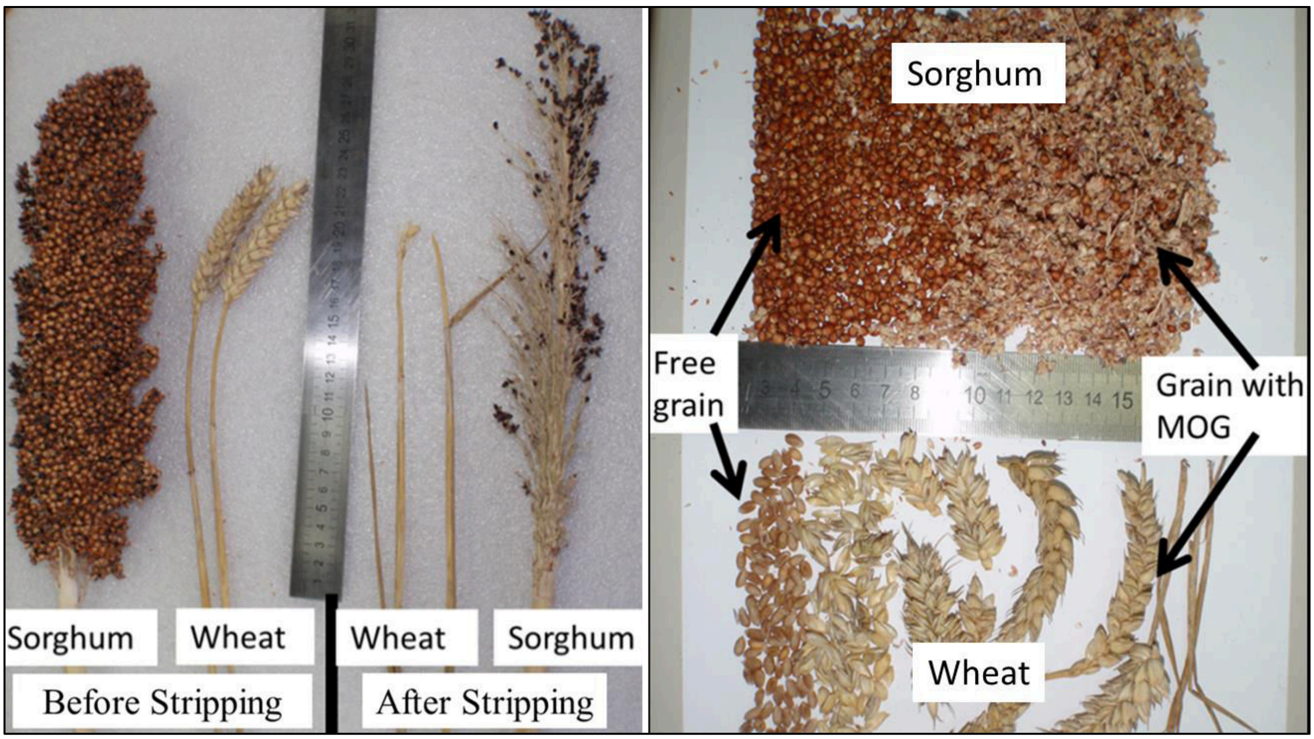

Fig. 2:Sorghum and wheat panicles, before and after stripping. Note the relative size comparison of sorghum and wheat panicles (left) while the right side shows a typical sorghum and wheat laboratory stripped material samples. Note that the stripped sample consists of both free grain and MOG with or without grain

III. RESULTS AND DISCUSSION

F. THE MASS OF THE WHEAT AND SORGHUM VARIETIES PANICLES

The results of the study show that the mean masses of sorghum heads and wheat were found to be significantly ($p<0.001$) (Fig. 3). Using Tukey's multiple range test the average mass of wheat (Claire variety) grain panicles of 8.3g was significantly less than the average masses of the three sorghum varieties equivalent to 43.9g, 35.0g and 134.4g for MBT (B),MBT (UK) and PS respectively. There was no significant difference between the mean mass of MBT-B and MBT-UK. The mean mass of PS was significantly higher than the masses of wheat and of MBT (B and UK).

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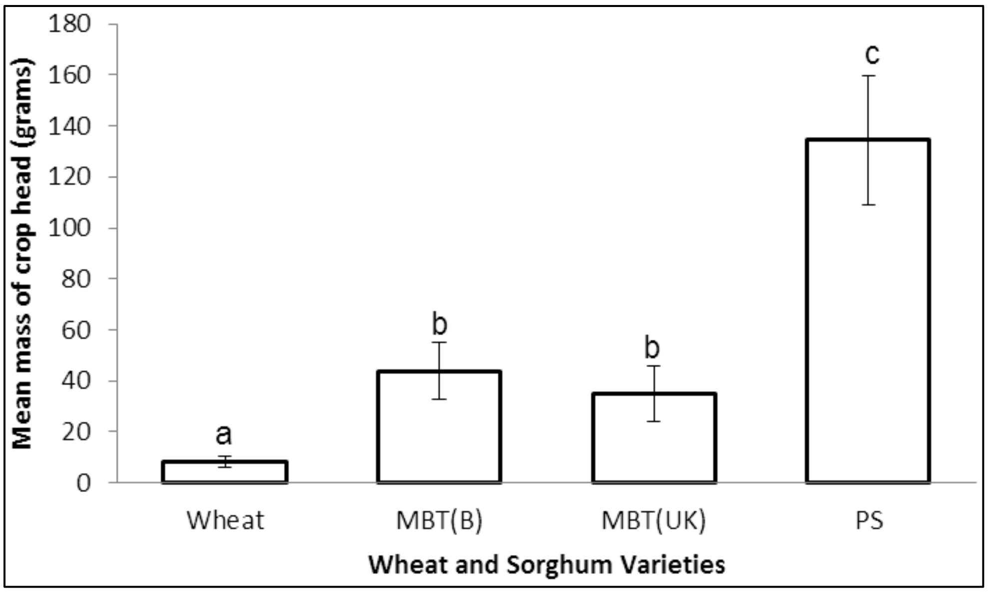

Fig. 3: Mean mass (g) of grain-bearing panicle of single wheat variety and three of sorghum. Treatments not accompanied by the same letter are significantly different at P = 0.05 according to Tukey's multiple range test. Error bars shows SEM

G. *THE OVERALL EFFECT OF STRIPPING TOOL DESIGN*

Varying degree of un-stripped material losses were found (Fig. 4)when stripping with different stripping tools. In some varieties sorghum grains were not completely removed by the process of stripping.Fig. 5 shows the stripping tool design geometry (CG) significantly ($P < 0.001$) affected stripping performance. The three re-designed stripping tools, 1.5X*20deg, 1.5X*30deg and 2X*20deg yielded mean un-stripped grain loss of 0.3%, 1.0% and 0.8% respectively. Using Tukeys multiple range test shows that the re-designed stripping tools all significantly improved stripping performance by reducing the mean un-stripped grain losses compared to the original stripping tool which had 4.5% mean un-stripped grain loss. However, the mean un-stripped grain losses of the three redesigned stripping tools were not significantly different to each other. The improvement ratios over the 1X*30deg (control) for 2X*30deg, 2X*20deg and 1.5X*20deg were 4.25, 5.67 and 17 times better respectively.

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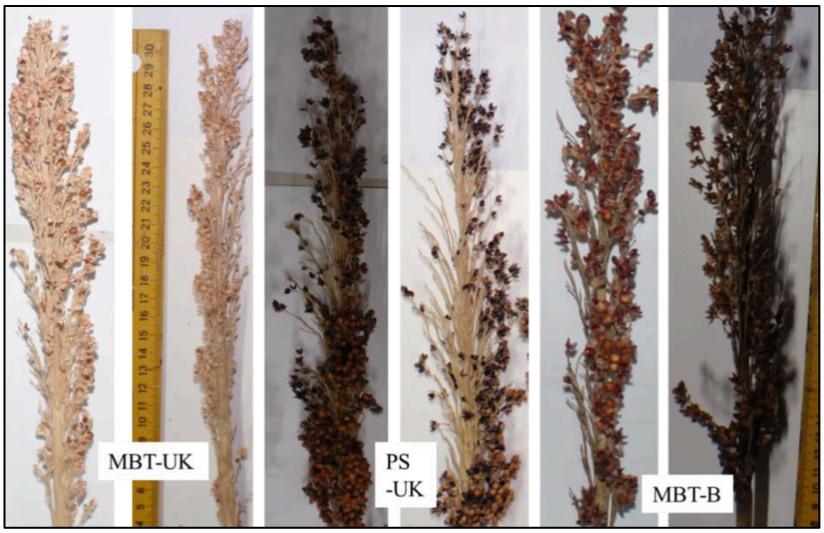

Fig. 4: sorghum panicles after stripping, showing varying stripping success

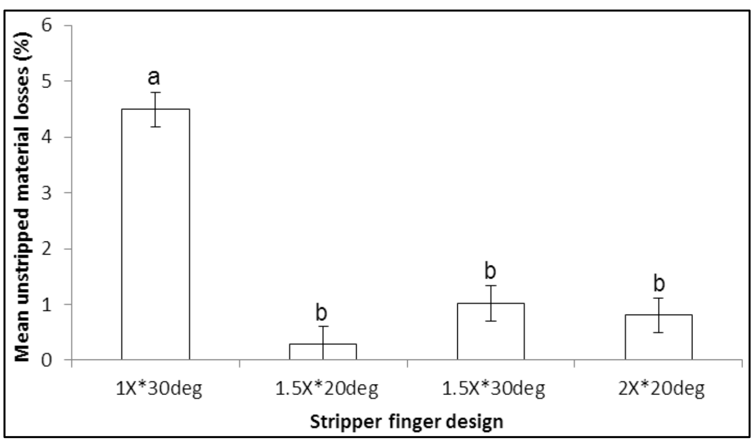

Fig. 5: Levels of un-stripped grain losses of various stripping tool designs. Treatments not accompanied by the same letter are significantly different at P = 0.05 according to Tukey's multiple range test. ($P < 0.001$, LSD at 5% level = 0.9%, DF = 48 and CV = 79.7%)

This improved performance of the re-designed stripping tools could be due to a number of factors including the redesigned stripping combs having longer stripping edges which could result in increased stripping ability or stripping opportunity time. Secondly, the re-designed stripping combs have a wider front opening which could result in the head/panicles slotting easily into the V-shaped

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stripping area and the variation in the angle enclosed between the stripping edges could be responsible for the observed effect in stripping performance evidenced by 2X*20deg versus. 2X*30deg. In this case the 20° stripping tool with 0.6% grain loss outperforms the 30° stripping tool at 0.8% grain loss. However, the two were not significantly different, which is in agreement with [7] who also observed that the importance of increasing the rotational speed and narrowing the teeth's angle to an optimum range was helpful in improving the stripping tool's performance.

Previous work conducted on grain strippers in crops such as rice[6],[9],wheat and barley[4],[5] and grass[11] which have smaller panicles than sorghum and thus easily slot into the original smaller stripping combs, unlike sorghum which can be up to 50 times the size of a single wheat panicle in the case of PS variety (Fig. 3).

H. COMBINED EFFECT OF STRIPPING TOOL DESIGN AND VARIETY ON UN-STRIPPED MATERIAL LOSSES

The combined effect of stripping tool design and variety on un-stripped material losses showed that the conventional stripping tool has significant higher losses on all the sorghum varieties as compared to other stripping tool designs (Fig. 6).When stripping PS sorghum variety, the stripping tool 1X*30deg had significantly higher losses of 5.6% as compared to 1.5X*20deg at 0.3%, 1.5X*30deg had 2.3% while 2X*20deg losses were 1.7%. There was no significant difference between 1.5X*20deg (0.3%) and 2X*20deg (1.7%), Also between 1.5X*30deg (0.3%) and 2X*20deg (1.7%). However 1.5X*20deg (0.3%) losses were significantly lower than those of 1.5X*30deg (2.3%)

During the process of stripping MBT-B sorghum variety, the stripping tool 1X*30deg had significantly higher losses of 4.3% as compared to 1.5X*20deg at 0.3%, 1.5X*30deg had 0.5% while 2X*20deg losses were 0.6%. There was no significant difference between the other three stripping tool designs namely 1.5X*20deg (0.3%), 1.5X*30deg (0.5%) and 2X*20deg (0.6%).When stripping MBT-UK sorghum variety, the stripping tool 1X*30deg had significantly higher losses of 3.6% as compared to 1.5X*20deg and 1.5X*30deg both at 0.3%, while 2X*20deg losses were 0.2%. There was no significant difference between the other three stripping tool designs namely 1.5X*20deg (0.3%), 1.5X*30deg (0.3%) and 2X*20deg (0.2%).

The combined effect of stripping tool design 1X*30deg and Prime-Silo sorghum variety had the highest losses, which may be due to the fact that the larger PS heads are too large for the stripping tool design (1X*30deg). The variety Prime Silo had the highest losses on three of the four stripping tool designs. Only stripping tool 1.5X*20deg has losses that are not significantly different from the other two varieties this may be due to an increased stripping tool sizes and wider opening with a narrower stripping edge angles.

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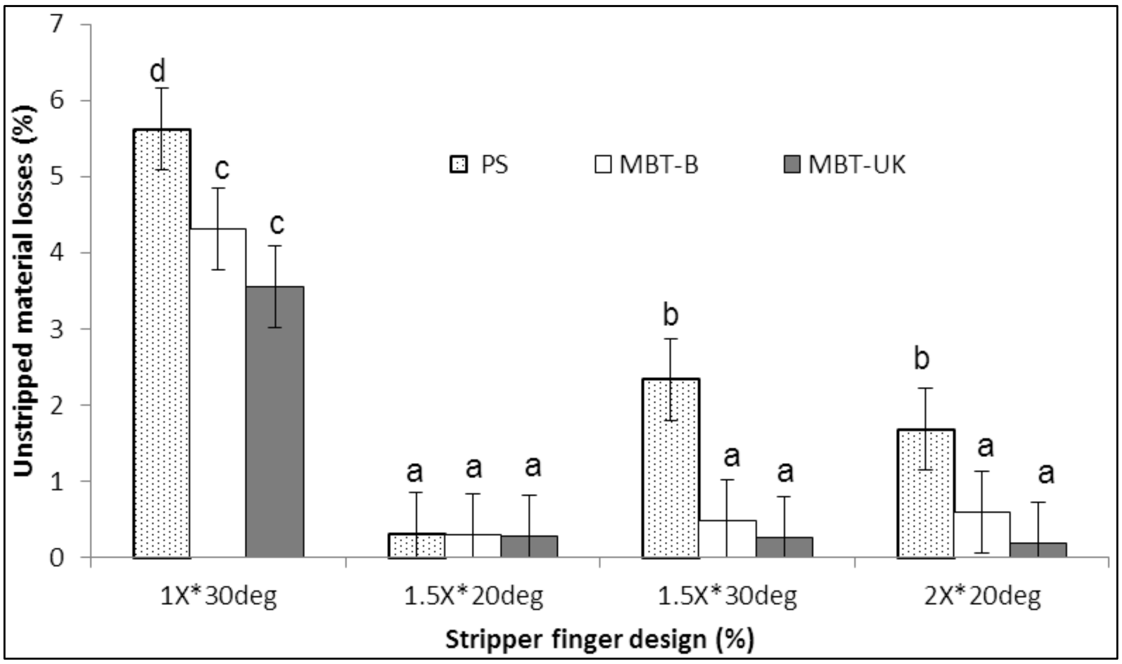

Fig. 6: The combined effect of stripping tool design and sorghum variety on un-stripped losses (p-value = 0.487, LSD at 5% level = 1.5%, DF = 48 and CV = 79.7%), Treatments not accompanied by the same letter are significantly different

IV. CONCLUSION

This work has shown that stripping of sorghum using stripping tools is possible since after stripping occurs low proportion of grain is left still attached to the panicles. All the three re-designed larger stripping tools(1.5X*20deg., 1.5X*30deg. and 2X*20deg.) showed potential for improving stripper harvesting of sorghum by significantly reducing un-stripped sorghum grain losses in comparison to the current commercially available stripping tool(1X*30deg). Of the three re-designed stripping tools, the 1.5X*20deg had the significant lowest losses when stripping PS variety. The larger stripping tools are more suitable for stripping sorghum than the smaller conventional stripping tool.

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