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Minimum Performance Standards of Tillage Implements

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Authors' contributions

This work was carried out in collaboration among all authors. Author MS, as a part of M.Tech Thesis work under guidance of author MJ and he is also responsible for preparation of the manuscript. Author VRK performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MJ and MK provided technical guidance and assisted in statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

This article focuses on formulation of minimum performance standards (MPS) for tillage machinery such as rotavator, disc harrow and cultivator. The required minimum performance standard of different tillage machinery under sandy loam soil condition is discussed further in this paper and recommended in order to ensure availability of quality tillage machinery to the farmers. The minimum performance standards for minimum depth of cut, minimum depth of puddle, minimum area covered per meter working width, minimum field efficiency, maximum fuel consumption per meter working width, minimum puddling index and maximum PTO power requirement per meter working width is 6.50 cm, 14 cm, 0.23 ha h^{-1}, 76%, 3.0 l h^{-1}, 77% and 11 kW respectively. The minimum performance standards for minimum depth of cut, minimum area covered per meter of working width, minimum field efficiency, maximum fuel consumption per meter of working width, maximum draft per meter of working width and maximum drawbar power per meter of working width of disc harrow is 8 cm, 0.43 ha h^{-1}, 70%, 3.0 l h^{-1}, 213 kg-f and 4.0 kW respectively. Similarly, minimum performance of the cultivators were recommended based on the analysis of results of different parameters such as minimum depth of cut, minimum area covered per meter of working

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width, minimum field efficiency, maximum fuel consumption per meter of working width, maximum draft per meter of working width and maximum drawbar power per meter of working width is 9 cm, 0.41 ha h^{-1}, 75%, 2.0 l h^{-1}, 244 kg-f and 3.4 kW respectively. Along with the performance parameters, other requirements like safety, dimensions, label, material of construction and breakdowns are discussed and recommended.

Keywords: Tillage implements; minimum performance standards; rotavator; technological innovations.

1. INTRODUCTION

In India testing of agricultural machinery is done by Farm Machinery Training & Testing Institutes (FMT&TIs), which are located at four zones of India i.e. Central Farm Machinery Training and Testing Institute (CFMT&TI), Budni, Madhya Pradesh; Southern Region Farm Machinery Training and Testing Institute (SRFMT&TI), Garaladinne, Andhra Pradesh; Northern Region Farm Machinery Training and Testing Institute (NRFMT&TI), Hisar, Haryana; and North East Region Farm Machinery Training and Testing Institute (NERFMT&TI), Biswanath Chariali, Assam. Apart from these institutes, State Agricultural Universities, State Government Institutes and ICAR institutes are also conducting the testing of small agricultural equipments except tractor. Testing of agricultural machinery including tractors is the only solution to make the manufacturers aware about performance, suitability under varying field conditions and durability of the equipment for appropriate/proficient use along with providing technical information to the farmers for appropriate choice of the required equipment. Since 1960, test standards provided by Bureau of Indian Standard (BIS), for the testing of agriculture tractor, machinery, equipment and implements etc. remain unchanged but are slightly modified over the years with respect to technological innovations in the machinery.

BIS has published several test codes for evaluating the performance of the tillage machinery. The tillage machineries are tested according to these test standards. The test standards are an effective tool for meeting quality requirements, promoting improvements, facilitate International trade, securing the safety of operators, enhancing environmental conservation and saving energy. These test standards are based on straight forwardness, liberality, equity, consistency, adequacy, and due process [1].

In the same way, BIS has also developed certain codes regarding the minimum performance of the agricultural machinery. The minimum performances indicate the minimum criteria of performance parameters which the equipment or the machinery is supposed to perform during testing. These standards specify the minimum limits of the various characteristics which are functionally important for the machine. However, minimum performance standards are not available for all the agricultural machinery. In the absence of minimum performance standards, it is very difficult to evaluate the testing report and draw any valuable conclusion.

2. MATERIALS

The study was carried using the commercial test reports of the agricultural machinery selected for the study. The commercial test reports from the testing centre of CCS HAU and NRFMT&TI, Hisar were used for the study. This study was performed at Department of FMPE, COAE&T, CCSHAU, Hisar.

3. METHODS

The data was collected from the commercial test reports of the respective testing authority. The process adopted for establishment of minimum performance standard is followed as per BIS test codes for the establishment of MPS of power tiller (IS: 13539-2008), tractor (IS: 12207-2014), rotavator (IS: 17045-2018) [2] and combine harvester (IS: 15806-2018).

For this study, tillage machinery like rotavator, cultivator and disc harrow machine were selected. The performance parameters included in the study were depth of cut (cm), width of cut (cm), speed of operation (km h^{-1}), area covered (ha h^{-1} per meter working width of machine), time required to cover one ha (h), field efficiency (%), fuel consumption (l h^{-1} & l ha^{-1}) per meter working width of machine, implement draft (kg-f per meter working width of machine), depth of puddle for rotavator (cm), PTO power utilized (kW per meter working width of machine), drawbar power used (kW per meter working width of machine).

The performance parameters were again classified into evaluative and non-evaluative parameters as per guidelines. Fifty two test reports of rotavator, forty six test reports of disc harrow and sixty one test reports of different manufacturers and tested by different testing centres were studied to establish MPS. The data pertaining to above mentioned parameters were collected from test reports and recorded in MS-Excel 2016. All data were arranged in ascending order separately and number of classes and class width among the observations were calculated as suggested by Sturges [3].

$$k = 1 + 3.322 \quad \llbracket log \rrbracket\_10 \text{ N}$$

Where,

N: Number of observations

$$h = \frac{L - S}{k}$$

Where,

h: Class width
L: Largest value of observations
S: Smallest value of observations
K: Number of classes

In order to establish MPS of different machinery, the data collected for individual parameter from the commercial test reports were arranged in the form of frequency table with different class interval. To determine the mean of individual parameter, corresponding values of the most occurring frequency (about 50% of the frequency) was only considered.

4. RESULTS

4.1 Formulation of Minimum Performance Standard for Rotavator

After analysis of the data for the rotavator, data was classified into seven classes with a class interval of 1.7, 3.1, 0.06, 3.2, 0.44, 5.2 and 2.2 for minimum depth of cut, the minimum depth of puddle, the minimum area covered per meter working width, minimum field efficiency, maximum fuel consumption per meter working width, minimum puddling index and maximum PTO power requirement per meter working width, respectively as given in Table 1. The suggested MPS for rotavator for the above-mentioned parameters are 6.50 cm, 14 cm, 0.23 ha h^{-1}, 76%, 3.0 l h^{-1}, 77% and 11 kW, respectively which is depicted in Tables 2 & 3.

4.2 Disc Harrow

The number of class as suggested by Sturges [3] for a set of observations was seven with class interval of 2.1, 0.04, 4.8, 0.41, 64.7, and 0.8 for minimum depth of cut, the minimum area covered per meter working width of the disc harrow, minimum field efficiency, maximum fuel consumption per meter working width of the disc harrow, maximum draft kg-f per meter working width of disc harrow and drawbar power kW per meter working width of disc harrow, respectively as given in Table 4.

Based on results obtained from the analysis, MPS suggested for above-mentioned parameters are 8 cm, 0.43 ha h^{-1}, 70 %, 3.0 l h^{-1}, 213 kg-f and 4.0 kW, respectively which is tabulated in Tables 5 & 6.

4.3 Cultivator

The number of classes as suggested by Sturges [3] for a set of observations was seven with class interval of 1.8, 0.05, 5.4, 0.37, 45.1 and 0.9 for minimum depth of cut, the minimum area covered per meter working width of the cultivator, minimum field efficiency, maximum fuel consumption per meter working width of the cultivator, maximum draft and maximum drawbar power per meter working width of the cultivator, respectively as given in Table 7. Based on results obtained from analysis of cultivator data, MPS suggested for above-mentioned parameters are 9 cm, 0.41 ha h^{-1}, 75 %, 2.0 l h^{-1}, 244 kg-f and 3.4 kW, respectively which is represented in Tables 8 & 9.

4.4 Safety and Other Requirements

Rotavator shield and guard over the propeller-shaft, guards against all moving parts/drives and guarding of the transmission system should be provided in the rotavator for the safety of operator/observer during field work. The safety parameters are evaluative parameters (mandatory compliance requirement) due to which they must be fulfilled to avail financial and subsidy assistance under the Govt. schemes. Sealings which are found in rotavator are provided in the primary reduction gear/box, secondary reduction gear box and rotary axle bearing cap and are listed under non-evaluative parameters. To avoid unnecessary repair and breakdown during operations, the effectiveness of sealings must be ensured in rotavator.

Table 1. Minimum, maximum, class and class width of different parameters of rotavator

Characteristics	Min. depth of cut	Min. depth of puddle	Min. area covered (dry land)	Min. field efficiency (dry land)	Max. fuel consumption	Min. puddling index	Max. PTO power
Unit	cm	cm	ha h^{-1} m^{-1}	%	l h^{-1} m^{-1}	%	kW m^{-1}
Min.	5	2.5	0.12	67	1.54	56	4.9
Max.	16.2	23	0.48	88	4.39	90.2	19.5
Class No.	7	7	7	7	7	7	7
Class width	1.7	3.1	0.06	3.2	0.44	5.2	2.2

Table 2. Minimum performance value of depth of cut, depth of puddle, area covered (dry land) and field efficiency (dry land) of rotavator

Class No.	Min. depth of cut			Min. depth of puddle			Min. area covered (dry land)			Min. field efficiency (dry land)		
	Cm			Cm			ha h^{-1} m^{-1}			%		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	5.0 - 6.7	12	5.74	2.5 - 5.6	1		0.12 - 0.18	7		67.0 - 70.2	8	
2	6.7 - 8.4	19	7.39	5.6 - 8.7	11	7.49	0.18 - 0.24	21	0.21	70.2 - 73.4	16	72
3	8.4 - 10.1	5		8.7 - 11.8	6		0.24 - 0.30	21	0.25	73.4 - 76.6	8	
4	10.1 - 11.8	2		11.8 - 14.9	6		0.30 - 0.36	2		76.6 - 79.8	12	79
5	11.8 - 13.5	8		14.9 - 18.0	8	16.41	0.36 - 0.42	0		79.8 - 83.0	6	
6	13.5 - 15.2	2		18.0 - 21.1	13	19.61	0.42 - 0.48	0		83.0 - 86.2	1	
7	15.2 - 16.9	1		21.1 - 24.2	7		0.48 - 0.54	1		86.2 - 89.4	1	
Average			6.57 ≈ 6.50			14.50 ≈ 14			0.23			76

Table 3. Minimum performance value of fuel consumption, puddling index, PTO power and nominal closed length of the drive shaft of rotavator

Class No.	Max. fuel consumption			Min. puddling index			Max. PTO power		
	l h^{-1} m^{-1}			%			kW m^{-1}		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	1.54 - 1.98	3		56.0 - 61.2	5		4.9 - 7.1	4	
2	1.98 - 2.42	9		61.2 - 66.4	3		7.1 - 9.3	6	9
3	2.42 - 2.86	19	2.6	66.4 - 71.6	9		9.3 - 11.5	8	10
4	2.86 - 3.30	12	3.05	71.6 - 76.8	14	74	11.5 - 13.7	4	13

Class No.	Max. fuel consumption			Min. puddling index			Max. PTO power		
	l h^{-1} m^{-1}			%			kW m^{-1}		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
5	3.30 - 3.74	5		76.8 - 82.0	15	80	13.7 - 15.9	4	
6	3.74 - 4.18	2		82.0 - 87.2	4		15.9 - 18.1	3	
7	4.18 - 4.62	1		87.2 - 92.4	2		18.1 - 20.3	1	
Average			2.82 ≈ 3.0			77			11

Table 4. Minimum, maximum, class and class width of different parameters of disc harrow

Characteristics	Min. depth of cut	Min. area covered	Min. field efficiency	Max. fuel consumption	Max. draft	Max. drawbar power
	cm	ha h^{-1} m^{-1}	%	l h^{-1} m^{-1}	kg-f m^{-1}	kW m^{-1}
Min.	5.5	0.37	58	1.68	144	3
Max.	19.2	0.64	89	4.30	557	8
Class No.	7	7	7	7	7	7
Class width	2.1	0.04	4.8	0.41	64.7	0.8

Table 5. Minimum performance value of depth of cut, area covered and field efficiency of disc harrow

Class No.	Min. depth of cut			Min. area covered			Min. field efficiency		
	cm			ha h^{-1} m^{-1}			%		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	5.5 - 7.6	12	6.75	0.37 - 0.41	8	0.4	580 - 62.8	5	
2	7.6 - 9.7	16	8.72	0.41 - 0.45	10	0.43	62.8 - 67.6	6	65
3	9.7 - 11.8	6		0.45 - 0.49	9	0.47	67.6 - 72.4	10	70
4	11.8 -13.9	9		0.49 - 0.53	4		72.4 - 77.2	17	75
5	13.9 - 16.0	1		0.53 - 0.57	3		77.2 - 82.0	5	
6	18.1 - 20.2	1		0.57 - 0.61	6		82.0 - 86.8	1	
7	20.2 - 22.3	0		0.61 - 0.65	2		86.8 - 91.6	2	
Average			7.73 ≈ 8.0			0.43			70

Table 6. Minimum performance value of fuel consumption, draft and drawbar power of disc harrow

Class No.	Max. fuel consumption			Max. draft			Max. drawbar power		
	l h^{-1} m^{-1}			kg-f m^{-1}			kW m^{-1}		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	1.68 -2.09	3		144.2 - 208.7	13	189	3.0 - 3.8	6	3
2	2.09 - 2.5	8	2.33	208.7 - 273.4	19	236	3.8 - 4.6	10	4
3	2.5 - 2.91	5		273.4 - 338.1	1		4.6 - 5.4	1	
4	2.91 - 3.32	16	3.09	338.1 - 402.8	1		5.4 - 6.2	4	
5	3.32 - 3.73	5		402.8 - 467.5	6		6.2 - 7.0	4	
6	3.73 - 4.14	4		467.5 - 532.2	1		7.0 - 7.8	1	
7	4.14 - 4.55	4		532.2 - 596.9	1		7.8 - 8.6	1	
Average			2.71 ≈ 3.0			213			4

Table 7. Minimum, maximum, class and class width of different parameters of the cultivator

Characteristics	Min. depth of cut	Min. area covered	Min. field efficiency	Max. fuel consumption	Max. draft	Max. drawbar power
	cm	ha h^{-1} m^{-1}	%	l h^{-1} m^{-1}	kg-f m^{-1}	kW m^{-1}
Min.	3.9	0.19	51	0.93	64	1.4
Max.	16.2	0.52	88	3.46	370	7.7
Class No.	7	7	7	7	7	7
Class width	1.8	0.05	5.47	0.37	45.1	0.9

Table 8. Minimum performance value of depth of cut, area covered and field efficiency of the cultivator

Class No.	Min. depth of cut			Min. area covered			Min. field efficiency		
	cm			ha h^{-1} m^{-1}			%		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	3.9 - 5.7	3		0.18 - 0.23	2		51.0 - 56.4	1	
2	5.7 - 7.5	4		0.23 - 0.28	4		56.4 - 61.8	1	
3	7.5 - 9.3	21	8.47	0.28 - 0.33	6		61.8 - 67.2	2	
4	9.3 - 11.1	22	10.1	0.33 - 0.38	16	0.37	67.2 - 72.6	17	
5	11.1 - 12.9	9		0.38 - 0.43	14	0.41	72.6 - 78.0	33	75
6	12.9 - 14.7	1		0.43 - 0.48	12	0.45	78.0 - 83.4	4	
7	14.7 - 16.5	1		0.48 - 0.53	7		83.4 - 88.8	3	
Average			9.29 ≈ 9	`		0.41			75

Table 9. Minimum performance value of fuel consumption, draft, and drawbar power of the cultivator

Class No.	Max. fuel consumption			Max. draft			Max. drawbar power		
	l h^{-1} m^{-1}			kg-f m^{-1}			kW m^{-1}		
	Class interval	Freq.	Average	Class interval	Freq.	Average	Class interval	Freq.	Average
1	0.93 - 1.3	4		63.9 - 109.1	3		1.4 - 2.4	3	
2	1.3.0 - 1.67	8		109.1 - 154.2	6		2.4 - 3.3	20	3.1
3	1.67 - 2.04	15	1.89	154.2 - 199.3	9		3.3 - 4.3	19	3.7
4	2.04 - 2.41	17	2.2	199.3 - 244.4	23	226	4.3 - 5.2	6	
5	2.41 - 2.78	13		244.4 - 289.5	11	262	5.2 - 6.1	0	
6	2.78 - 3.15	3		289.5 - 334.6	4		6.1 -7.1	4	
7	3.12 - 3.52	1		334.6 - 379.7	5		7.1 - 8.0	3	
Average			2.05 ≈ 2.0			244			3.4

Table 10. Breakdown/defects of rotavator

Sl. No.	Characteristics	Category Evaluative/ Non-Evaluative	Requirements	As observed	Remarks
i)	Critical breakdowns	Evaluative	No breakage/crack and failure of	Power input shaft, propeller shaft, transmission gears, primary & secondary gear box & rotor shaft	Conforms/ Does not conform
ii)	Major breakdowns	Evaluative	No breakage/crack and failure of	Drive chain, sprocket, rotor blades and bearings	Conforms/ Does not conform
iii)	Minor breakdowns	Evaluative	No oil leakage of	'O' ring gasket, primary & secondary gear box	Conforms/ Does not conform

Table 11. Breakdown/defects of disc harrow

Sl. No.	Characteristics	Category Evaluative/ Non-Evaluative	Requirements	As observed	Remarks
i)	Critical breakdowns	Evaluative	No breakage/crack and failure of	Hydraulic assembly, bearing spool and gang shaft	Conforms/ Does not conform
ii)	Major breakdowns	Evaluative	No breakage/crack and failure of	Spool, all bearings, concave disc and disc gang	Conforms/ Does not conform
iii)	Minor breakdowns	Evaluative	No crack/oil leakage from	Hydraulic assembly, bumper, hitching assembly, nut bolt and fastener	Conforms/ Does not conform

Table 12. Breakdown/defects of cultivator

Sl. No.	Characteristics	Category Evaluative/ Non-Evaluative	Requirements	As observed	Remarks
i)	Critical breakdowns	Evaluative	No breakage/ crack of	Hitching system, shovels & tine	Conforms/ Does not conform
ii)	Major breakdowns	Evaluative	No breakage/ crack of	Springs	Conforms/ Does not conform
iii)	Minor breakdowns	Evaluative	No breakage/ crack of	Nut, bolt & fasteners	Conforms/ Does not conform

Material of construction (hardness and chemical composition of critical parts) for rotavator, disc harrow and cultivator must comply the recommendations given by IS: 6690-1981, IS: 4366-1985, IS: 9442-1980, IS: 6638-1972, IS: 6813-2000 and IS: 6024- 1983, IS: 6025-1982 and IS: 10378- 1982.

Dimensional requirements for rotavator, disc harrow and cultivator as per IS: 4468 part I-1997 [4], IS: 4931-1995 [5], IS: 6690-1981 [6], IS:4366-1985, IS: 7230- 1974, IS: 7565 (part I)- 1975, IS: 6638- 1972 and IS: 6813- 2000 must be ensured to fulfil its conformity.

Other requirement of machinery includes provision for anticorrosive coating, harrow stand, thickness of cutting edge etc. for disc harrow and cultivator. This parameter has been included so as to sensitize the farmers about the machine quality. However, this parameter is classified under non evaluative category and it is not mandatory for manufacturer to provide these parameters compulsorily.

General requirement for tillage machinery includes proper arrangement for lubrication, bearing shall be adequately protected against the ingress of dust, provision for easy transportation, provision for easy adjustment of components etc. must be provided for easiness of operation, transportation and handling of the machinery.

Machinery manufacturer must ensure to provide operator cum service manual and parts catalogue as per IS: 8132-1999 and it is included under evaluative category.

Labelling of all selected machinery is an important feature which should be provided on the machine with permanent fixture. In the label plate, the manufacture must include name and address of the manufacturer, make, model/trade marks, size of the machine, country of origin, year of manufacturing, machine serial number, and recommended P.T.O speed for prime mover etc. Looking into the importance of the labelling, it has been included in the list of evaluative parameters

Lists of breakdowns and defects such as critical, major and minor breakdowns have been identified for selected machinery which is given in Tables 10, 11 & 12. This parameter has been included in the list of evaluative parameters in order to ensure supply of better-quality products to the end-user.

5. DISCUSSION

BIS has also published IS: 17045-2018 (MPS on rotavator) [2]. As per this code, minimum depth of cut, minimum depth of puddle, minimum field efficiency and minimum puddling index were 10 cm, 12 cm, 75% and 65%. However, the results observed in the study are almost near to test code observations except for the minimum depth of cut. As the present study is more scientific, it is recommended that the depth of cut may be reduced from 10 cm to 6.50 cm.

In line with the results of the present study, Sharma et al. [7] found that the minimum depth of cut and maximum fuel consumption of disc harrow was 6 cm and 3.80 l h^{-1} per meter of working width of disc harrow, respectively.

Similar to the findings of the present study, Potekar and Tekale [8] reported that the area coverage and fuel consumption rate of the cultivator were 0.41 ha h^{-1} and 2.01 l h^{-1} per meter of working width of cultivator, respectively.

6. CONCLUSION

6.1 Rotavator

For rotavator, minimum depth of cut, minimum depth of puddle, minimum area covered per meter of working width, minimum field efficiency, maximum fuel consumption per meter of working width, minimum puddling index and maximum PTO power requirement per meter of working width are 6.50 cm, 14 cm, 0.23 ha h^{-1}, 76%, 3.0 l h^{-1}, 77%, 11 kW and 817 mm, respectively.

6.2 Disc Harrow

In disc harrow, minimum depth of cut, minimum area covered per meter working width of the disc harrow, minimum field efficiency, maximum fuel consumption per meter of working width, maximum draft per meter of working width and maximum drawbar power per meter of working width of disc harrow are 8 cm, 0.43 ha h^{-1}, 70%, 3.0 l h^{-1}, 213 kg-f and 4.0 kW, respectively.

6.3 Cultivator

In case of cultivator, minimum depth of cut, minimum area covered per meter of working width, minimum field efficiency, maximum fuel consumption per meter of working width, maximum draft per meter of working width and maximum drawbar power per meter of working width of cultivator are 9 cm, 0.41 ha h^{-1}, 75 %, 2.0 l h^{-1}, 244 kg-f and 3.4 kW, respectively.

Safety requirements, material of construction of machinery, dimensional requirements, and other requirements of machinery like technical literature, general requirements, labelling of machinery and list of break downs and defects have also been suggested.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Takahashi H. Generality of the official testing system for agricultural machinery. In: 9th OCED members meeting, Bologna. Italy; 1998.
2. Anonymous. Rotary Tiller (Rotavator) - Tractor driven - Test procedure, and recommendations on selected performance characteristics, IS 17045, Bureau of Indian Standard, New Delhi; 2018.
3. Sturges HA. The choice of a class interval. Journal of the American Statistical Association. 1926;21(153):65-66.
4. Anonymous. Agricultural wheeled tractors Rear-mounted three-point linkage, Part 1: Categories 1, 2 3, 4 (Fourth Revision), IS 4468-1, Bureau of Indian Standard, New Delhi; 1997.
5. Anonymous.Agricultural tractors - Rear mounted power take off Types 1, 2 and 3 (Third Revision), IS 4931, Bureau of Indian Standard, New Delhi; 1995.
6. Anonymous. Blades for rotavator for power tillers, IS 6690, Bureau of Indian Standard, New Delhi; 1981.

7. Sharma S, Gaba M, Singh T. Performance evaluation of tractor with attached implements. International Journal of Research in Engineering and Applied Sciences. 2016;6(11):146-157.

8. Potekar JM, Tekale DD. Comparative performance of tractor drawn implements tillage system with rotavator tillage system. Karnataka Journal of Agricultural Sciences. 2004;17(1).

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