PERFORMANCE EVALUATION OF DIFFERENT FODDER CUTTERS

Hafiz Sultan Mahmood[1], Tanveer Ahmad[1], Zulfiqar Ali[1] and Asif Ali Mirani[2]
[1]Agricultural and Biological Engineering Institute, National Agricultural Research Centre, Islamabad
[2]Agricultual Engineering Division, Pakistan Agricultural Research Council, Islamabad
E-Mail: sultan_fmi@hotmail.com

ABSTRACT

Manual fodder cutting for dairy and livestock industry is a time-consuming and laborious practice. The objective of this study was to evaluate the performance of locally available fodder cutters and to identity a suitable machine for cutting oats and berseem fodders. Four fodder cutters were identified available across the country. They included Agritec rotary mower, Taj rotary mower, Mobi reaper-windrower and AMRI sickle bar. All machines were acquired at Remount Depot, Sargodha for comprehensive field testing to cut oats and berseem fodders. Results revealed that Agritec and Taj rotary mowers were suitable for cutting berseem and oats, whereas Mobi reaper-windrower and AMRI sickle bar were only suitable for cutting oats and other long fodders. The performance of Agritec rotary mower was the best for cutting berseem as well oats. The field capacity of Agritec rotary mower was 0.35 and 0.25 ha/h with field efficiency of 64.8 and 59.7 % for cutting oats and berseem, respectively. Using fodder cutters, the cost of operation and cutting time can be decreased up to 70-80 % as compared with manual cutting. For dairy farming, suitable fodder cutters should be promoted in the country for speedy work. However, reliability of machine is the prerequisite for commercialisation of a machine.

Keywords: fodder crops, fodder cutters, rotary mowers, sickle bar cutter, engine-operated cutter-windrower.

INTRODUCTION

The demand of meat and dairy products has been increasing in Pakistan due to increase in population. Livestock sector is playing a vital role in the subsistence of small holders in the rural areas of the country. It contributes 58.55 % to agricultural sector and 11.61 % to national GDP with a positive growth of 3.63 % during the year 2015-16. The livestock population (cattle, goats, buffaloes, sheep, camels, asses, mules and horses) is 186.2 million heads in Pakistan (Ministry of Finance, 2016). Livestock industry of Pakistan is private-sector based, whereas public sector deals with policy matters, conducts new research and suggests better practices for livestock farming. The Government of Pakistan is paying special attention to mechanisation of agricultural sector, especially dairy or cattle farming as an industry for enhancing milk and meat production in the country. Efforts are being made for bringing white revolution in the country by boosting up the dairy and livestock industry (Hussain *et al.* 2012).

Cattle feed largely depends on fodder crops, such as oats, berseem, sorghum, barley, maize, millet, lucerne (alfalfa) and grasses. Green fodder is a nutritious and economical feed for livestock (Hussain *et al.* 2011). By using nutritional fodders, the production of milk and meat can be increased significantly. As, there are no suitable natural pastures in the county for grazing of animals, every farmer cultivates a portion of his land with fodder crops for feeding his cattle. The cropped area under fodder crops varies from farmer to farmer. The people who rear cattle not only meet their milk and protein demand, but also earn money by selling milk, milk products and meat in the market. Some farmers grow fodder crops for business purpose and sell fodder commercially to dairy and livestock industry. Fodder crops were cultivated on an area of 2.33 million hectares, which is about 10.5 % of the total cropped area (Ministry of Finance, 2011). Therefore, the need for fodder crops in the country can never be denied.

Berseem and oats are two important winter fodder crops. Berseem (*Trifolium alexandrinum* L.) is a multi-cut leguminous winter fodder crop, which is grown in irrigated areas of the country (Naeem *et al.* 2006). Similarly, oats (*Avena sativa*, L.) are also multi-cut and nutritious fodder, which are very good for milch animals. It is also available in lean period and is suitable as green fodder, silage or hay making (Hussain *et al.* 2011).

In Pakistan, harvesting of fodder crops is generally accomplished manually by using sickle. The operation is labour-intensive and involves strenuous and monotonous work. To sell a massive quantity of fodder daily at commercial level is a big issue for fodder growers. With the versatility of the dairy and livestock industry in the country, the importance of fodder harvesting technology has become more crucial. Rearing more milking cattle demands more fodder to be grown and a speedy mechanised harvesting process. Therefore, fodder harvesting has been an issue in the country for the last few years. Owing to increase in the demand of fodder to be sold commercially in the large cities for feeding milking animals, the harvesting of fodder crops on large scale must be mechanised to save time and labour. Therefore, the importance of fodder harvesting machinery can be accentuated by the above facts.

Fodder harvesting machinery has not yet been introduced in the country. A few fodder cutters have been developed by local manufacturers or public-sector organisations, but the performance of those machines has not been evaluated for cutting fodder cops. The farmers were not aware about the capabilities of those machines and were therefore reluctant to purchase them. Identification of a suitable machine for a specific type of fodder was necessary. Therefore, the objective of this study was to evaluate the performance of locally available fodder cutters and to identity a suitable machine for cutting oats and berseem fodders.

MATERIALS AND METHODS

Description of machines

Field performance of four available machines were evaluated to cut berseem and oats fodders. Machines included Agritec drum mower, Taj drum mower, Mobi cutter-windrower and AMRI sick bar. Cutting principles of all machines are described below.

Agritec drum mower

This is a side-mounted rotary machine rear the tractor. The machine cuts the fodder with rotary action. Two counter rotating drums having cutters at their bottom cut the fodder and push it back between the rotary drums. The drums were driven from the bottom and were free from the top. Three cutters were hinged at the bottom of each drum, which move freely. The power is transmitted to drums through belt and pulleys. The cutting swath of the machine was 1.25 m and can cut small fodders, such as berseem, lucerne, grasses and oats. The machine can be operated with a 50-hp tractor. Maximum rotation speed of drums was 2200 rpm at maximum PTO shaft speed (540 rmp) of the tractor. Agritec drum mower is shown in Figure-1.

Figure-1. Agritec drum mower.

Taj drum mower

Taj drum mower also consisted of two counter rotating drums having cutter on their periphery as shown in Figure-2. The machine was a side-mounted at the rear of the tractor. The working principle of this machines was same as that of Agritec drum mower. The drums were driven from the top and free from the bottom. The only difference from Agritech drum mower was its mode of drive. The drive was given to drums and cutters from the top frame of the machine, whereas in Agritec drum mower the power was transmitted from the bottom side. A 50-hp tractor was able to operate this machine. The cutting width of the machine was 1.6 m, which could cut small fodders, such as berseem, lucerne, oats and grasses. Maximum rotation speed of drums was 2200 rpm at 540 rpm of tractor PTO speed.

Figure-2. Taj drum mower.

Mobi cutter-windrower

This machine was self-propelled consisted of a 3.7-hp petrol engine to provide power to the machine Figure-3. The machine had forward, reverse and neutral gears. The overall cutting width of the machine was 1.2 m. The engine can be started pulling a rope wrapped inside at flywheel shaft. The power was transmitted from engine to the cutter bar through gear box and other transmission systems. The cutter bar moves to and fro inside the stationary guards by chain drive. The upper conveyor chain lugs rotate the star wheels. The star wheels are covered with tapered header shields which divide and guide the crop into the cutter bar. The star wheels hold and feed the crop into the cutter bar. The harvested fodder is transported vertically to the right side of the machine by chain conveyor. The harvested crop is laid down on the ground in the form of a windrow. A composite skid has been provided underneath the cutter bar assembly to prevent the machine from breakage and ploughing the ground. Both forward and cutter bar movements can be controlled by hand clutches. Right hand hook is the clutch, which can be engaged and disengaged for forward or reverse movement of the machine. The left hook can be used to engage and disengage the cutter bar.

Figure-3. Mobi cutter-windrower.

AMRI sickle bar

This was a side-mounted machine rear the tractor as shown in Figure-4. It was driven from the tractor PTO shaft. The design of this machine was very simple. Rotary motion of PTO was transformed into reciprocating motion of the sickle bar through belts and pulleys. The cutter reciprocates to and fro in the fixed guards and the cutter bar assembly floats on the ground while in operation. To and fro motion of the cutter bar cuts the crop at 7-10 cm height and lay down at back side over the cutter bar while machine advances forward. The machine can be operated with a 50-hp tractor and can cut a swath of 1.8 m.

Figure-4. AMRI sick bar.

Field testing of machines

All machines were commissioned to Remount Depot, Sargodha for comparison and comprehensive field performance evaluation. Two types of fodder crops were available at this site: oats and berseem. Test area under oats crop was 2-ha, whereas berseem fodder was available on 1-ha land. All test plots were marked in rectangular shape, which emphasised the ease of operation of machines and increased their performance. For fodder harvesting, circuitous pattern with rounded corners was used. Prevalent method of fodder cutting at Remount Depot, Sargodha, was manual cutting. They also had an old horse-operated sickle bar type fodder cutter to cut berseem and oats, which was not operational now. A plot size of 0.17 to 0.23 ha was selected for evaluating each machine for each fodder. Each machine was tested in two plots of oats and in one plot of berseem due to availability of crop and time. Machines were evaluated comprehensively and clogging, breakage, quantity of uncut fodder and ease for operator were determined. Before starting experiments, forward speeds of all machines was set by changing different field speeds. Finally, only single suitable forward speed was used for each machine during data collection.

Data collection

Data were collected on machine aspects, crop aspects and field performance aspects. Machine aspects included qualitative parameters, such as ease of operation, handling, transportation, adjustment, maintenance and level of safety. These parameters were measured qualitatively. Crop aspects included plant height, number of tillers per hill, stem diameter and plant density. Plant height was measured using a measuring tape. Number of tillers was measured from different locations of test plots. Diameter of stems was measured using a vernier callipers. Plant density was measured using a square bar frame. Each parameter was measured from 10 locations and then averaged to get mean results. Similarly, machine performance aspects included forward speed, theoretical field capacity, effective field capacity, field efficiency, fuel consumption and cost of operation. Machine performance parameters are described below:

Theoretical and effective cutting widths

Theoretical cutting width was measured before operation, whereas effective cutting width of each machine was measured in the field for five consecutive runs. Average of these measurements were taken to get effective cutting width.

Forward travelling speed

Two pegs were inserted on the field at 30 m distance. Time taken for travelling from first peg to the second peg was measured using a stop watch. The process was repeated three times and then averaged to calculate travelling speed.

Cutting height

Cutting height is an important parameter. The farmer never accepts a machine which cuts the fodder at a higher level from the ground. Therefore, machines were operated at minimum possible cutting height. The height of cut was measured for each machine from stubbles using a measuring tape after cutting the crop.

Theoretical field capacity

The performance of machine in ideal conditions is called theoretical field capacity, when no time is lost in unproductive operations and full width of machine is used without overlapping. The theoretical field capacity is determined using Equation 1 (Field and Solie, 2007; RNAM, 1995):

Effective field capacity

Effective field capacity is the actual performance of the machine in the field when both productive and unproductive times were summed up to determine its performance. Actual field capacity can be determined using Equation 2 (Field and Solie, 2007; RNAM, 1995).

Field efficiency

It is the ratio of actual field capacity and theoretical field capacity when expressed in percentage, which can be calculated using Equation 3.

Operating cost

Operating cost of machines was determined for comparing it with manual method. Operating cost consisted of fixed cost and variable cost. Fixed cost involved depreciation, interest, insurance, tax, and shelter, whereas variable cost involved labour, fuel and lubricant cost and repair and maintenance cost.

Fuel consumption

The tank was filled to full capacity before and after the test. Amount of refuelling after the test was the quantity of fuel consumption.

Labour requirement

The man-hours required for machine operation during the test were measured. The man-hours required for gathering the cut fodder and loading at the trolley and cutting headlands were noted during the test.

$$TFC = \frac{S \times W}{10} \quad (1)$$

$$EFC = \frac{A}{T_P + T_L} \quad (2)$$

$$\eta = \frac{EFC}{TFC} \times 100 \quad (3)$$

Where, *TFC* is theoretical field capacity (ha/h), *S* is forward speed (km/h), *W* is theoretical working width (m), *EFC* is effective field capacity (ha/h), *A* is total area actually covered by the machine (ha), T_P is productive time of the machine (h), T_L is the non-productive time or time lost (h) in turning and machine adjustment and η is the efficiency of the machine (%).

RESULTS AND DISCUSSIONS

Results of machine aspects are shown in Table-1. Handling, operation and adjustment greatly affect the performance of work. All machines were easy or manageable in handling, operation, adjustment and maintenance. However, Mobi reaper-windrower was rather difficult to operate in the field. The reason is that the machine is self-propelled and involves all control in hands, such as forward speed, cutter bar speed, turning and stopping. Major reason of this difficulty was the operator's skill to operate this machine. This machine was new for operator, therefore, it seemed difficult to operate. Once the operator grasps machine handling and operation techniques, it would be even easier than other machines. According to safety point of view all machines were safe in operation and no big safety problem was noticed. Transportation, repair and maintenance of all machines were also easy or manageable. All machines were reliable enough to avoid frequent breakdown.

Table-1. Data of machines regarding machine aspects.

Parameters	Agritec			Taj			Mobi			AMRI		
	G/E	A/M	P/D	G/E	A/M	P/D	G/E	A/M	P/D	G/E	A/M	P/D
Ease of handling/operation	✓				✓				✓		✓	
Adjustment	✓			✓					✓		✓	
Maintenance		✓		✓					✓		✓	
Safety	✓				✓			✓		✓		
Ease of transportation		✓			✓		✓				✓	
Local repair		✓			✓			✓		✓		
Defects and breakdown	✓				✓			✓			✓	

Note: Abbreviations: G/E = Good/Easy; A/M = Acceptable/Manageable and P/D = Poor/Difficult.

Results related to crop aspects are shown in Table-2. Both crops were mature and ready for cut. Results were averaged from all tests fields. Average plant height of berseem and oats was 74.4 and 159.5 cm, respectively. The height of berseem was ranged from 32 to 84 cm, whereas the height of oats was ranged from 90 cm to 180 cm. Number of tillers were more for berseem than oats. Diameter of stems of both fodders was alike as shown in Table-2.

Table-2. Average crop related parameters of berseem and oats fodders.

Crop parameters	Berseem	Oats
Plant height (cm)	74.4	159.5
Number of tillers per hill	8.4	4.7
Diameter of stem (mm)	4.1	4.3
Plant density per m^2	61	140

Theoretical and effective cutting widths

Theoretical and effective cutting widths of all machines are given in Table-3. Effective cutting width of all machines was smaller than the theoretical cutting width due to overlapping of swaths. AMRI sickle bar was the widest machine, which had an effective cutting width of 1.5 m. Mobi reaper had the smallest cutting width of 0.9 m.

Forward speed

Forward speeds of all machines were determined and summarised in Table-3. Speeds of machines were different for berseem and oats crops due to different crop conditions. Agritec drum mower was able to be operated from 2-8 km/h due to easy operation and good cutting mechanism, whereas other machines did not have such provision.

Cutting height

Cutting heights of all machines were different for both crops Table-3. Both Agritec and Taj rotary mowers were able to cut oats as well berseem, whereas Mobi reaper and AMRI sickle bar was not able to cut berseem crop.

Table-3. Forward speed, cutting width and cutting height of fodder cutters.

Machine	Cutting width (m)		Forward speed (km/h)		Cutting height (cm)	
	Theoretical	Effective	Oats	Berseem	Oats	Berseem
Agritec rotary mower	1.25	1.0	4.34	3.3	7.5	7.0
Taj rotary mower	1.65	1.4	3.5	3.1	6.3	6.0
Mobi reaper-windrower	1.2	0.9	2.5	-	10	-
AMRI sickle bar	1.8	1.5	3.0	-	5.5	-

Theoretical field capacity

Theoretical field capacity of all machines for cutting oats and berseem is shown in Table-4. This is the product of theoretical width and operating speed. For cutting oats, the theoretical field capacities of Agritec, Taj, Mobi and AMRI fodder cutters were 0.54, 0.58, 0.30 and 0.54 ha/h, respectively. For cutting berseem, the theoretical field capacity was 0.41 and 0.51 for Agritec and Taj rotary cutters, respectively. Mobi and AMRI fodder cutters were not able to cut berseem due to clogging reason.

Effective field capacity

Effective field capacities of all machines were lower than the theoretical field capacities Table-4. The reason is that the actual work in the field involves a lot of non-productive time, such as time lost in turning, clogging and adjustment. For oats crop, the effective field capacities of Agritec, Taj, Mobi and AMRI fodder cutters were 0.35, 0.33, 0.16 and 0.28 ha/h, respectively. Similarly, for berseem crop, the effective field capacity of Agritec and Taj fodder cutters were 0.25 and 0.30 ha/h, respectively. Actual working time in the field is not a constant parameter. It varies mainly with the geometry of field, skill of operator, machine forward speed and crop and soil conditions at the time of harvest.

Field efficiency

Field efficiency of all machines was less than 65 % for cutting both oats and berseem. Agritec rotary fodder cutter exhibited the highest field efficiency (64.8 %). This machine did not waste any time in clogging, whereas other machines spent considerable time in clogging. Similarly, the lowest field efficiency was noticed for AMRI sickle bar, which was 51.8 %. The lower field efficiency of this machine is attributed to the time lost in turning, clogging and adjustment as has been reported previously (Field and Solie, 2007; RNAM, 1995). Field efficiencies of all fodder cutters were reasonably lower than other field implements. The reason behind this fact is that the performances of these machines need to be improved by incorporating necessary modifications. The machines should be reliable enough to work for hours in the field without any trouble. It is also envisaged that less time is wasted in turning by adopting circuitous pattern in the field. The skill of the operator is very crucial in lowering the performance of a machine. He should operate a machine by wasting minimum time in turning and should use maximum width of the machine without overlapping. Mobi reaper-windrower and AMRI sickle bar were not suitable for cutting berseem. AMRI sickle bar was clogged in berseem due to ploughing of soil, whereas Mobi reaper-windrower was also clogged in berseem because it was not able to convey cut berseem aside for making a windrow. For cutting berseem, higher speeds were not possible due to moist soil. Both rotary cutters cut berseem crop smoothly.

Cost of operation

Operating cost of all machines was determined to assess their economic feasibility Table-4. The operating cost was determined based on the man-hours required, hourly cost of labourers, fuel and input costs and other fixed costs. The operating cost for cutting oats was Rs. 2074, Rs. 2165, Rs. 3187 and Rs. 2115 for Agritec, Taj, Mobi and AMRI fodder cutters, respectively. The highest cost was for Mobi reaper. It involved more repair and adjustments and the initial cost of the machine was also higher. Manual fodder harvesting cost for oats was more than Rs. 6000 per hectare and the drudgery of finding huge labour is another big issue. Timely harvesting of fodder crop was very difficult to ensure timely cutting of fodder using manual labour.

Fuel consumption

Fuel consumption of all machines varied depending upon the gear used. For cutting oats, the average fuel consumption was about 11.5 l/ha for Agritec, Taj and AMRI fodder cutters. Mobi reaper-windrower used 9.5 l/ha for cutting oats. For cutting berseem, Agritec rotary used 14 l/ha and Taj used 12.7 l/ha.

Table-4. Field performance results of all fodder cutters for oats and berseem.

Crop	Parameters	Agritec rotary	Taj rotary	Mobi reaper	AMRI sickle bar
Oats	Test area (ha)	0.22	0.23	0.18	0.19
	Theoretical field capacity (ha/h)	0.54	0.58	0.30	0.54
	Effective field capacity (ha/h)	0.35	0.33	0.16	0.28
	Field efficiency (%)	64.8	56.9	53.3	51.8
	Operating cost (Rs./ha)	2074	2165	3187	2115
Berseem	Test area (ha)	0.17	0.18	-	-
	Theoretical field capacity (ha/h)	0.41	0.51	-	-
	Effective field capacity (ha/h)	0.25	0.30	-	-
	Field efficiency (%)	59.7	58.5	-	-
	Operating cost (Rs./ha)	2638	2576		

Note: All field tests were carried out in two plots of oats and one plot of berseem. Average results are given in Table-4.

The labour input for cutting one hectare of a fodder crop was also determined. Three persons were engaged in gathering cut fodder and loading on to a cart and two men were engaged for cutting headlands. The total man-hours for operating machine, gathering cut fodder, cutting headlands and loading the crop are shown in Table-5. The results were the average of two tests. Manual cutting of oats and berseem required 110 and 95 man-hours per hectare, respectively, whereas the machines can reduce this labour up to 70-80 %. Timely cutting of a crop is also ensured using fodder cutters.

Table-5. Man-hours required for different operations for all machines.

Name of machine	Oats				Berseem			
	Operator	Cutting headlands	Gathering and loading	Total	Operator	Cutting headlands	Gathering and loading	Total
Agritec rotary mower	2.9	15.5	8.0	26.4	4.0	12.2	5.7	21.9
Taj rotary mower	3.0	16.3	7.0	26.3	3.3	12.0	5.5	20.8
Mobi reaper	6.3	12.7	7.0	26.0	-	-	-	-
AMRI sickle bar	3.3	18.2	10.5	32	-	-	-	-
Manual using sickle	-	-	-	110	-	-	-	95

Recommendations

The performance of Agritec rotary mower was better than other fodder cutters for cutting oats as well as berseem Figure-5. No frequent clogging or choking was observed during field testing. It can cut a swath of 1.0 m from the right side of the tractor. The height of cut was also acceptable by the farmer, which was about 7 cm. It can cut berseem, oats and short sorghum. The machine can be operated up to 8 km/h field speed. The only drawback of this machine was its shorter width than tractor wheels. The swath of this machine must be a bit wider so that the tractor could not smash the cut fodder in the next run.

Figure-5. Agritec rotary mower cutting oats.

Taj rotary mower performed well for cutting oats and berseem just like Agritec rotary mower. Its effective cutting width was 1.4 m and the cut fodder was not quenched with the rear wheels of the tractor. The machine was somewhat heavier than the Agritec mower and intensive care was involved in its operation Figure-6. It can cut berseem, oats, small sorghum and barley. It makes a band of 0.6 m of cut fodder in between the drums at rear side of the machine. Its belt and pulleys should be covered with a casing to avoid fatal accidents.

Figure-6. Taj rotary mower cutting oats.

Mobi reaper cut the oats very good Figure-7. It cut the crop and made a smooth windrow at right side of the machine. The machine comprised a number of systems such as power, power transmission, forward movement, cutter bar movement and cut fodder movement. Therefore, the machine was a bit complicated and its maintenance was difficult. Similarly, initial cost of the machine was also higher than other machines, which was not affordable to small farmers. The machine can cut oats, or barley very well, but cannot cut berseem. The height of berseem is too low to be cut and conveyed aside by the star wheels. This machine is advantageous over all other machines because it is manually operated and tractor does not damage roots of fodder for the next cut, provided the machine offers less maintenance and adjustments.

Figure-7. Mobi reaper-windrower cutting oats.

AMRI cutter bar was suitable to cut long fodders Figure-8. Due to reciprocating motion of the cutter bar, the cut and uncut fodder/grass was stuck in the cutter bar frequently and choked the machine. The reason is that the cutter bar cannot flow back the cut fodder due to absence of a pushing mechanism. Cut fodder was also wrapped by the PTO shaft of the machine, which caused machine clogging and choking frequently. Two men were also required to remove the cut fodder immediately to clear the tractor passage for the next pass, otherwise the tractor would destroy the cut fodder. The machine was not suitable for heavy oats or berseem as its cutter bar clogged into these crops. The far end of the cutter bar tilted back at an angle and the other end touched the rear tractor tyres, which was also very dangerous. The machine was suitable to cut long fodders, such as maize, sorghum, barley and thin oats. Small fodders like berseem was difficult to cut using this machine.

Figure-8. AMRI sickle bar cutting oats.

CONCLUSIONS

The performance of four types of locally available fodder cutters was evaluated in the field for cutting oats and berseem fodders. These fodder cutters included Agritec rotary mower, Taj rotary mower, Mobi reaper-windrower and AMRI sickle bar. Agritec and Taj rotary mowers were suitable for cutting both berseem and oats. Mobi reaper-windrower and AMRI sickle bar were only suitable for cutting oats and other long fodders. Agritec rotary machine was the best for cutting berseem as well oats. Using fodder cutters, cutting time and cost of operation can be decreased up 70-80 % as compared with manual cutting. For dairy farming, suitable fodder cutters should be promoted in the country for speedy work. However, reliability of machine is the prerequisite for commercialisation of a machine.

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