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Performance evaluation of swiveling head type power brush cutter

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Abstract
Grass cutting is a tedious operation in agriculture field. In India, agriculture has facing serious challenges of scarcity of agricultural labour not only peak in seasons and almost throughout the year. It is very time consuming and stressful operation. A swiveling head type power brush cutter was developed at ASPEE Agril. Research and Development Foundation, Mumbai. Three different forward speed (0.8-1.2, 1.3-1.7 and 1.8-2.2 km/h) and three different swiveling shaft speed (15, 20 and 25 rpm) with three different nylon wire length (10, 15, 20 cm) were used for the test performance. The maximum field capacity was found 0.123 ha/h. The total energy consumption was found 21.31 % less as compared to the existing brush cutter.

Keywords: Alfalfa grass, grass cutting, ergonomics, brush cutter

Introduction
In India, grass is cut either by manual method (conventional method) or by different machines. In the past and even until now, cutting of grasses on field surfaces, forest, sports tracks, industries, hotels, public centre, etc. are cut with a cutlass. Manual cutting is time consuming and stressful operation. In addition, inaccuracy in cutting level was also observed in manual cutting method (Khodke, 2018) [1].

In India, still most of the agricultural machines/tools/equipments are designed and developed by trial and error methods. Not much of attention has so far been paid to the ergonomic aspects. But it is now an accepted fact that for deriving the maximum efficiency from a machine, the ranges and limitations of the operator who works with it should also be given due consideration. In the case of a knapsack type harvesting machine the operator has to carry a load on his shoulder and work. The hostile environment he is exposed to include temperature, humidity, biological dust, acceleration, vibration, noise and noxious gases. All these factors affect operator's performance.

The main aim is to improve the design of the existing power operated brush cutter with a view to reduce working stress and increase working capacity considering ergonomic factors. The final model of the machine was tested ergonomically and economically.

Magar *et al*. (2010) [2] conducted the performance evaluation of grass cutter. The newly developed grass cutter was able to operate at an average speed of 2 km/h without disturbance in operation. The effective field capacity of the machine was 0.07 ha/hr with an efficiency of 70%. One hp single phase electric motor was sufficient to operate at working width of 500 mm cutter bar.

Reddy *et al.* (2010) [3] performed an experiment of grass trimming device having a petrol engine. They suggested that the hand vibration during the operation were significantly influenced by the length of nylon thread. optimum value for operating a grass trimming device was found length of nylon thread 20 cm and engine speed 3300 rpm.

Verma *et al.* (2013) [5] studied the ergonomics of women operators involved in weeding by evaluating the performance of improved weeder that is single wheel hoe in reducing drudgery among women engaged in weeding activity. The results showed that the total cardiac cost of work was 285.0 beats, the physiological cost of work was 6.33 beats/min, the average working heart rate during weeding was 112.5 beats/min and the average energy expenditure was 9.16 KJ/min during the weeding activity performed by improved tool to the single wheel hoe. Weeding activity was performed for maximum number of days in a year from morning till evening in squatting position majority of women perceived it as moderately heavy activity.

Materials and Methods
A swiveling head type power brush cutter was developed to cut grass in the field surface of orchard, forest and from other field. The machine was consisted of main frame, 2-stroke-petrol engine, DC motor, 3-wheels for easy movement, battery, cutting unit, throttle trigger and debris shield.
For working of brush-cutter 2 stroke petrol engine was used to transmit power to cutting unit through drive shaft assembly which contains a specially designed inner solid drive shaft. A DC motor was used to transmit power to the drive shaft through eccentric arm and connecting arm to convert the reciprocating action to swiveling action of cutting shaft.

Power unit
Engine power - A 2 hp, 2 stroke petrol engine was used to supply power to cutting blade.

Battery power - A 12 V, 7 Ah rechargeable battery was used as power source to swivel a cutting shaft

Power transmission unit
DC motor - A 12 V, 15 W DC motor was used to transfer power to swiveling shaft.

Speed controller - Speed Controller was used to control the speed of DC motor in the range of 0 to 30 rpm.

Cutting unit: A cutting unit was used to cut the grass. It consisted of mainly a nylon string, nylon cutter head and throttle trigger.

Machine transporting unit:
Transport wheels: Two rubber wheels of 450 mm diameter size were used for easy transportation of machine on the field with minimum push force.

Supporting wheel: To facilitate the easy movement and weight supporting of the machine, one solid polyurethane plastic wheels was also provided, having 150 mm diameter and 5 cm thickness.

Machine Testing
The developed power brush cutter was tested in field. During testing cutting height, speed of operation, theoretical field capacity, effective field capacity, field efficiency and cutting efficiency was measured/calculated.

Ergonomic evaluation
Heart rate: The heart rate is the speed of the heart beat measured by the number of contractions of the heart per minute.

Oxygen consumption rate
The oxygen consumption rate is defined as the amount of oxygen consumed by the tissues of the body, usually measured as the oxygen uptake in the lung. It increases with increased in metabolic rate. It is measured in l/min or ml/min or ml/kg/min.

$$Y = 0.0114 X - 0.68$$

Where,
Y = oxygen consumption, l/min
X = heart rate.

Energy expenditure rate
Energy expenditure was computed by using calorific value of 20.93 KJ/l of oxygen by multiplying oxygen consumption rate during the experiment (Singh, 2012) [4].

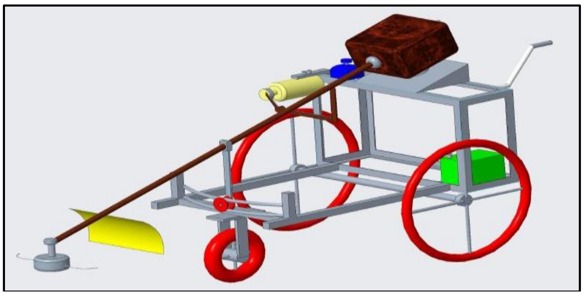

Fig 1: Conceptual Design of Power Brush Cutter

Fig 2: Developed brush cutter

Results and Discussion
The result of performance evaluation of swiveling head type power brush cutter was obtained during the field test. The results obtained have been analysed and discussed under the following headings.
Field efficiency
Cutting efficiency
Heart rate
Energy expenditure rate
Analysis of experimental data:
The observation on different parameters were collected and analysed using ANOVA

Field efficiency
The effect of forward speed was highly significant on field efficiency, where as it has non-significant effect of swiveling shaft speed and nylon wire length on field efficiency. . Interaction among forward speed, swiveling shaft speed and nylon wire length was also found non-significant on field efficiency.

Effect of forward speed on field efficiency
Comparisons of mean values of field efficiency of all three forward speeds were statistically analysed, compared and shown in Table 1 from the table it was clear that the effect of forward speed was highly significant on field efficiency and 0.8-1.2 km/h speed shows the highest field efficiency. It may be due to if forward speed increases productive time of operation decreases and non-productive time remains same due to which field efficiency was decreased.

Table 1: Mean values of field efficiency at different forward speed

Forward speed, km/h	0.8-1.2	1.3-1.7	1.8-2.2
Field efficiency, %	90.26	84.21	78.70

SEM 0.47 $CD_{0.05}$ 1.38

Effect of swiveling shaft speed on field efficiency

The mean values of field efficiency at all the three levels of swiveling shaft speed were compared and given in Table 2. It is clear that the effect of swiveling shaft speed was non significant on field. It also shows that on 15 rpm of swiveling shaft speed, field efficiency was maximum.

Table 2: Mean values of field efficiency at different swiveling shaft speed

Swiveling shaft speed, rpm	15 rpm	20 rpm	25 rpm
Field efficiency, %	85.01	84.44	83.72

SEM 0.47 $CD_{0.05}$ NS

Effect of nylon wire length on field efficiency

The mean values of field efficiency at all the three levels of nylon wire length were compared and given in Table 3. It shows that mean values of field efficiency for all three nylon wire length were non-significant effect. It also shows there is a minor difference in field efficiency at different nylon wire length. It also shows that on 10 cm of nylon wire length, field efficiency was maximum.

Table 3: Mean values of field efficiency at different nylon wire length

Nylon wire length, cm	10 cm	15 cm	20 cm
Field efficiency, %	84.79	84.33	84.01

SEM 0.47 $CD_{0.05}$ NS

Combined effect of forward speed, swiveling shaft speed and nylon wire length on field efficiency.

Combined effect of forward speed, swiveling shaft speed and nylon wire length on field efficiency was found non-significant. It has been presented in Fig. 3. The highest field efficiency was found 91.41 % at 0.8-1.2 km/h speed, 15 rpm swiveling shaft speed and 10 cm nylon wire length.

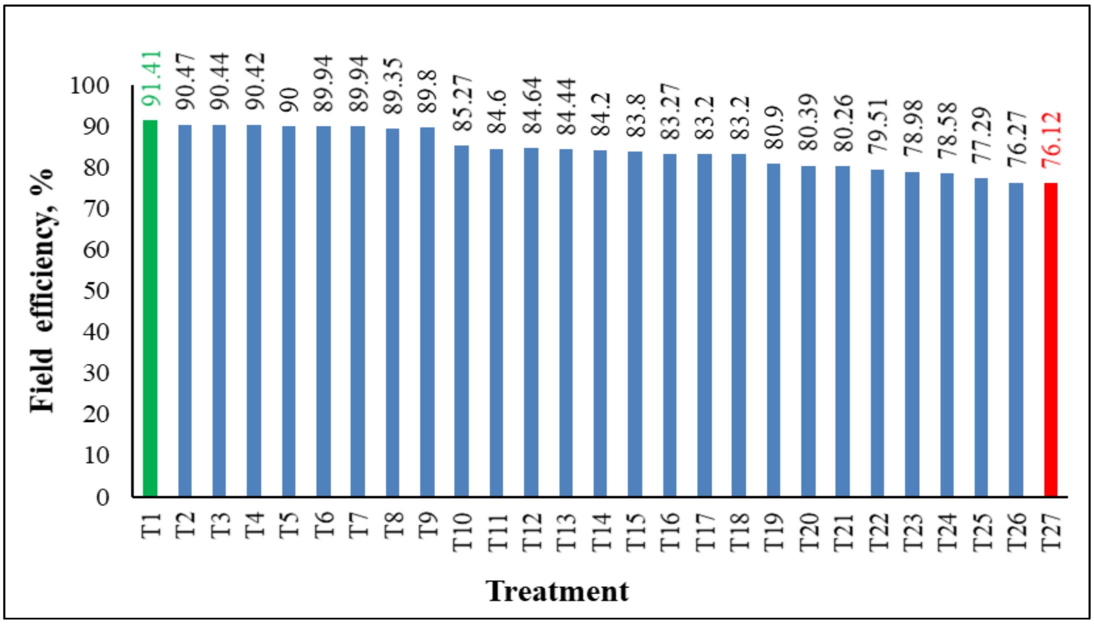

Fig 3: Combined effect of forward speed, swiveling head speed and nylon wire length on field efficiency

Cutting efficiency

The effect of forward speed and swiveling shaft speed on cutting efficiency were highly significant but nylon wire length shows non-significant effect on cutting efficiency. Interaction among forward speed, swiveling shaft speed and nylon wire length was also found non-significant.

Effect of forward speed on cutting efficiency

The mean values of cutting efficiency at all three forward speeds were statistically analysed, compared and given in Table 4. From the table it is clear that the effect of forward speed on cutting efficiency was highly significant, 0.8-1.2 km/h speed shows the maximum cutting efficiency, and 1.8-2.2 km/h speed shows the minimum cutting efficiency.

Table 4: Mean values of cutting efficiency at different forward speed

Forward speed, km/h	0.8-1.2	1.3-1.7	1.8-2.2
Cutting efficiency, %	92.47	89.74	87.29

SEM 0.43 $CD_{0.05}$ 1.25

Effect of swiveling shaft speed on cutting efficiency

The mean values of cutting efficiency at all three swiveling shaft speed are given in Table 5. It shows that the swiveling shaft speed had significant effect on cutting efficiency. It may be due as increasing swiveling shaft speed resulted increase in shearing force as well as swiveling shaft covers that area in minimum time due to that cutting efficiency was increased. It also shows that on 25 rpm of swiveling shaft speed, cutting efficiency was highest.

Table 5: Mean values of cutting efficiency at different swiveling shaft speed.

Swiveling shaft speed, rpm	15 rpm	20 rpm	25 rpm
Cutting efficiency, %	87.93	89.86	91.71

SEM 0.43 $CD_{0.05}$ 1.25

Effect of nylon wire length on cutting efficiency

The mean values of cutting efficiency at all three nylon wire length are given in Table 6. It shows that nylon wire length had non-significant effect on cutting efficiency. It shows that at 10 cm of nylon wire length, cutting efficiency was highest.

Table 6: Mean values of cutting efficiency at different nylon wire length.

Nylon wire length, cm	10 cm	15 cm	20 cm
Cutting efficiency, %	89.88	89.84	89.79

SEM 0.43 $CD_{0.05}$ NS

Combined effect of forward speed, swiveling shaft speed and nylon wire length on cutting efficiency.

Interaction effect of forward speed, swiveling shaft speed and nylon wire length on cutting efficiency was found non-significant. It has been presented in Fig. 4. The maximum cutting efficiency was observed with forward speed of 0.8-1.2 km/hr, swiveling shaft speed of 25 rpm and nylon wire length of 20 cm.

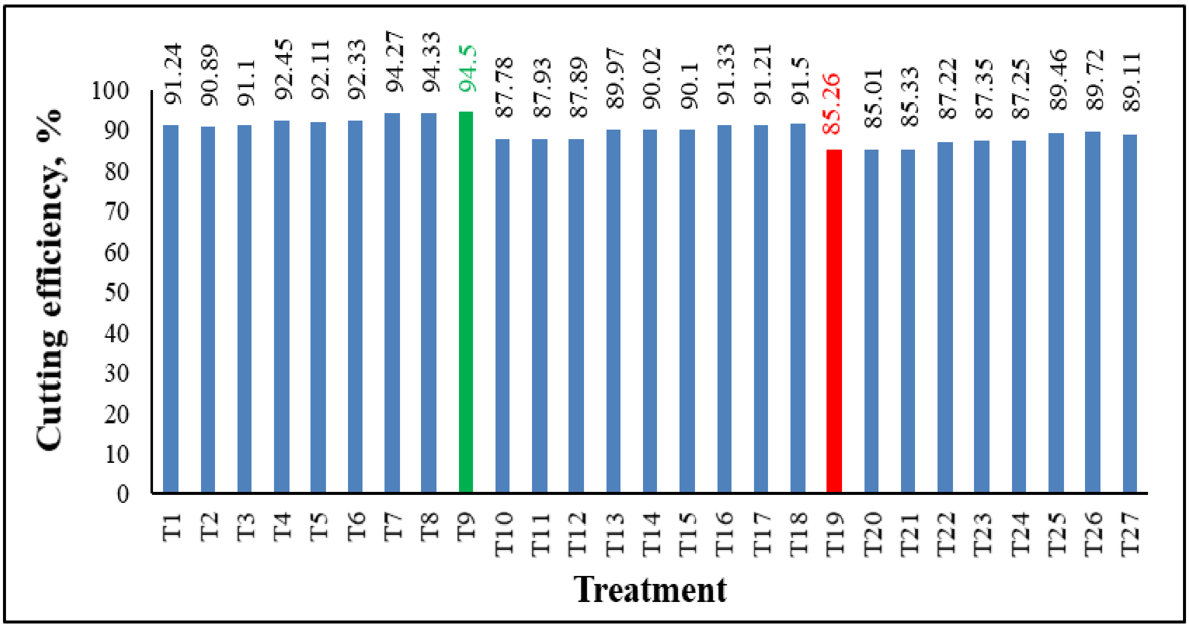

Fig 4: Combined effect of forward speed, swiveling head speed and nylon wire length on cutting efficiency.

Heart rate

The effect of forward speed was highly significant on heart rate. Where, as the swiveling shaft speed shows significant effect on heart rate and nylon wire length shows non-significant effect. Interaction among forward speed, swiveling shaft speed and nylon wire length was also found non-significant.

Effect of forward speed on heart rate

The mean values of heart rate of all three forward speeds are statistically analysed, compared and given in Table 7. from the table it is clear that the forward speed had highly significant effect on heart rate and 0.8-1.2 km/h speed shows the minimum heart rate. It may be due to as increase in forward speed, heart beats are increased due to which heart rates was increased.

Table 7: Mean values of heart rate at different forward speed

Forward speed, km/h	0.8-1.2	1.3-1.7	1.8-2.2
Heart rate, beats/min	86.61	96.83	102.94

SEM 0.36 $CD_{0.05}$ 1.04

Effect of swiveling shaft speed on heart rate

The mean values of heart rate of three swiveling shaft speed are compared and given in Table 8. It shows that heart rate for all three swiveling shaft speed shows significant effect. It also shows that on 25 rpm of cutter bar speed, heart rate was maximum.

Table 8: Mean values of heart rate at different swiveling shaft speed

Swiveling shaft speed, rpm	15	20	25
Heart rate, beats/min	94.94	95.44	96.22

SEM 0.36 $CD_{0.05}$ 1.049

Effect of nylon wire length on heart rate

The mean values of heart rate of three nylon wire length are compared and given in Table 9. It shows that heart rate for all nylon wire length shows non-significant effect on heart rate. It also shows that there is a minor difference of heart rate at all three nylon wire length.

Table 9: Mean values of heart rate at nylon wire length

Nylon wire length, cm	10	15	20
Heart rate, beats/min	95.11	95.50	95.77

SEM 0.36 $CD_{0.05}$ NS

Combined effect of forward speed, swiveling shaft speed and nylon wire length on heart rate.

Interaction effect of forward speed, swiveling shaft speed and nylon wire length on heart rate was found non-significant. It has been presented in Fig. 5. Maximum heart rate was found in 1.8-2.2 km/h forward speed, 25 rpm swiveling shaft speed and 20 cm nylon wire length. Minimum heart was found in 0.8-1.2 km/h forward speed, 20 rpm swiveling shaft speed and 15 cm nylon wire length.

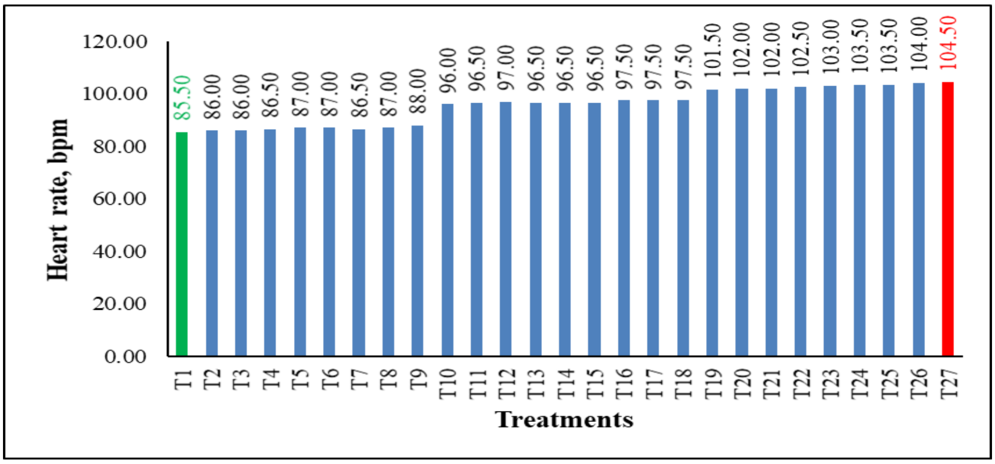

Fig 5: Combined effect of forward speed, swiveling shaft speed and nylon wire length on heart rate.

Energy expenditure rate

The effect of forward speed was highly significant on oxygen consumption rate and swiveling shaft speed shows significant effect on oxygen consumption rate but nylon wire length shows non-significant effect. Interaction among forward speed, swiveling shaft speed and nylon wire length was also found non-significant.

Effect of forward speed on energy expenditure rate

The mean values energy expenditure rate of all three forward speeds are statistically analysed and shown in Table 10. It is clear from the mean value table that the forward speed had highly significant effect on energy expenditure rate; it has also shown the increasing trend with increase with forward speed. This seems to be due to higher energy requirement in moving the machine at higher forward speed.

Table 10: Mean values of energy expenditure rate at different forward speed

Forward speed, km/h	0.8-1.2	1.3-1.7	1.8-2.2
Energy expenditure rate, kJ	6.44	8.88	10.33

SEM 0.068 $CD_{0.05}$ 0.19

Effect of swiveling shaft speed on energy expenditure rate.

The mean values of energy expenditure rate of three different level of swiveling shaft speed are compared and given in Table 11. Swiveling shaft speed has shown significant effect on energy expenditure rate.

Table 11: Mean values of energy expenditure rate at different swiveling shaft speed

Swiveling shaft speed, rpm	15	20	25
Energy expenditure rate, kJ	8.37	8.54	8.72

SEM 0.0668 $CD_{0.05}$ NS

Effect of nylon wire length on energy expenditure rate.

The mean values of energy expenditure rate of three different level of nylon wire length are compared and given in Table 12. Nylon wire length has shown non-significant effect on energy expenditure rate even then maximum energy expenditure rate was observed at higher length of nylon wire.

Table 12: Mean values of energy expenditure rate at different nylon wire length.

Nylon wire length, cm	10	15	20
Energy expenditure rate, kJ	8.46	8.55	8.62

SEM 0.0668 $CD_{0.05}$ NS

Combined effect of forward speed, swiveling shaft speed and nylon wire length on energy expenditure rate.

The interaction of forward speed, swiveling shaft speed and nylon wire length shows non-significant effect on energy expenditure rate. Maximum energy expenditure rate was found at 1.8-2.2 km/h forward speed, 25 rpm swiveling shaft speed and 20 cm nylon wire length. Minimum energy expenditure rate was found at 0.8-1.2 km/h forward speed, 15 rpm swiveling shaft speed and 10 cm nylon wire length. Energy expenditure rate at different forward speed, swiveling shaft speed and nylon wire length are plotted in Fig 6.

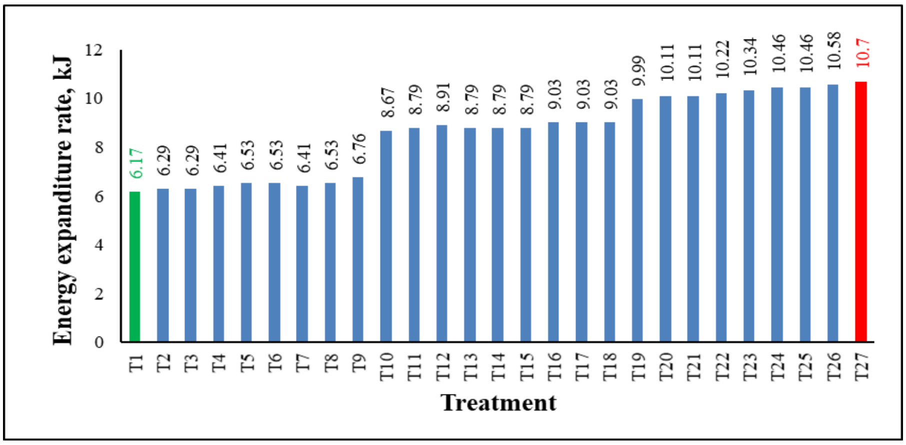

Fig 6: Combined effect of forward speed, swiveling shaft speed and nylon wire length on Energy expenditure rate.

Economical Comparison of developed and existing brush cutter

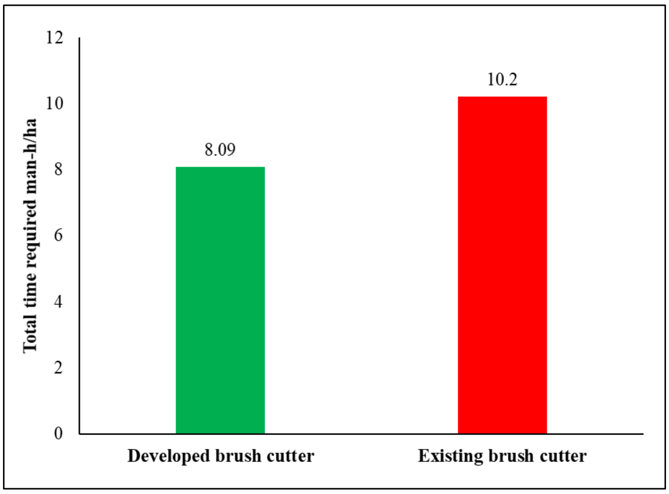

Fig 7: Comparison of Total Time required (man-h/ha) in grass cutting using developed and existing brush cutter.

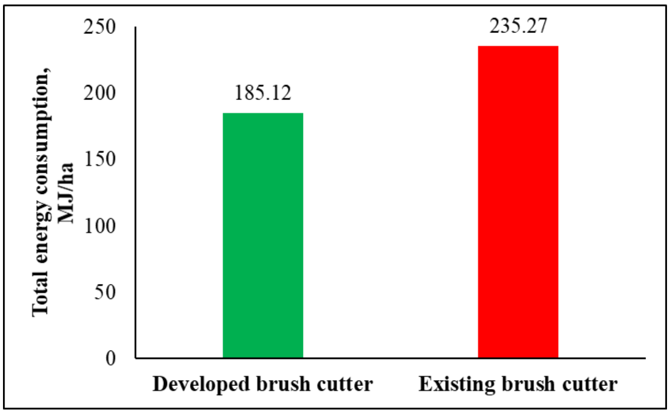

Fig 8: Comparison of Total energy consumption (MJ/ha) in grass cutting using developed and existing brush cutter.

Conclusion

The following conclusions may be drawn from the undertaken study:

1. Field efficiency was increased with decreased in forward speed. The maximum field efficiency was found 91.47 % at 0.8-1.2 km/h forward speed at 15 rpm swiveling shaft speed with 10 cm nylon wire length.
2. Cutting efficiency was increased with decreased in forward speed and increased in swiveling shaft speed. Cutting efficiency also increased with increase in nylon wire length. The maximum cutting efficiency was found 94.81 % at 0.8-1.2 km/h, 25 rpm swiveling shaft speed with 20 cm nylon wire length.
3. Heart rate, Oxygen consumption rate and energy expenditure rate were increased with increase in forward speed and swiveling shaft speed. Minimum heart rate, oxygen consumption rate and energy expenditure rate were found at 0.8-1.2 km/h forward speed, 15 rpm swiveling shaft speed and with 10 cm nylon wire length.
4. The field capacity of existing brush cutter was 0.098 ha/h, but in case of developed brush cutter it was 0.123 ha/h. The time required to harvest one hectare by developed brush cutter was decreased by 20.68 % as compared to existing brush cutter.
5. The energy consumption of developed brush cutter was observed 185.13 MJ/ha while by existing brush cutter operation it was 235.27 MJ/ha. The total energy consumption was decreased by 21.31 % as compared to existing brush cutter.

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