Journal of Agroecology and Natural Resource Management
Print ISSN: 2394-0786, Online ISSN: 2394-0794, Volume 1, Number 3; November-January, 2014 pp. 166-170

http://www.krishisanskriti.org/janrm.html

Influence of Blade Parameters on Force for Cutting Sorghum Stalks

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Abstract: *Cutting of stalks is an important process in sorghum harvesting. The study was aimed to develop cutting mechanism for harvesting Sorghum. The experiments were conducted to determine force for cutting stalks at different combinations of blade parameters. The combine effect of bevel angle, rake angle and shear angle of blade on the force for cutting stalks with plane blade indicated that for varieties CSV-20, CSV-23 and CSH-9, minimum force (0.89, 0.83 and 0.45 N respectively) was recorded at the combination of blade bevel angle 35˚, blade rake angle 0˚and blade shear angle 30˚. The results of effect of blade bevel angle, blade rake angle and blade velocity on force for cutting sorghum stalk for the varieties CSV-20, CSV-23 and CSH-9 indicated that for the variety CSV-20, minimum force (1.67 N) was recorded at the combination of blade bevel angle 45˚, blade rake angle 20˚and blade velocity 350 rpm whereas for the varieties CSV-23 and CSH-9, the minimum force (1.20 N) and (0.85 N) was required at the combination of blade bevel angle 45˚, blade rake angle 0˚and blade velocity 350 rpm and at the combination of blade bevel angle 35˚, blade rake angle 0˚ and blade velocity 350 rpm respectively*

Keywords: *Bevel angle, Shear angle, Rake angle, torque sensor*

1. 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). Harvesting operation is achieved by four different actions, i)Slicing action with a sharp smooth edge; ii)Tearing action with a rough, serreted edge; iii)High velocity single element impact with sharpor dull edge and iv) A two element scissors type action.

The present practice of harvesting is carried out using a mannually operated sickle. Generally manual harvesting involves slicing and tearing actions that result in plant structure failure due to compression, tension or shear. The total harvesting of Sorghum requires two stages cutting of plant, one at the top for separating cobs and second at the bottom for fodder. Hence double labour is required for harvesting of this crop and about 25% of the total labour for grain production is consumed by harvesting operation alone.In case of hybrid Jowar when the crop attains maturity, the stand is erect and the cobs at the top of the plant are nearly at uniform height.

This genetic factor is favourable for introducing a mechanical harvesting device. Thus mechanized harvesting of Sorghum is a need of a day which will reduce the drudgery and save the time. Also it will be the solution for labour problem. Hence the present study was aimed to develop cutting mechanism for harvesting Sorghum.

2. 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 the experiments were conducted to determine cutting force of stalks at different combinations of blade parameters.

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

2.1 Stalk diameter

The Sorghum stalk diameter was determined with the help of a slide calliper having a least count of 0.01mm. Three repeated measurements were taken for upper, middle and lower sections to get average value.

2.2 Experimental Techniques

The laboratory set up of cutting mechanism was developed to measure force required for cutting sorghum stalks of three selected varieties at different combinations of various blade parameters such as blade bevel angle; shear angle; rake angle

and blade velocity (Plate 1). The plane blade having dimensions 230 X 60 X 10 mm was used for the experiment. Different parameters selected for the study are described herewith as follows.

Parameters selected for the studywere three varieties of sorghum (CSV-20, CSV-23 & CSH-9), three levels of blade bevel angle(25º, 35º, 45º), three levels of blade shear angle (25º, 30º, 35º), three levels of blade rake angle (20º, 0º, -20º) and three levels of blade velocity (350, 500, 650 rpm) as independent variables whereas dependent variable was peak force. The experiment was replicated thrice and statistical design used was Completely Randomised Design.

The developed laboratory set up of cutting mechanism had different components such as central shaft, rotating disc, torque sensor, electric motor with variable frequency drive (VFD) etc. Rotating disc was mounted on central shaft at lower end for cutting stalks. The blades were fitted on the rotating disc with different shear angle and rake angle sims according to the treatment combinations. Torque sensor was mounted on the central shaft in between rotating disc and middle bearing. Torque sensor was used to measure the cutting torque (Plate 2). The power for operating set up was supplied by electric motor and the speed of rotation was varied with the help of variable frequency drive.

The samples for investigations were collected at random. The stalks of an average equal diameter were selected for the experimentation. The experiment was planned on the same day to avoid the fluctuation in the moisture content of the stalk. Before starting the trials, the diameter of the Sorghum stalks were measured at three different points and was averaged and the moisture content was also determined. The samples of three varieties of sorghum stalks were hold in the stalk holder and the disc was rotated at three different speeds selected for study. The torque observations were noted for each speed separately from the excel sheet data of torque sensor. The trials were repeated thrice for different treatments selected for study.

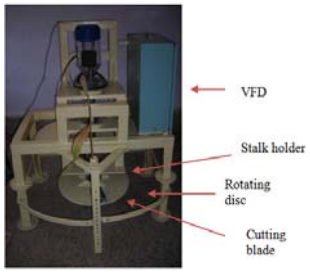


Plate 1: Laboratory set up of cutting mechanism

Plate 2:Torque sensor

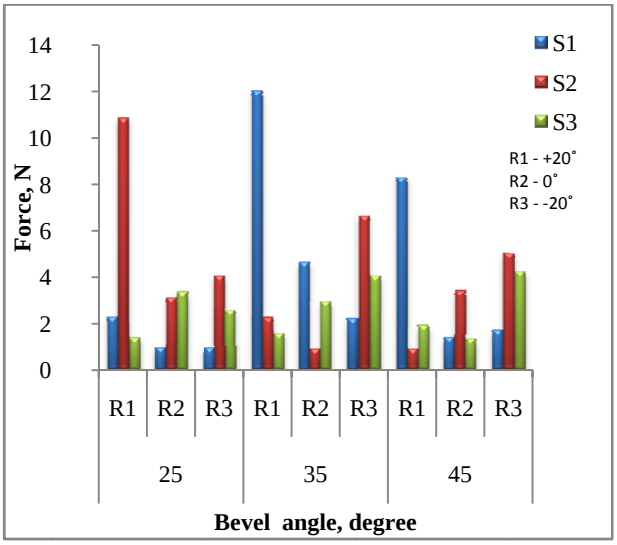
3. RESULTS AND DISCUSSION

The combine effect of three parameters i.e.blade bevel angle, blade shear angle, blade rake angle and blade velocity on force for cutting sorghum stalk of three selected varieties are tabulated in the following tables.

3.1 Effect of blade bevel angle, blade rake angle and blade shear angle

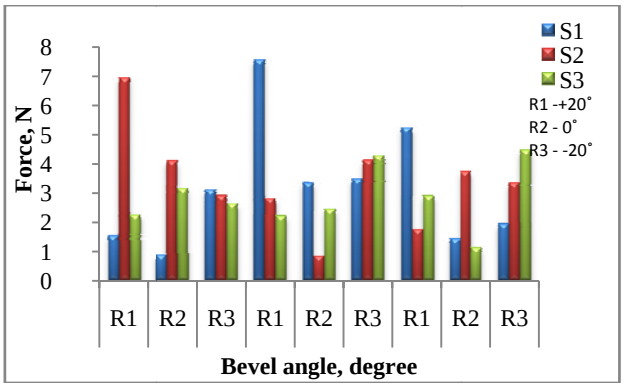
The table 1 represents the combine effect of blade bevel angles, blade rake angles and shear angles of plane blade on the force for cutting sorghum stalks.

The results of combine effect of bevel angle, rake angle and shear angle of blade on the force for cutting stalks with plane blade for the sorghum varieties indicated that for varieties CSV-20, CSV-23 and CSH-9, minimum force (0.89, 0.83 and 0.45 N respectively) was recorded at the combination of blade bevel angle 35˚, blade rake angle 0˚and blade shear angle 30˚. Mc Randal and McNulty (1978) reported a slightly lower energy requirement for a 60˚ bevel as compared to 45˚ bevel angle. The reason for this is not understood but it may be that the stems consumed more energy in friction due to the greater penetration of 45˚ bevel blade as opposed to the 60˚ bevel blade. Among three varieties, CSH-9 required minimum force and CSV-20 required maximum force while the variety CSV-23 reported intermediate value. This may be due to the variation in the size, maturity and moisture content of the stalks (Chancellor 1958).

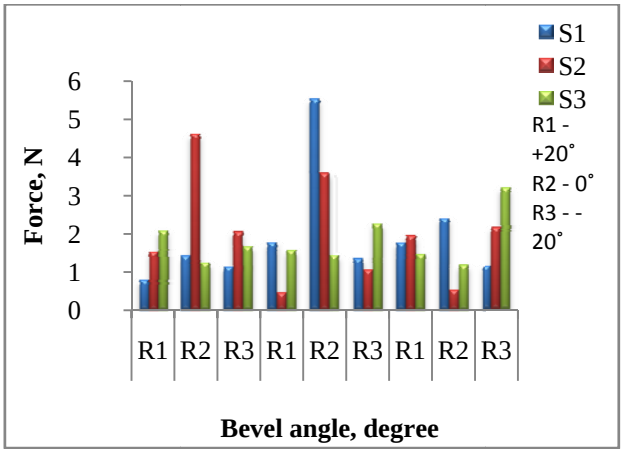


CSV-20

Person, 1987 also reported that the species related material features which would be expected to influence the maximum cuttingforce are ultimate tensile strength of the fiber, stiffness of the fiber, thickness of the strong fiber and structure of the stem.



CSV-23



CSH-9

Fig. 1: Interaction effect of blade bevel angle, blade rake angle and blade shear angle on force for cutting stalks of three sorghum varieties

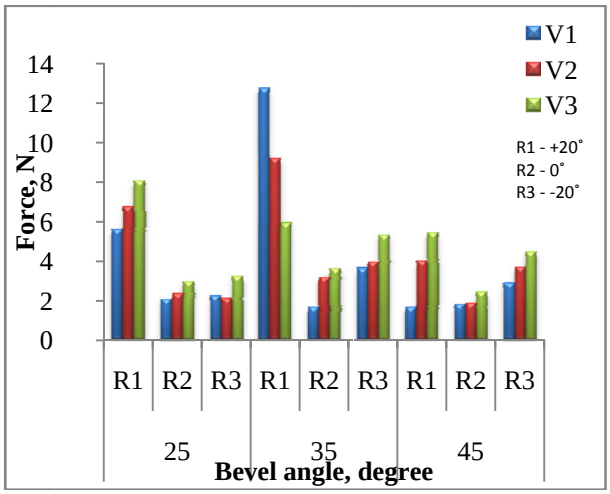
3.2 Effect of blade bevel angle, blade rake angle and blade velocity

The table 2 represents the combine effect of blade bevel angles, blade rake angles and blade velocity on force for cutting sorghum stalks with plane blade.

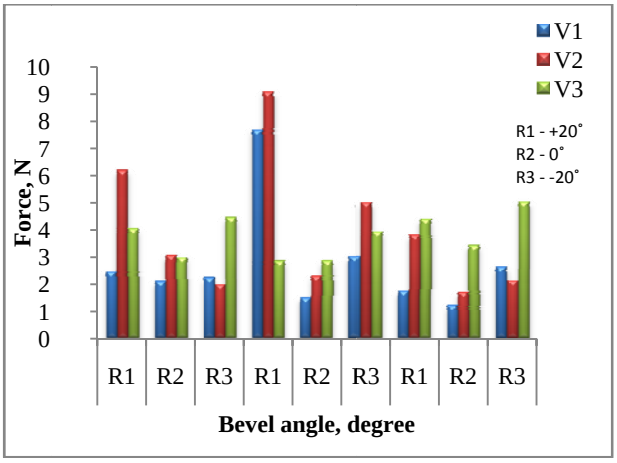
The results of effect of blade bevel angle, blade rake angle and blade velocity on force for cutting sorghum stalk with plane blade for the varieties CSV-20, CSV-23 and CSH-9 indicated that for the variety CSV-20, minimum force (1.67 N) was recorded at the combination of blade bevel angle 45˚, blade rake angle 20˚and blade velocity 350 rpm whereas for the varieties CSV-23 and CSH-9, the minimum force (1.20 N) and (0.85 N) was required at the combination of blade bevel angle 45˚, blade rake angle 0˚and blade velocity 350 rpm and at the combination of blade bevel angle 35˚, blade rake angle 0˚ and blade velocity 350 rpm respectively. Among three varieties, CSH-9 required minimum force and CSV-20 required maximum force while the variety CSV-23 reported intermediate value. The interaction effect of bevel angle, rake angle and velocity was found statistically significant for all three varieties.

4. CONCLUSIONS

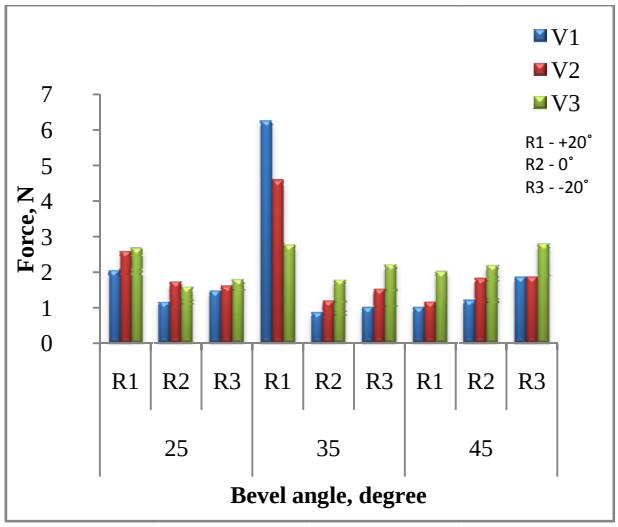
1. The combine effect of bevel angle, rake angle and shear angle of blade on the force for cutting stalks with plane blade indicated that for varieties CSV-20, CSV-23 and CSH-9, minimum force (0.89, 0.83 and 0.45 N respectively) was recorded at the combination of blade bevel angle 35˚, blade rake angle 0˚and blade shear angle 30˚.
2. The results of effect of blade bevel angle, blade rake angle and blade velocity on force for cutting sorghum stalk for the varieties CSV-20, CSV-23 and CSH-9 indicated that for the variety CSV-20, minimum force (1.67 N) was recorded at the combination of blade bevel angle 45˚, blade rake angle 20˚and blade velocity 350 rpm whereas for the varieties CSV-23 and CSH-9, the minimum force (1.20 N) and (0.85 N) was required at the combination of blade bevel angle 45˚, blade rake angle 0˚and blade velocity 350 rpm and at the combination of blade bevel angle 35˚, blade rake angle 0˚ and blade velocity 350 rpm respectively.



CSV-20



CSV-23



CSH-9

Fig. 2Interaction effect of blade bevel angle, blade rake angle and blade velocityon force for cutting stalks of three sorghum varieties

3. Among three varieties, CSH-9 required minimum force and CSV-23 required maximum force while the variety CSV-20 reported intermediate value for all combinations of blade parameters.

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Table 1 Effect of blade bevel angle, blade rake angle and blade shear angle on force for cutting sorghum stalks

Sr. No.	Blade bevel angle, degree	Blade rake angle, degree	Force, N								
			Variety								
			CSV-20			CSV-23			CSH-9		
			Blade shear angle, degree								
			25	30	35	25	30	35	25	30	35
1	25	20	2.27	10.85	1.38	1.52	6.91	2.23	1.42	4.62	1.24
		0	0.96	3.11	3.35	0.84	4.10	3.15	0.79	1.54	2.10
		-20	0.95	4.05	2.57	3.11	2.91	2.63	1.13	2.05	1.66
	35	20	12.02	2.24	1.56	7.57	2.81	2.20	5.54	3.59	1.44
		0	4.64	0.89	2.94	3.35	0.83	2.44	1.77	0.45	1.56
		-20	2.21	6.64	4.06	3.43	4.14	4.30	1.35	1.05	2.27
3	45	20	8.30	0.91	1.91	5.26	1.75	2.90	2.42	0.52	1.18
		0	1.40	3.40	1.34	1.43	3.75	1.12	1.78	1.95	1.46
		-20	1.71	5.04	4.27	1.94	3.36	4.49	1.14	2.15	3.20
		F-test		S			S			S	
		SE(m)+		1.662			0.323			0.127	
		CD (5%)		3.827			0.745			0.293	

S - Significant

Table 2 Effect of blade bevel angle, blade rake angle and blade velocity on force for cutting sorghum stalks

Sr. No.	**Blade bevel angle, degree**	**Blade Rake angle, degree**	**Force, N**								
			Variety								
			CSV-20			**CSV-23**			**CSH-9**		
			Blade velocity, rpm								
			350	**500**	**650**	**350**	**500**	**650**	**350**	**500**	**650**
1	**25**	**20**	5.63	6.78	8.09	2.45	6.18	4.03	2.04	2.57	2.66

		0	2.08	2.36	2.98	2.09	3.05	2.97	1.15	1.72	1.57
		-20	2.24	2.11	3.23	2.23	1.98	4.44	1.46	1.59	1.78
2	**35**	**20**	12.72	9.18	5.91	9.67	10.07	2.84	6.25	4.57	2.75
		0	1.68	3.18	3.62	1.49	2.29	2.85	0.85	1.17	1.76
		-20	3.64	3.96	5.31	3.01	4.99	3.92	0.98	1.50	2.19
3	**45**	**20**	1.67	4.01	5.43	1.74	3.80	4.38	0.99	1.14	1.98
		0	1.82	1.87	2.44	1.20	1.69	3.41	1.19	1.81	2.18
		-20	2.88	3.69	4.45	2.62	2.13	5.03	1.85	1.85	2.79
		F-test		**S**			**S**			**S**	
		SE(m)±		1.662			0.323			0.127	
		CD (5%)		3.827			0.745			0.293	

S-significant