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Mukesh M Soyam
M.Tech Student (Farm Power and Machinery) Dr. PDKV, Akola, Maharashtra, India

MM Deshmukh
Associate Professor, Department of Farm Power and Machinery, Dr. PDKV Akola, Maharashtra, India

Amol S Ghadge
Ph.D. Student Department of Farm Machinery and Power, DBSKKV, Dapoli Department of Farm Power and Machinery, Dr. PDKV Akola, Maharashtra, India

SH Thakare
Professor and Head of the Department of Farm Power and Machinery, Dr. PDKV Akola, Maharashtra, India

SK Thakare
Associate Professor Department of Farm Power and Machinery, Dr. PDKV Akola, Maharashtra, India

SS Karhale
Program Coordinator, Krishi Vigyan Kendra, Gadchiroli, Maharashtra, India

Corresponding Author
Mukesh M Soyam
M.Tech Student (Farm Power and Machinery) Dr. PDKV, Akola, Maharashtra, India

Performance evaluation of bund cutter for paddy cultivation

Mukesh M Soyam, MM Deshmukh, Amol S Ghadge, SH Thakare, SK Thakare and SS Karhale

Abstract
India is one of the world's largest producers of rice, accounting for 20% of the world rice production. The paddy cultivation system in India almost fully mechanized at different level except bund reconditioning. In this study the machine parameters evaluated were the effective depth, width of operating area of cut, wheel slip, fuel consumption, energy requirement and bund cutting efficiency at different speed of tractor i.e. 1.5, 2.5 and 3.4 km/h were used to determine the performance of machine. The optimal operating forward speed was found to be 3.5 km/h, the equipment achieved maximum bund cutting efficiency as 84% with the fuel consumption of 2.712 L/h was found to the operation. In low speed of operation i.e. 1.5 km/h the equipment achieved lowest bund cutting efficiency as 75.41%. The fuel consumption for this operation was noted as 3.974 L/h. The energy requirement for operation of bund cutting was maximum as 154.98 MJ/h at a speed of 1.5 km/h and minimum as 105.77 MJ/h at speed of 3.5 km/h, this is due to the high fuel consumption during operation. The average cost of operation was Rs 551.50 per hector which was less than manually i.e. Rs. 1661.38/ ha (wages of 5 labour). The results of the field tests showed that, the tractor speed had a significant effect on the performance on the machine.

Keywords: Bund cutter, paddy cultivation, rice

1. Introduction
In paddy cultivation, bunds are very important and play very significant role to store the water in basin made by using bunds, for cultivation of paddy required lots off water from seedling to maturity. Bunds store water in basin formation and all the practiced required for paddy cultivation done in the basin structure. For best paddy cultivation sufficient water available in the paddy field throughout its whole lifecycle, and the good bunds achieved this, with minimum seepage and percolation. High water loss and the weeds on the bunds are restrict aeration resulting weeds causes huge reduction in crop yield as well as increase cost of cultivation, decreases input efficiency, interfere with agricultural operations, damage quality, act as alternate hosts for several insect-pests, diseases, disturb aesthetic appearance of the ecosystem, native biodiversity, also affect human and cattle health. In traditional method, bunds are usually done in two steps at the beginning of each crop season. First the bund should be cleared from weeds and grass before initial ploughing. Then the bund should be plastered with a layer of mud after the second plough ha with an average productivity of 3.0 t/ha.

1.1 Scope and Limitation
Farmers of Eastern Vidharbha region cut (trim) and pack the bund manually which is time, energy and money consuming, therefore there is a necessity of Mechanization of bund or ridge forming which is an important process in the preparation of the paddy field before transplanting. No such machine is commercially available to cut and shape the formed bund in the country. To ease the farming operation, an attempt was made to design and develop such machine which enables combined operations of bund cutting and packing in single pass for saving fuel and resources. Equipment is simple in design and fabricated by local manufacturer within reasonable coast.

2. Performance evaluation of bund cutting equipment
The measurements techniques of various parameters involve in the field experiments are described here under:

Fig 1: Performance evaluation of bund cutter

2.1 Soil parameter
The soil parameter also has influence on mechanical operation of bund cutting. The soil properties relevant to the design of equipment for bund cut were identified as soil type, soil texture, soil moisture and bulk density. The type of soil influenced the design of bund cutter as the soil resistance varies with soil type. The moisture content of soil affected the draft required for bund cutting operation and slip of tractor wheel. Bulk density of soil is the measured of a compaction of soil condition which influenced draft required for bund cutting operation.

2.1.1 Soil type
The soil of vidharbha region of Maharashtra is characterized under as black, medium black, red and clay loam that content predominantly montmorillonite clay. The soil has good moisture holding capacity and is swells considerably with moisture content. When dry soil shrinks and forms cracks. It was necessary to know the resistance offered by different soil to the soil working equipment. The moisture content of the soil, bulk density and soil resistance was considered for design.

2.1.2 Soil moisture content
The soil moisture content has influence on draft, work ability, power transmission of equipment during operation and wheel slippage. Hence moisture content of soil is major soil parameter which influence the design.

2.1.3 Bulk density of soil
The core sample method (Blake and Hartge, 1986) was used for determining the bulk density. Soil sample were collected randomly from each location of experimental plot with standard core sampler. The height and diameter of core sampler were 130 mm and 100 mm, respectively.

2.2 Effective depth of cut
For determining average effective depth of cut at experiment bund after passing the bund cutting equipment, measurement was taken in different location on each treatment by measuring with a scale.

2.3 Operating width
Operating width of cut could not be measured accurately due to quick gap filling in the wet muddy condition of bund. However almost uniform depth of 30 cm was maintained by lowering the cutting unit with the help of hitching unit.

2.4 Speed of operation
The machine was operated in three treatments i.e., 1, 2 and 3rd gears of tractor and speed of operation was measured by recording the time required to cover 25 m length of bund during operation. Simultaneously time required for turning the equipment was also noted. As such four observations were taken to get the accuracy.

2.5 Wheel slip
The tractor drive wheel normally slips in all field operation. The tractor wheel slip depends upon the depth of operation and moisture content of the soil.

2.6 Bund cutting capacity and efficiency
Bund cutting efficiency was calculated by using the theoretical and effective bund cutting efficiencies.

Fig 2: Field before operation

Fig 3: Field after operation

3. Results and Discussion
Developed equipment was tested in the field and various field performance parameters were measured at the time of field test. The detailed results obtained in the present investigation are discussed.

3.1 Energy requirements of existing bund cutting methods
The energy requirements of existing tools used for bund cutting (Spade and Trench hoe) presented in the following table.

Table 1: Energy requirements of existing tools (Shaikh F. 2018)

Physiological parameters	Bund cutting with Trench hoe	Bund cutting with Spade
WHR (beats/min)	124.3	131.6
OCR (lit/min)	0.79	1.12
EER (kJ/min)	16.3	23.5

(*Working heart rate – WHR, Oxygen consumption rate – OCR, Energy expenditure rate -EER)

3.2 Soil parameter of eastern Eastern Vidharbha region
While designing the bund cutter the data regarding soil characteristics of region was taken into consideration and presented in table.

Table 2: Physical characteristics of the soil in Gadchiroli Region

Sr. No.	Particulars	Value
1	Texture (%)	Sandy loam
2	Porosity (%)	32
3	Field capacity at 0.3 bar (%)	43
4	Percolation rate of soil	10 mm/h
5	Ph	7.5

(Bhandkkar V. 2019) [2]

3.3 Performance evaluation of bund cutting equipment
The performance evaluation of developed bund cutter equipment was conducted with the operating parameters such as soil moisture content, bulk density, and performance parameter such as effective working depth, operating width of operation, wheel sleep, speed of operation, fuel consumption, time requirement, energy requirement, bund cutting efficiency etc.

3.3.1 Soil parameters
3.3.1.1 Soil moisture content
Soil moisture content was determined during field test by gravimetric method. The results which found during field test reveals that the average moisture content of soil recorded was 46.92%

3.3.1.2 Bulk density
The bulk density of soil was calculated by core cutter method considering the weight of core cutter, the mass of core cutter + wet soil, the mass of core cutter + dry soil and volume of core cutter. From the obtained data result revealed that the average bulk density of soil was 1.82 g/cm^3.

3.3.2 Equipment performance parameters
3.3.2.1 Speed of operation
Three different speed of tractor i.e., 1.5, 2.5 and 3.5 km/h were considered for calculation of wheel slip, fuel consumption, effective bund cut capacity and all other parameter.

3.3.2.2 Depth and operating width of operation

Table 3: Depth of cutting and operating width

Sr. No	Speed of operation, km/h					
	1.5		2.5		3.5	
	Operating Width, cm	Cutting depth, cm	Operating Width, cm	Cutting depth, cm	Operating Width, cm	Cutting depth, cm
1	11.0	28.5	12.6	29.1	13.0	28.8
2	11.5	29.1	12.2	28.7	13.7	29.1
3	10.0	28.4	13.5	27.9	15.0	30.0
4	12.5	28.8	14.0	29.7	14.8	29.8
5	11.2	28.7	12.4	29.4	14.3	29.5
6	10.6	29.4	12.7	29.1	13.9	29.5
7	12.7	28.9	13.4	28.3	14.1	30.0
8	13.0	28.1	12.7	28.1	14.3	31.0
9	11.6	28.7	13.1	27.0	14.6	29.1
10	10.9	28.5	12.0	28.6	15.0	28.0
Avg.	11.5	26.13	12.76	28.59	14.27	29.48

From table.3, it was observed that the highest depth (29.48cm) and highest operating width (14.27 cm) of operation was observed at a speed of 3.5 km/h and for speed 1.5 km/h lowest depth (26.13cm) and lowest operating width (11.5cm) of operation was observed. This was due to more bund cutting efficiency at speed 3.5 km/h.

3.3.2.4 Effect of travelled speed on fuel consumption
The fuel consumption per hour was recorded as 3.974, 3.453 and 2.721 l/h at speed 1.5, 2.5 and 3.5 km/h. fuel consumption were maximum at a tractor forward speed of 1.5 km/h as 3.947 l/h. and the minimum amount of fuel was consumed at a speed of 3.5 km/h as 2.721 l/h. Having the same area and operation due to high speed of travel during operation with maximum wheel slip.

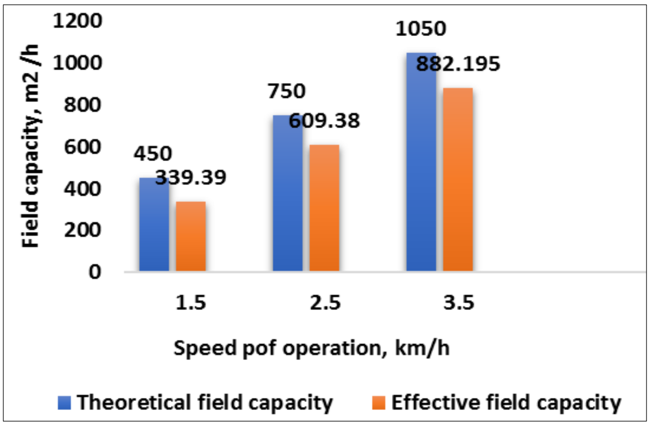

Fig 4: Effect of travelled speed on fuel consumption

3.3.2.5 Effect of travelled speed on energy requirement

The energy consumption was computed from the equation 3.16 for three speeds during operation of the equipment. The operational energy refers to the energy required for mechanization, i.e. direct energy (fuel and human labour). The total operational energy consumption was highest at a speed of 1.5 km/h as 154.947MJ/h due to high rate of fuel consumption and high speed of operation than others speeds (Kumar *et al.* 2017), with the energy consumption was lowest for low speed of operation i. e. 3.5 km/h as 105.768 MJ/h.

3.3.2.6 Effect of travelled speed on bund cut capacity

The bund cutting capacity of an equipment is a function of its depth of operation, forward **speed** and efficiency of operation and it was computed by the equation 3.13, 3.14 and 3.15.

Table 4: Theoretical field capacity, Effective field capacity and field efficiency of bund cutter at travel speed 1.5 km/h

Sr. No	Theoretical Field Capacity, m^2/h	Effective Field Capacity, m^2/h	Field Efficiency, %
1	450	342.00	76.00
2	450	334.01	74.22
3	450	325.30	72.28
4	450	351.17	78.00
5	450	332.72	73.93
6	450	326.85	72.63
7	450	335.61	74.58
8	450	348.25	77.38
9	450	366.61	81.46
10	450	331.47	73.66
Average			75.41

Table 5: Theoretical field capacity Effective field capacity and field efficiency of bund cutter at travel speed 2.5 km/h

Sr. No	Theoretical Field Capacity, m^2/h	Effective Field Capacity, m^2/h	Field Efficiency, %
1	750	628.56	83.80
2	750	628.90	83.80
3	750	602.64	80.30
4	750	599.10	79.88
5	750	601.20	80.16
6	750	628.56	83.80
7	750	584.26	77.90
8	750	602.01	80.26
9	750	607.50	81.00
10	750	611.13	81.40
Average			81.13

Table 5: Theoretical field capacity Effective field capacity and field efficiency of bund cutter at travel speed 3.5 km/h

Sr. No.	Theoretical Field Capacity, m^2/h	Effective Field Capacity, m^2/h	Field Efficiency, %
1	1050	870.00	82.80
2	1050	891.57	84.90
3	1050	907.20	86.40
4	1050	874.13	83.25
5	1050	898.61	85.58
6	1050	857.76	81.69
7	1050	872.30	83.07
8	1050	901.38	85.84
9	1050	873.00	83.14
10	1050	876.00	83.42
Average			84.00

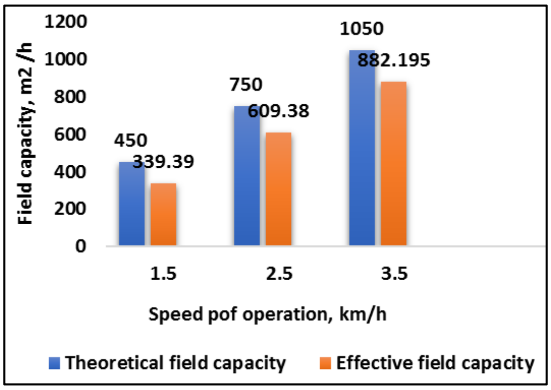

Fig 4: Effects of travel speed on bund cutting capacity

Effective bund cutting capacity was compared with the theoretical bund cutting capacity as shown in fig 4.3. It was observed that the bund cutting capacity was increased with travelled speed i.e, at a speed of 3.5 km/h.

3.4 Cost economics of bund cutting operation

Table 6: Cost of operation for tractor and equipment per hour for bund cutter

Sr. No	Particulars	Cost of operation for tractor	Cost of operation for equipment
A) Fixed cost			
1	Depreciation, Rs/h	48.6	10.08
2	Interest, Rs/h	29.7	3.08
3	Insurance, Rs/h	5.4	0.56
4	Tax, Rs/h	5.4	0.56
5	Housing cost, Rs/h	5.4	0.56
	Total fixed cost, Rs/h	94.5	14.84
B) Operating costs			
1	Fuel cost, Rs/h	260.352	Nil
2	Lubricant cost, Rs/h	78.10	Nil
3	Repair and maintenance cost, Rs/h	54	1.4
4	Operational (labour) wages, Rs/h	37.5	Nil
	Total operating cost, Rs /h	429.952	1.4
C) Cost of operation			
1	Total cost of operation (Rs/h) =Fixed cost + Operating cost	524.452	16.24
D) Cost of operation (Rs/h)		540.692	
E) Cost of operation (Rs/ha)		551.50	

Table 7: Performance evaluation data for bund cutting at travel speed 1.5, 2.5 and 3.5 km/h

Sr. No	Performance parameters	Speeds (km/h)		
		1.5	**2.5**	**3.5**
1	Soil moisture content, %	47.11	47.10	46.92
2	Bulk density, g/cm^3	1.90	1.87	1.70
3	Wheel slip, %	28.07	22.68	17.37
4	Depth of cut, cm	26.13	28.59	29.48
5	Operational width, cm	11.50	12.76	14.27
6	Theoretical bund cut capacity, m^2/h	450	750	1050
7	Effective bund cut capacity, m^2/h	339.39	609.38	882.19
8	Bund cut efficiency, %	75.41	81.13	84
9	Field capacity, ha/h	0.42	0.70	0.98
10	Fuel consumption, lit/h	3.974	3.453	2.712
11	Energy requirement, MJ/h	154.94	134.66	105.76
12	Wear, %	0.15	0.22	0.27
13	Cost, Rs/ h	689.062	633.18	540.692
14	Cost, Rs/ ha	1661.38	899.11	551.50

4. Summary and Conclusion

Following conclusions are drawn from the study.

1. The average moisture content of soil was recorded as 46.92% for three speeds of operation.
2. The average bulk density of soil was recorded 1.82 g/cm^3 for three speeds of operation.
3. The average operating width (14.27 cm) and depth (29.48 cm) of operation was maximum at high speed of operation (3.5 km/h) while it was minimum at low speed of operation (1.5 km/h) compared to other treatments.
4. The wheel slip for speed 1.5, 2.5 and 3.5 km/h were 28.07, 22.68 and 17.37% respectively. For high speed (3.5 km/h) wheel slip was low.
5. The fuel consumption of tractor for operation of bund cutting was 3.973, 3.453 and 2.713 L/h with respect to three different speeds of tractor i.e.,1.5, 2.5 and 3.5 km/h respectively.
6. The average energy requirement for bund cutting equipment was 105.77 MJ/h.
7. The bund cutting efficiency for the equipment was maximum at high speed (3.5 km/h) of operation as 84% and at low speed (1.5 km/h) the bund cutting efficiency was minimum as 75.41%.
8. The cost of operation hector per hour for developed bund cutting equipment was Rs**.** 1661.38, 633.18 and 551.50 with respect to three speeds i.e1.5, 2.5 and 3.5 km/h.
9. The money and time saving are 55.88% and 87.5% respectively at 3.5 km/h travel speed of equipment.

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