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Research Article

EVALUATION OF TORQUE AND ENERGY CHARACTERISTICS OF SELECTED ROTARY BLADES FOR INTER CULTURE OPERATION

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Abstract- Mechanical inter row weeding is a system of operation to reduce the consumption of herbicides and the time of operation than the manual method. Powered rotary weeding is one of the efficient methods in all growth stages of the weeds. Different types of blades geometries are used in different conditions. The energy characteristics of the blade geometries depend on the forward speed of operation and rotary speed of the blade. Of the blades tested straight blade was the most effective. Straight blade required about 15 to 20% less torque than the C shaped blade at higher rotary speed. Power requirement of the straight geometry was 0.331 kW and 0.39 kW for C shape at 200 rpm at 1 km h^{-1}. Specific energy requirement was directly proportional with the rotary speed and inversely proportional with the forward speed. Straight blade has 25 to 30% lesser specific energy requirement than the C shaped blade.

Key words- Rotary blade, Torque, Power, Specific tilling energy, Soil bin

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Introduction

Weeds in between the crop rows can be controlled by inter row weeding. The less spacing between the crop rows are the main constrain to operate the machines in the inter row weeding. At present there are numerous inter row power weeders are available but the problem comes with the width of the machine. Most of the existing machines are wider than the recommended spacing of the crops. [8], found that mechanical treatments achieved equal or better weed control than the herbicide treatment. The powered rotary weeder performed 99 % weed killing in heavy weed infested areas at higher forward speed and the performance declined to 79% with increase in forward speed.

The soil fragmentation by the tool is inversely proportional to the soil slice length. As the increase in rotary speed of the blade and decrease in forward speed of the implement, the slice length decreased [5]. The blade geometry, forward speed of operation and rotary speed are the parameters affect the soil cutting, thawing, final tilled soil condition and the energy requirement of the rotary blades [6,7]. For optimizing the blade for the development of the narrow spaced row crop weeder testing of different blade geometries to study their soil throwing and soil breaking efficiencies is necessary. in addition to this, experiments were conducted by comparing the torque, power and specific energy calculation of the two type of blades at different forward and rotary speeds.

Materials and Methods

The experiments were conducted in an indoor laboratory rectangular soil bin of 42 m length, 2.2 m width and 0.75 m depth of clay soil [Fig-1]. The moisture content of the soil was 12% to 13 %, and cone index of 575 kPa to 590 kPa. The tilled soil was compacted with a tractor operated roller to maintain the compaction. The soil samples were randomly collected from the test bed with a core cutter to obtain the soil moisture content and bulk density. The moisture content was determined by oven drying the soil at 105 ° C for 24 h. The uniformity of soil compaction of the teat soil bed was checked in five places by a type B cone penetrometer with a cone base area of 129 mm², cone base diameter of 12.83 mm and apex angle of 30° was pushed in to the soil layer by hand [10]

Fig-1 Indoor rectangular soil bin 1. Loading car, 2. Clay soil, 3. Sandy soil

A frame was fabricated to carry the rotary blade assembly, rotor shaft, inline torque transducer and hydraulic motor. A square flange of 3 mm thickness was fabricated to fix four blades and fitted to the shaft of 25 mm diameter and 1000 mm length through a sunk key. The shaft was connected with the rotor frame with pillow block bearings. The rotor drive frame set up was fastened with the main frame with bolts and nuts [Fig-2].

For the study, four blades were fitted in a square flange at an angular spacing of about 90°, in an experimental setup suggested in the previous studies [6]. The diameter of the flange with blades was rotor of 250 mm was rotated in forward direction to attain the maximum soil breaking and torque requirement as outlined in the previous studies [6, 7]. Three forward speeds of 1.0, 1.5 and 2.0 km h^{-1} and three rotor speeds of 200, 250 and 300 rpm were selected for this study. The depth of operation was selected as 50 mm to cut the germinated weeds and width of operation was 100 mm. The effect of two blade geometries, rotary speed and forward speed of operation on torque, power and specific energy were analysed using Factorial Completely Randomized Factorial Design (FCRD) with three replications. The statistical software AGRES was used to analyze the data.

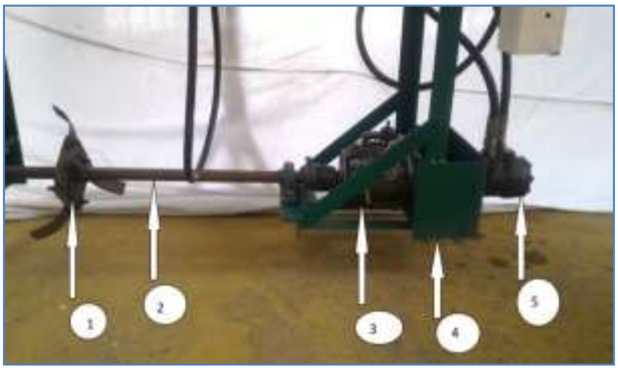


Fig-2 Experimental setup: 1. Rotary blade assembly, 2. Blade attaching shaft, 3. In line torque transducer, 4. Rotor assembly frame, 5. Hydraulic motor

Torque measurement

An inline transmission type torque transducer of 50 N m capacity of UNIQUE make was used to measure the torque requirement of the blades. It was placed in between the rotor shaft and the hydraulic motor. One end of the transducer was attached with the rotor shaft with a flexible coupling and the other end was connected with the hydraulic motor with a flexible double crowned gear coupling [Fig-3]. A computer based data acquisition system recorded the voltage output from the transducer. Before conducting the experiments, an experimental setup made was used to calibrate the torque transducer. A lever arm of one metre length was connected with one side of the transducer shaft and another end was arrested. A hole was drilled at another end of the lever arm to fix a weighing pot. A known weight of 5 to 50 kg at an increment of 5 kg was added. The known value and the indicated values were noted to draw the calibration chart.

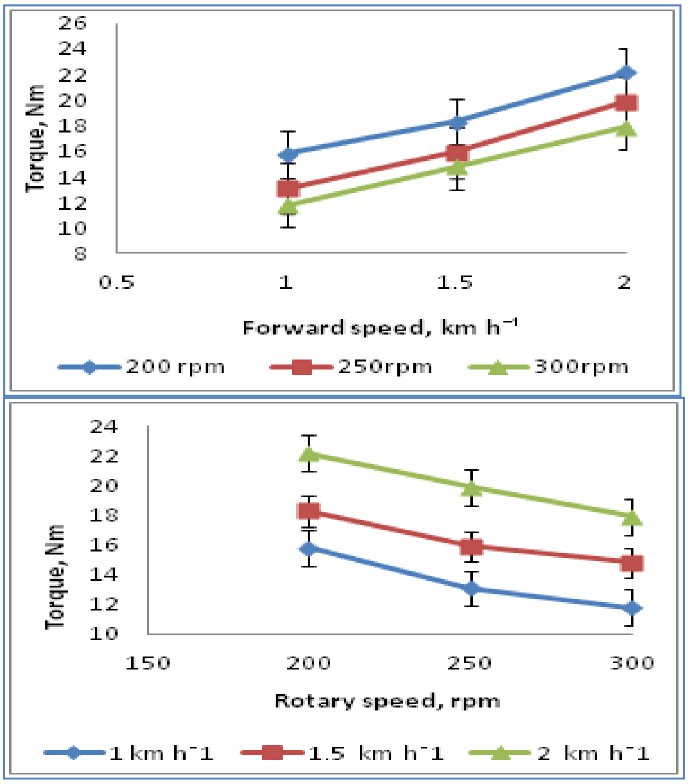


Fig-3 Effect of forward speed and rotary speed on torque for straight blade

Power

The power requirement corresponding to the torque was calculated using the [Eq-1]

$$P = \frac{2\Pi \, x \, N \, x \, T}{60000} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Where:
P: peak power requirement, kW
T: peak torque, N m
N: rotary speed, rpm

Specific tilling energy

It is the energy requirement of the tilling tool to loosen a volume of soil. The specific energy was proposed by [7] was calculated using the [Eq-2]

$$SE = \frac{P}{v} x \frac{1}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Where:
SE: specific energy requirement, kj m^{-3}
P: peak power, kW
v : forward speed of rotor, m s^{-1}
V: volume of soil loosened per meter length of furrow, $m^3 m^{-1}$

Results and discussion

Torque

The analysis of variance for torque requirement was performed to get the significance of the variables *viz*., forward speed of operation and rotary speed of the blade assembly is furnished in [Table-1]. The analysis of variance showed that there was significant different among the two factor interaction except the interaction between blade and forward speed. The individual effect of the variables *viz*., forward speed (F) and rotary speed (N) were highly significant at 1 Per cent level of probability. The three factor interaction between the blade, forward speed and rotary speed was not significant. The forward speed of operation and rotary speed of the blade has a significant effect on torque requirement [Fig-4]. The torque requirement has increased with an increase in forward speed from 1to 2 km h^{-1}correspondingly. For the straight blade, minimum torque of 11.8 N m was obtained when the blade operated at a forward speed of 1km $h^{-1}$and rotary speed of 300 rpm. For all the forward speed levels the minimum torque was reported for a rotary speed of 300 rpm. This may be due to the larger bite length at lower rotary speeds; the maximum torque was required to cut the soil, where as in higher rotary speeds lower torque is required to cut the soil.

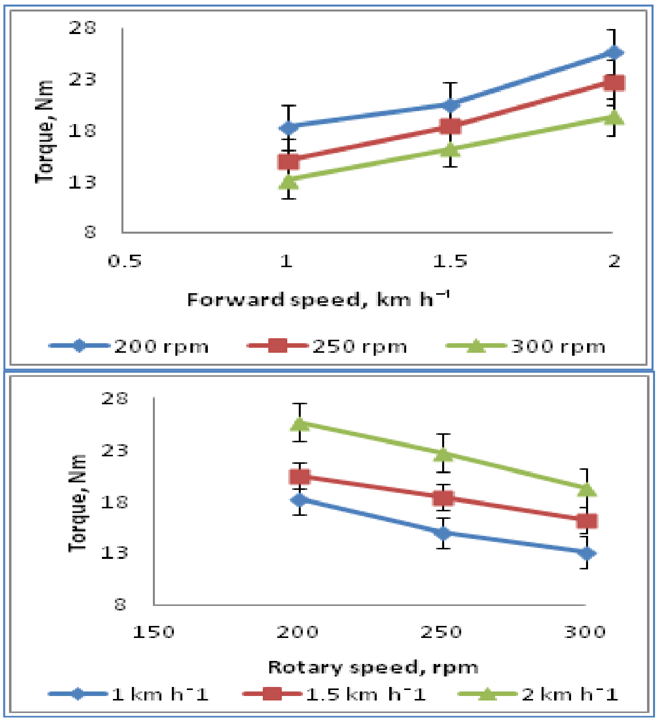


Fig-4 Effect of forward speed and rotary speed on torque for C shaped blade

The blade geometry, forward speed of operation and rotary speed of the blade have significant effect (p<0.01) on torque requirement. This result was supported by the findings of [9]. The C shaped blade attained minimum torque of 13.1 N m when the blade operated at a forward speed of 1 km $h^{-1}$and rotary speed of 300 rpm. The maximum torque 25.65 N m was reported by the C shaped blade. The torque requirement of the blades found to depend on their tilling width and maximum radius of rotation confirming to the results reported by [6]. Straight blade required about 15 to 20% less torque than the C shaped blade at 300 rpm at 1 km h^{-1}.

Table-1 *ANOVA for torque*

Sl. No.	Source	df	SS	MS	F	SEd	CD
1	Blade (B)	1	62.79	62.79	228.59 **	0.142	0.387
2	Forward speed (F)	2	415.19	207.59	755.76**	0.174	0.475
3	Rotor speed (N)	2	191.69	95.84	348.94**	0.174	0.475
4	B x F	2	1.08	0.54	1.97 NS	0.247	0.671
5	F x N	4	4.15	1.03	3.78 **	0.302	0.822
6	B x N	2	4.40	2.20	8.00 **	0.247	0.671
7	B x F x N	4	0.86	0.21	0.79 NS	0.427	1.163
8	Treatment	17	680.18	40.01	145.66 **		
9	Error	36	9.88	0.27	1.00		
10	Total	53	690.07	13.02	47.40		

cv = 2.96 %, ** = significance at 1 % level, NS = non significant

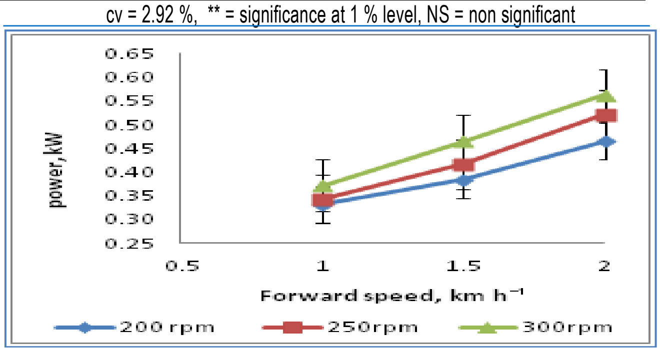
Power

The analysis of variance showed that there was significant different among the two factor interaction between forward speed and rotary speed [Table-2]. The individual effect of the variables *viz.*, forward speed (F) and rotary speed (N) were highly significant at 1 Per cent level of probability. The interaction between blade and forward speed, blade and rotary speed was not significant. The three factor interaction between the blade, forward speed and rotary speed was not significant. There was a significant effect of blade geometry, forward speed and blade rotary speed on power requirement. The power requirement has increase with increase in forward speed from 1to 2 km h^{-1} [Fig-5]. The minimum power requirement of 0.331 kW was obtained when the blade operated at a forward speed of 1 km h^{-1} and rotary speed of 200 rpm. This may be due to the lesser soil throwing by the straight blade compared with the C shaped blade as observed by [2,3]. The power requirement has increased with the increase in rotary speed for all levels of forward sped.

Table-2 ANOVA for power

Sl. No.	Source	df	SS	MS	F	SEd	CD
1	Blade (B)	1	0.037	0.037	213.01 **	0.003	0.009
2	Forward speed (F)	2	0.281	0.140	790.34 **	0.004	0.012
3	Rotor speed (N)	2	0.040	0.020	114.96 **	0.004	0.012
4	B x F	2	0.0004	0.002	1.385 NS	0.006	0.017
5	F x N	4	0.005	0.001	7.79 **	0.007	0.020
6	B x N	2	0.001	0.0005	2.94 NS	0.006	0.017
7	B x F x N	4	0.0004	0.0001	0.61 NS	0.010	0.029
8	Treatment	17	0.367	0.021	121.52 **		
9	Error	36	0.006	0.0001	1.00		
10	Total	53	0.373	0.007	39.65		

cv = 2.92 %, ** = significance at 1 % level, NS = non significant



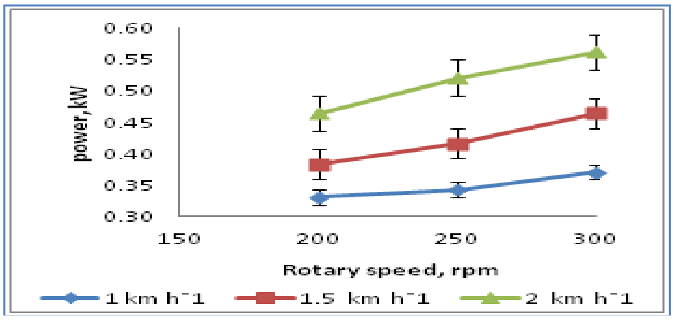
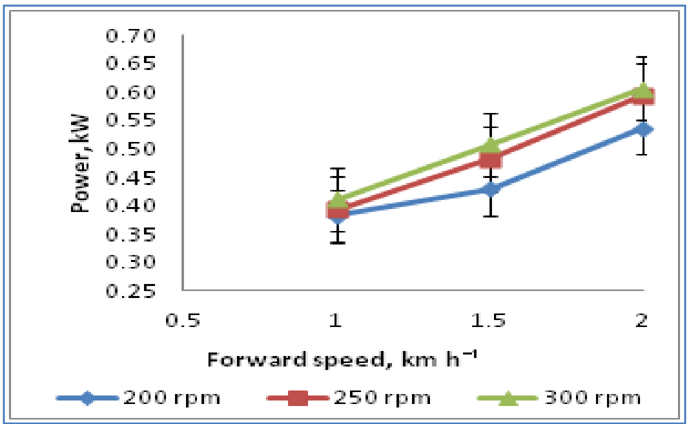


Fig-5 Effect of forward speed and rotary speed on power for straight blade

The minimum power requirement of C shaped blade was 0.382 kW at a forward speed of 1 km h^{-1} and rotary speed of 200 rpm [Fig-6]. Both blade geometries showed an increase in power requirement with increase in rotary speed and forward speed of operation. The straight blade showed a 15 -20% lesser power requirement than C shaped blade due to lesser torque requirement than the C shaped blade.



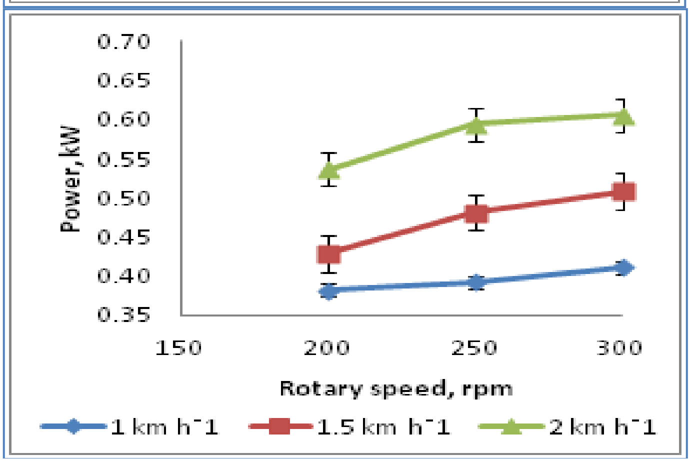


Fig-6 Effect of forward speed and rotary speed on power for C shaped blade

Specific tilling energy

The analysis of variance for specific energy was carried out to get the significance of the variables *viz.*, forward speed of operation and rotary speed of the blade assembly is tabulated in [Table-3]. The analysis of variance showed that the two-factor interaction except the interaction between blade and forward speed was significant at 5 per cent level of probability. Inter action between the blade, rotary speed and forward speed, rotary speed was not significant. The individual effect of the variables *viz.*, forward speed (F) and rotary speed (N) were highly significant at 1 Per cent level of probability. The three-factor interaction between the blade, forward speed and rotary speed was not significant. It was observed that a decrease in specific energy with the increase in forward speed from 1to 2 km h^{-1} and an increase in specific energy with the increase in rotary speed from 200 to 300 rpm which confirms the results in the previous investigations carried out by

[1,4]. The minimum specific energy for the straight blade of 163.58 kJ m^{-3} was obtained when the blade operated at a forward speed of 2 km h^{-1} and rotary speed of 200 rpm. The minimum specific energy was attained for a rotary speed of 200 rpm for the forward speeds of 1 and 1.5km h^{-1} was 236.25 kJ m^{-3} and 176.58 kJ m^{-3} respectively [Fig-7].

Table-3 *ANOVA for specific energy*

Sl. No.	Source	df	SS	MS	F	SEd	CD
1	Blade (B)	1	29876.04	29876.04	714.12 **	1.76	4.78
2	Forward speed (F)	2	52312.55	26156.27	625.21 **	2.15	5.86
3	Rotor speed (N)	2	8733.84	4366.92	104.38 **	2.15	5.86
4	B x F	2	346.63	173.31	4.14 *	3.04	6.18
5	F x N	4	290.02	72.50	1.73 NS	3.73	10.15
6	B x N	2	201.33	100.66	2.40 NS	3.04	8.29
7	B x F x N	4	138.42	34.60	0.82 NS	5.28	14.36
8	Treatment	17	91898.85	5405.81	129.21 **		
9	Error	36	1506.08	41.83	1.00		
10	Total	53	93404.94	1762.35	42.12		

cv = 2.79 %, ** = significance at 1 % level, * = significance at 5 % level NS = non significant

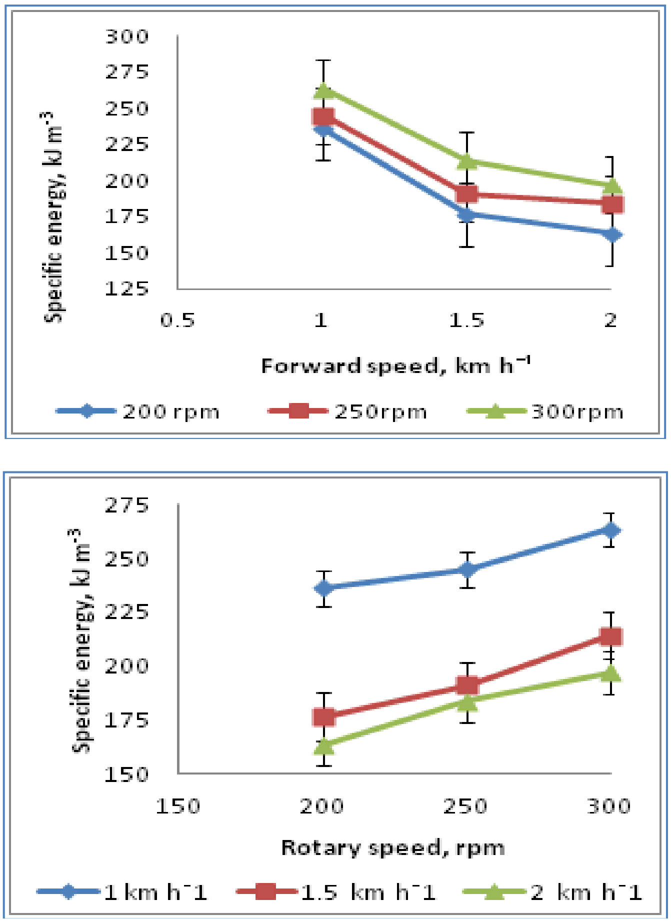


Fig-7 Effect of forward speed and rotary speed on specific energy for straight blade

The minimum specific energy of 207.42 kJ m^{-3} was obtained when the blade operated at a forward speed of 2 km h^{-1} and rotary speed of 200 rpm [Fig-8]. The minimum specific energy was attained for a rotary speed of 200 rpm for the forward speeds of 1 and 1.5km h^{-1} was 288.73 kJ m^{-3} and 213.26 kJ m^{-3} respectively. The straight blade reported the minimum specific energy requirement than the C shaped blade. This is because of the minimum torque and power requirement than the C shaped blade. Straight blade has 25 to 30% lesser specific energy requirement than the C shaped blade.

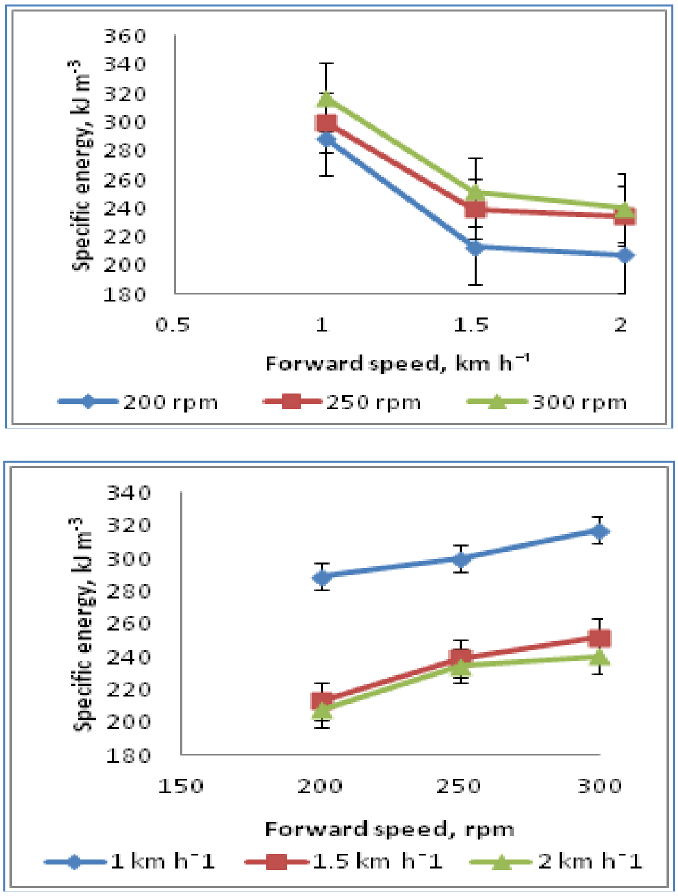


Fig-8 Effect of forward speed and rotary speed on specific energy for C shaped blade

Conclusion

A single row four blade weeding unit with straight and C shaped blades were tested in clay soil under laboratory conditions to study the energy requirement of the blades during the operation. It was observed that both the blade geometry has an increasing trend in torque requirement with increase in forward speed and a decrease with increase in rotary speed. Rotary speed of 200 rpm at a forward speed of 2 km h^{-1} reported the maximum torque requirement for both blade geometries. Amongst the blade geometries tested straight blade required the minimum power and specific energy requirement. Power requirement has increased with increase in both forward and rotary speeds. Specific energy requirement has increased with rotary speed and decreased with increase in forward speed. Based on the laboratory study results, the straight blade geometry shows the lesser torque, power and specific energy requirements.

Application of research: Inter crop cultivation/ row crop weeding

Research category: Farm Machinery/Agricultural Engineering

Abbreviation: %- percent, kW-kilo watt, k Pa-kilo Pascal, km h^{-1}-kilometer per hour, m-meter, °C-degree centigrade, h-hour, mm^2-millimeter square, mm-millimetre, N m-Newton meter, kg-kilogram, rpm-revolutions per minute, kj m^{-3} kilo joule per meter cube, m s^{-1}- meter per second, m^3 m^{-1}-meter cube per meter, p-probability,

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