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### COMPARATIVE STUDY OF SHEARING CHARACTERISTICS OF SORGHUM STALK

MRUDULATA DESHMUKH, S.K.THAKARE

Deptt.of Farm Power and Machinery, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) – 444 104

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**Abstract:** Shearing strengths of Sorghum (*Sorghum bicolor* L. Moench) stalks of three varieties CSV-20, CSV-23 and CSH-9 were determined. The stalk specimens were deformed at two loading rates (50 mm/min and 75 mm/min). The cutting force required for shearing of sorghum stalks, Ultimate cutting stress and Specific shearing energy were determined at three sections for three varieties. The mean of the force required for cutting upper section of stalk of all varieties at first and second loading rate was 241.66 and 243.83 N respectively. The Ultimate cutting stress at upper section of stalk for the variety CSV-20 at the first loading rate found more by 12.03 % as compared with the second loading rate. The UCS was found 35.13 % and 36.35 % more at 75 mm/min loading rate for the varieties CSV-23 and CSH-9 respectively. The mean values of cutting force required for middle section of stalk recorded as 303.36 N and 307.42 N respectively at first and second loading rate. The Ultimate cutting stress at middle section of stalk for the variety CSV-20 at first loading rate was increased by 33.42 % as compared with the second loading rate. The value of UCS was slightly increased by 6.81 % in case of the variety CSV-23. The trend of UCS was observed reverse for the variety CSH-9. The Specific Shearing Energy had increasing trend for the variety CSV-20 as the loading rate is increased from 50 mm/min to 75 mm/min. However, the reverse trend of SSE was observed in case of the varieties CSV-23 and CSH-9 for middle section of the stalk. The mean of the force required for cutting lower section of stalk of all varieties at first and second rate of loading was 358.58 and 541.92 N respectively. The Ultimate cutting stress had increasing trend for all three varieties as the rate of loading is increased from 50 mm/min to 75 mm/min for lower section. The Specific Shearing Energy had increasing trend for the variety CSV-20 & CSV-23 as the loading rate is increased from 50 mm/min to 75 mm/min.

**Keywords:** Loading rate; Cutting force; Ultimate cutting stress; Specific shearing energy



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Corresponding Author: MS. MRUDULATA DESHMUKH

Co Author: MR. S.K.THAKARE

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## INTRODUCTION

The India covers 34 % of the total Sorghum area in the world and produces around 17 % of the world production of sorghum grain per annum. It is being cultivated in Maharashtra for both grain and fodder during kharif (area 13.84 lakh ha) and rabi (area 30.17 lakh ha). Sorghum is second largest growing crop of Vidarbha region of Maharashtra. Important mechanical properties of the cellular forage material from the cutting standpoint are strength in tension, shear and bending. These properties are influenced by species, variety and age of the plant, moisture content and the cellular structure (Person, 1987).

It is also necessary to determine the physico mechanical properties such as shearing stress and energy requirement to design suitable cutting devices and optimise operational parameters.(Ince et al, 2005). The mechanical properties of sorghum stalk are essential for the design of equipment and analysis of the behavior of product during agricultural process operations such as harvesting, handling etc. The cutting of stalk is an important process in sorghum harvesting, forage harvesting, weeding, stalk shredding etc. The properties of the cellular material that are important in cutting are compression, shearing, density and friction (Taghijarah et al, 2011). In view of above the study was undertaken with the objective, 1) to determine compressive and tensile strength of sorghum stalk and 2) to determine the effect of loading rate on shearing characteristics of sorghum stalk.

## MATERIALS AND METHODS

The experimental material selected for the study was three different varieties CSV-20, CSV-23 and CSH-9 of sorghum planted in the year 2012 on the experimental field at Western Block of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Stalks of physiologically matured sorghum plants were selected and shear strengths were determined at upper, middle and lower position of stalk.

**Moisture content :** The moisture content of the sorghum stalk was measured according to ASAE Standard S.352 (ASAE Year Book 1979).

### Stalk diameter

The Sorghum stalk diameter was determined with the help of a slide caliper having a least count of 0.01mm. The measurements were taken for upper, middle and lower positions. The stalks of an average diameter were selected for the experiment. This procedure was repeated for all three varieties.

## Experimental Techniques

### Shear strength of stalk

The shearing tests were conducted using Food Texture Analyzer (Plate 1) to determine shearing force for the sorghum stalk. The machine consists mainly of a shearing blade, rigid fixture on the base platform to keep the stalk specimen and a load cell of capacity 250 kg for recording the shearing force. Data chart recorder where the live graph of each test can be observed separately as well as the tabular data can be recorded in the format of excel sheet. Two loading rates 50 mm/min and 75 mm/min were selected for the study. The stalk samples were kept on the fixture and during the downward movement of the crosshead; the knife cuts the specimen by shear and passed through the slots provided in the fixture below the specimen. The force required for shearing stalk at the crosshead speed of 50 and 75 mm/min. was recorded against time on the chart recorder. The indices which determine the shearing behavior of the plant material are ultimate cutting stress and specific shearing energy.

The Ultimate cutting stress is determined by using equation,

$$\sigma_s = \frac{F_{\max}}{A}$$

where,  $\sigma_s$  represents the ultimate cutting stress,  $F_{\max}$  the maximum shear force (N) and  $A$ , the cross-sectional area ( $\text{mm}^2$ ) of the stalk. The specific shearing energy was calculated as a quotient of the total strain energy and the stalk cross sectional area. (Chattopadhyay and Pandey, 1999 ).

$$E_{ss} = \frac{F}{A} \int dx$$

Where,

$E_{ss}$  = Specific shearing energy,  $\text{mJ}/\text{mm}^2$ ,

$F$  = Shearing force, N

$A$  = Cross section of sample at the place of cutting,  $\text{mm}^2$ ,

$x$  = Travel of knife (displacement), mm.

### Variables for the study

The independent variables were three sorghum varieties (CSV-20, CSV-23 & CSH-9) and two Rate of loadings (50 mm/min, 75 mm/min.). The dependent variables were cutting force, ultimate cutting stress and specific shearing energy. The experiments were replicated thrice and the results were analysed by using split plot design.

The samples of an average equal diameter were selected for the experimentation. Three samples were prepared from upper, middle and lower section of the stalk for the repetition of the experiment. The experiment was planned on the same day to avoid the fluctuation in the moisture content of the stalk.

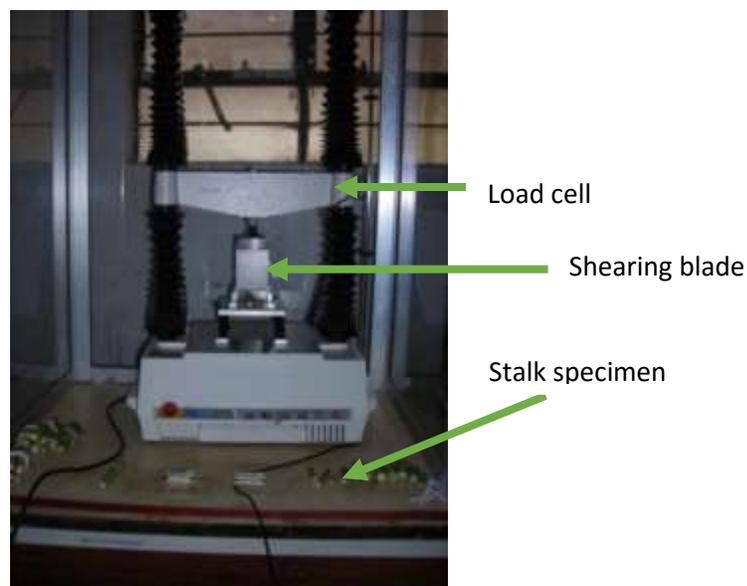


Plate 3 Food texture analyzer

### RESULTS AND DISCUSSION

The comparative results of Cutting force of three varieties at two loading rates for three sections are tabulated in table1. From the Table 1 it is clear that the force required for the variety, CSV-20 decreased at the loading rate of 75 mm/min. as compared to the force required at the loading rate of 50 mm/min for upper section of the stalk while at the middle and lower section the required force increased at the loading rate of 75 mm/min as compared to the force required at the loading rate of 50 mm/min. In case of variety CSV-23, the force required at the loading rate of 75 mm/min. and loading rate of 50 mm/min. is at par for upper and middle section of the stalk while for the lower section of stalk, increasing trend of required cutting force

is observed at the loading rate of 75 mm/min as compared to the loading rate of 50 mm/min. In case of third variety i.e. CSH-9, the force required at the loading rate of 75 mm/min. is increased as compared to the force required at the loading rate of 50 mm/min. at upper section while at the middle and lower section the reverse trend of the required force is observed.

The force required for shearing of the varieties CSV-20 and CSV-23 increased from upper section to the lower section. But in case of variety CSH-9 the increasing trend of force was in the sequence of middle, upper and lower section of the stalk. This may happened due to the

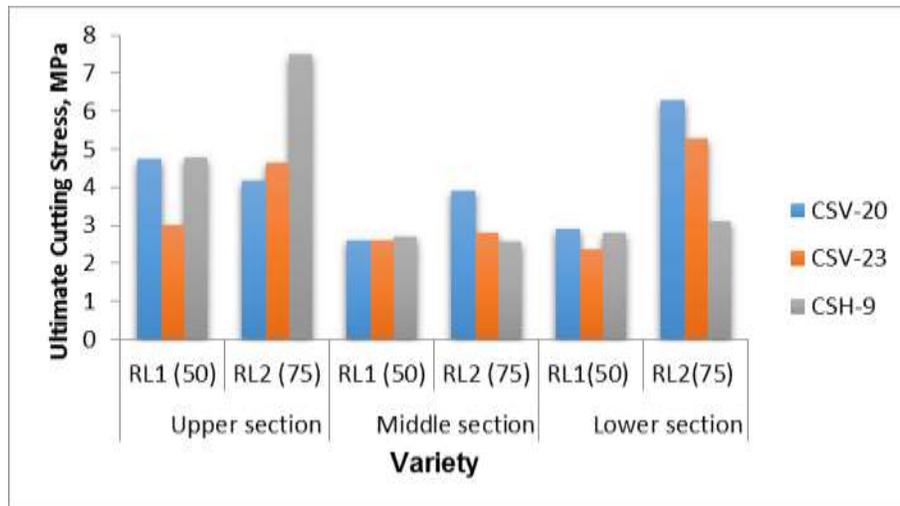
**Table 1 Cutting force for three varieties at two loading rates and three sections of sorghum stalk**

Upper Section				Middle Section				Lower section			
Rate of loading	Cutting force, N		Mean	Rate of loading	Cutting force, N		Mean	Rate of loading	Cutting force, N		Mean
	50 mm/min.	75 mm/min.			50 mm/min	75 mm/min			50 mm/min	75 mm/min	
↓	→			↓	→			↓	→		
Variety				Variety				Variety			
CSV-20	321.51	260.93	291.22	CSV-20	419.94	470.24		CSV-20	413.06	839.43	
CSV-23	192.51	193.10	192.81	CSV-23	286.94	277.05	445.09	CSV-23	301.70	512.67	626.24
CSH-9	210.96	277.47	244.22	CSH-9	203.20	174.98	281.99	CSH-9	360.97	273.67	407.19
<b>Mean</b>	241.66	243.83		<b>Mean</b>	303.36	307.42	189.09	<b>Mean</b>	358.58	541.92	317.32
	<b>Main Factor (A)</b>	<b>Sub Factor (B)</b>	<b>Interaction</b>		<b>Main Factor (A)</b>	<b>Sub Factor (B)</b>	<b>Interaction</b>		<b>Main Factor (A)</b>	<b>Sub Factor (B)</b>	<b>Interaction</b>
F Test	S	NS	NS	F Test	S	NS	NS	F Test	S	NS	NS
SE (m)±	21.522	33.010	57.175	SE (m)±	59.013	20.302	35.163	SE (m)±	84.505	103.105	178.584
CD (5%)	84.490	--	--	CD (5%)	231.673	--	--	CD (5%)	331.754	--	--

S-Significant, NS-Non significant

Size variation of the stalk from upper to the lower section. The maximum force is required for the lower section of the stalk for all three varieties.

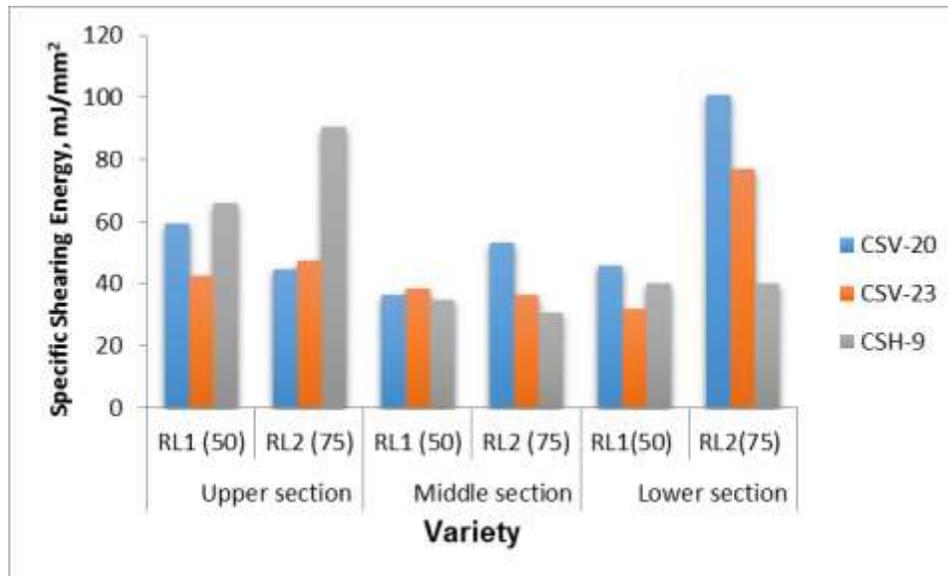
The comparative results of Ultimate cutting stress of three varieties at two loading rates for three sections are presented graphically in the Fig.2.



**Fig.2 Ultimate cutting stress of three varieties at two loading rates for three sections of Sorghum stalk**

From the Fig. 2, it is revealed that the value of the ultimate cutting stress decreased for the variety, CSV-20, at the loading rate of 75 mm/min. as compared to the ultimate cutting stress at the loading rate of 50 mm/min for upper section of the stalk while at the middle and lower section, increasing trend of the ultimate cutting stress is observed at the loading rate of 75 mm/min as compared to the UCS at the loading rate of 50 mm/min. In case of variety CSV-23, the ultimate cutting stress at the loading rate of 75 mm/min. and loading rate of 50 mm/min. is at par for middle section of the stalk while for the upper and lower sections, increasing trend of UCS at the loading rate of 75 mm/min is observed as compared to the loading rate of 50 mm/min. For third variety i.e. CSH-9, the ultimate cutting stress at the loading rate of 75 mm/min. is increased as compared to the UCS at the loading rate of 50 mm/min for upper section of stalk while at the middle and lower section the values of ultimate cutting stress at the loading rate of 75 mm/min and at the loading rate of 50 mm/min are at par. The increasing trend of ultimate cutting stress was in the sequence of middle, lower and upper section of the stalk. This may happened due to the sectional size variation of the stalk.

The comparative results of Specific searing energy of three varieties at two loading rates for three sections are presented graphically in the Fig.3.



**Fig. 3 Specific shearing energy of three varieties at two loading rates for three sections of Sorghum stalk**

The Fig. 3. shows the decreasing trend of specific shearing energy for the variety CSV-20, at the loading rate of 75 mm/min. as compared to the SSE at the loading rate of 50 mm/min for upper section of the stalk while at the middle and lower sections, the values of specific shearing energy had reverse trend. In case of variety CSV-23, the specific shearing energy at the loading rate of 75 mm/min. and loading rate of 50 mm/min. is at par for middle and upper section of the stalk while for the lower section, the values of SSE increased at the loading rate of 75 mm/min as compared to the loading rate of 50 mm/min. In case of the variety CSH-9, increased values of specific shearing energy at the loading rate of 75 mm/min are observed as compared to the loading rate of 50 mm/min for upper section of stalk while at the middle and lower sections of the stalk, at par values of SSE are observed at the loading rate of 75 mm/min and 50 mm/min. The increasing trend of specific shearing energy was in the sequence of middle, upper and lower section of the stalk.

## CONCLUSIONS

- The compressive strength was highest for the variety CSV-20 followed by the varieties CSV-23 and CSH-9.
- The tensile strength of varieties CSV-20, CSV-23 and CSH-9 were observed as 1.27kN, 1.60kN and 2.40kN respectively.

- The mean of the force required for cutting upper, middle and lower section of stalk of all varieties at 50 mm/min was 301.2 N and 75 mm/min loading rate was 364.39 N respectively.
- The ultimate cutting stress has decreasing trend for variety CSV-20 upper section of stalks as the loading rate was increased from 50 mm/min to 75 mm/min. For middle and lower section of stalk the trend of UCS was reverse. In case of varieties CSV-23 and CSH-9, the values of UCS had increasing trend for all three sections of stalks.
- The specific shearing energy for the variety CSV-20 had decreasing trend, while the value of SSE for varieties CSV-23 and CSH-9 increased as the loading rate was increased from 50 mm/min to 75 mm/min for upper section of stalk.
- The SSE had increasing trend for the variety CSV-20 as the loading rate is increased from 50 mm/min to 75 mm/min. However, the reverse trend of SSE was observed in case of the varieties CSV-23 and CSH-9 for middle section of the stalks.
- In case of lower section of stalks the SSE had increasing trend for all three varieties.

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