FUEL CONSUMPTION EVALUATION OF DIFFERENT FORAGE HARVESTING IMPLEMENTS USED FOR THE HARVESTING OF RHODES GRASS

Imran Arshad[1], and Ali Raza Shah[2]
[1]Star Services LLC, Abu Dhabi, United Arab Emirates,
[2]Sindh Agriculture University, Tandojam.
Corresponding author E-mail: engr_imran1985@yahoo.com

ABSTRACT: *The present study was conducted to evaluate the fuel consumption of different forage implements during harvesting of Rhodes grass at 50% flowering for different speed of operation i.e. engine speed (1/3rd, 2/3rd, and Full) respectively. Three different sets of forage harvesting implements was used during harvesting operations i.e. for cutting C-NH (Changfa 85 hp tractor with New Holland H6000 Series Mower Implement), for raking M-NH (Massy Ferguson 75 hp tractor with New Holland 260 Hay Rake Implement) and for baling M-C (Massy Ferguson 120 hp tractor with Challenger LB 34 Series Big Baler Implement) respectively. The results revealed that in all cases increase in engine speed decreased the time requirement of the specific field operation however; the fuel consumption was recorded more. Among the three discussed scenarios the engine speed of 2/3rd was found more economical to harvest Rhodes grass as it save good amount of fuel and time respectively.*

Keywords: Rhodes Grass, Fuel Consumption, Effective Field Capacity, Tractor, Mower Machine, Racking Machine, Big Baler, Agriculture.

INTRODUCTION

Farmers can consider several factors to overcome the fuel consumption i.e. reduce number of operation, match implement to tractor size, speed, combine field operations, alternative implements of similar operations, field efficiency, depth of tillage, crop conditions, and machine conditions etc. Initially the fuel consumption can be analyzed by calculating that how much fuel is being utilized for a particular field operation [1]. It can be simply done by filling the fuel tank of the tractor before an operation starts, and after completion of one acre / hectare by refilling the fuel tank to verify the liters of fuel used. The number of liters used by the tractor divided by the number of acres covered gives use in liters per acre [2]. Fuel savings can also be done if the implement matched with the tractor size. According to past studies it has been observed that if tractor can pull implement in the 5 to 13 kilometer per hour range than farmer may able to save good amount of fuel [3]. Speed is another parameter which can play a pivotal role in saving fuel. The fuel consumption will be more if the speed of field operation is fast and vice versa.

However, tractors should not drive with slow speed just to save fuel, as time requirement to finish field operations is also having more importance. If the size of the tractor and implements are matching then the normal range of operating speeds 6.5 to 11 KPH may save good amount of fuel for the farmers [4]. Good maintenance of the tractor can also save fuel consumption upto some extant as the condition of tractor and other farm implements can directly affect the fuel efficiency of the machines [5]. Therefore, farmers should change oil, fuel and air filters on regular basis as prescribed by the manufacturer; routine check for carburetor settings, fuel bowls and other fuel related components should to be followed eagerly, knives on forage harvesters, mowers, and other equipment should be checked on daily basis during peak season, lubrication of tractors and other implement should also followed on regular basis, and to avoid more wheel slippage tractors and tires should also maintained etc [6].

A crop condition also plays an important role in saving fuel consumption. The increase of fuel usage was observed while harvesting too wet or stiff crops. Under best possible crop and field conditions appropriate implement adjustment and harvest can result in fuel efficiency [7]. The procedure of making hay seems to be very easy but in reality it is not [8]. In general, to make hay, initially the forage has to be mowed with mower implement, and then it is allowed to dry, then it is going to be rake and finally baled with baler machine. The hay should to be harvested when protein and digestible nutrients reached at its desired level before plant get fully matured i.e. 25% to 50% flowering stages [9]. In present study the fuel consumption of different forage implements during harvesting of Rhodes grass at 50% flowering were determined at different engine speed of (1/3rd, 2/3rd, and full) to recommend proper method for use of tractor-implement system for better performance and fuel consumption.

MATERIALS AND METHODS

1. Land Preparation and Rhodes Grass Production

The comparative study to find out the fuel consumption of different forage harvesting implements was conducted in March (2015 / 2016) in Jam Farms, Tando Adam, Sindh – Pakistan. The study was conducted in sandy clay loam soil having average hydraulic conductivity (3.6×10^{-2}) and porosity (0.42) respectively. The layout of the experiment was split plot design with 3 replications. Altogether total nine plots were prepared and the main plots and there replicates given the name 1/3rd speed operation, 2/3rd speed operation, and full speed operation respectively. Each plot was having size one acre approximately. With the objectives to achieve precise results each plot was prepared in rectangular shape with dimension (101m x 40m). Rhodes grass cultivar source from Australia i.e. Finecut was used during this research work. In preliminary step the experimental site was prepared by using two split crosswise cultivator operations supplemented with rotavator to ensure uniform distribution of irrigation water and weeds and extra grass removal. The land was then rough leveled by tractor with front and rear blade to maintain a well prepared seedbed. Finally, with the help of border maker the prepared land was divided in to small sub-plots to carry out the research study. The Rhodes grass seeds

were sown at the rate of 10 kg/ acre in the prepared land and Phosphorous fertilizer dose applied at sowing accordingly. Nitrogen was applied in split doses by broadcasting. First irrigation was applied after sowing and 2nd irrigation applied after ten days from 1st irrigation respectively. In all plots total three irrigations were applied with the interval of ten days except for 1st cutting. Total three cuts were obtained during the study period and all three cuts were harvested at 50% flowering stages respectively.

2. Rhodes Grass Harvesting

In order to harvest Rhodes grass different sets of forage harvesting implements were used during harvesting operations. Initially for the cutting operation C-NH (Changfa 85 hp tractor with New Holland H6000 Series Mower Implement) was used during early afternoon hours and then grass was left for natural sun drying till next day. Then next day during late morning hours the raking operation was performed at 15% moisture within the grass by using M-NH (Massy Ferguson 75 hp tractor with New Holland 260 Hay Rake Implement) respectively. Once the raking operation was finished then hay bales was prepared with the help of M-C (Massy Ferguson 120 hp tractor with Challenger LB 34 Series Big Baler Implement) respectively.

3. Fuel Consumption

Before performing operations in all fields, the fuel tank of each tractor with different implements was filled with fuel (diesel) upto brim. After finalizing the operation per acre, the fuel was filled again in the tank with the help of 1,000 mm graduated cylinder upto initial level and the additional fuel which was filled at this time was measured accordingly. The fuel consumption was computed in liters per hour and liters per acre and the effective field capacity (EFC) of the implements was measured in acre per hour respectively. (Figure 1.1 – Figure 1.5) describes the overall harvesting operations flowed during this research study.

Figure 1.1. Rhodes Grass Cutting Operation with C-NH

Figure 1.2. Rhodes grass racking operation with M-NH

Figure 1.3. Rhodes grass after racking operation and natural sun drying

Figure 1.4. Rhodes grass baling operation with M-C

Figure 1.5. Ready bales coming out from the rear end of big baler machine.

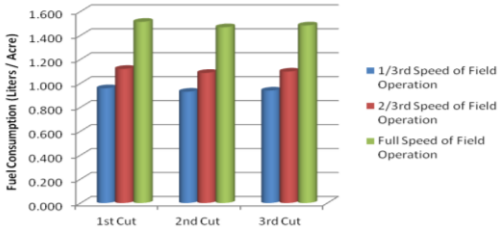

Figure 2.1. Comparison of fuel consumption (liter per acre) of C-NH at different speed of field operations

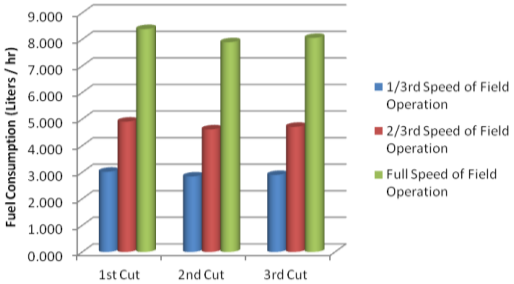

Figure 2.2. Comparison of fuel consumption (liter per hour) of C-NH at different speed of field operations

RESULTS AND DISCUSSION

The study was carried out to evaluate the fuel consumption of different forage implements during harvesting of Rhodes grass at 50% flowering for different speed of operation (1/3rd, 2/3rd, and Full) respectively. The critical gathered observations and data during the research study are appended below:

Fuel Consumption and Effective Field Capacity

1. C-NH (Changfa 85 hp tractor with New Holland H6000 Series Mower Implement)

According to the results obtained it has been observed that at 50% flowering stage the average fuel consumption of all three cuttings for C-NH at 1/3rd, 2/3rd, and Full speed of field operation was (0.942, 1.101, and 1.488 liter per acre) and (2.918, 4.743, and 8.112 liter per hour) respectively. The fuel consumption trend was increasing with the increase in speed of field operation. However, the time requirement to finish one acre was found more with 1/3rd as compared to 2/3rd and full engine speed (Figure 2.1 and Figure 2.2). Similar findings were reported by [10] for Alfalfa harvesting.

Likewise, the average effective field capacity of all three cuttings for C-NH at different engine speed i.e. 1/3rd, 2/3rd, and Full speed was found to be 3.098 acre per hour, 4.306 acre per hour, and 5.452 acre per hour respectively. The detailed results of C-NH for all three cuttings are elaborated in Table 1. The results confirmed that the maximum EFC can be attained by operating the cutting operation with full speed however, for the safe keeping and durability of tractor and implement the most suitable operational speed could be 2/3rd as it seems to be more economical from fuel and time saving point of view (Figure 2.3). Similar results were obtained for EFC for Rhodes grass by [13].

Table 1. Fuel consumed by C-NH during cutting of Rhodes grass at different speed of field operation.

S. No	Fuel Consumption of Changfa 85hp tractor (New Holland H6000 Series Mower Implement)								
	1st Cutting			2nd Cutting			3rd Cutting		
Speed of Field Operation	Lit / hr	Lit/ acre	Acre/hr	Lit / hr	Lit/ acre	Acre/hr	Lit / hr	Lit/ acre	Acre/hr
1/3rd	3.018	0.958	3.150	2.839	0.929	3.056	2.898	0.939	3.087
2/3rd	4.904	1.120	4.379	4.614	1.086	4.247	4.710	1.098	4.291
Full	8.388	1.513	5.544	7.892	1.468	5.378	8.056	1.483	5.433
Mean	5.437	1.197	4.358	5.115	1.161	4.227	5.221	1.173	4.270

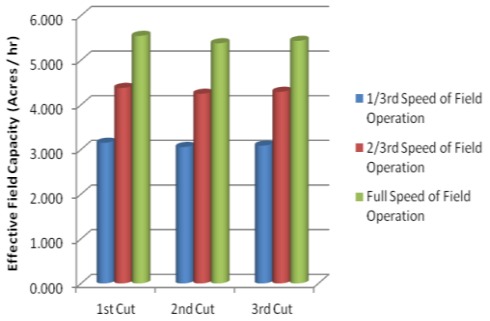

Figure 2.3. Comparison of Effective Field Capacity (Acres / hr) of C-NH at different speed of field operations

2. M-NH (Massy Ferguson 75 hp tractor with New Holland 260 Hay Rake Implement)

The results indicated that the average fuel consumption during raking of Rhodes grass in all three cuttings for M-NH at 1/3rd engine speed was (0.663 liter per acre and 3.090 liter per hour), at 2/3rd (0.813 liter per acre and 5.495 liter per hour) and at full speed (1.148 liter per acre and 8.345 liter per hour) respectively. The fuel consumed during racking operation by M-NH at 1/3rd engine speed was found less as compared to 2/3rd and full speed (Figure 2.4 and Figure 2.5). These results were according to the observation of [09, 11], who also observed the variation of fuel consumption in Rhodes grass during raking operation.

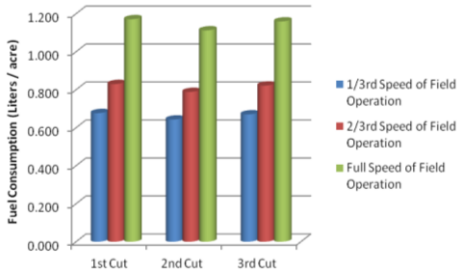

Figure 2.4. Comparison of fuel consumption (liter per acre) of M-NH at different speed of field operations

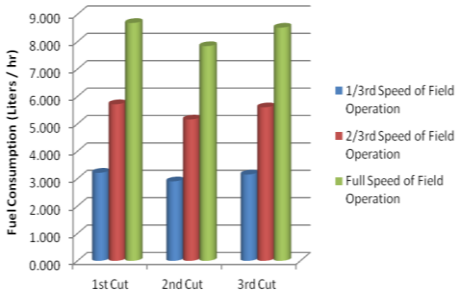

Figure 2.5. Comparison of fuel consumption (liter per hour) of M-NH at different speed of field operations

Through field data it has been observed that an area of one acre at different engine speed (1/3rd, 2/3rd, and full speed) was raked in average time of 12.889 minutes, 8.886 minutes, and 8.254 minutes which produced the effective field capacity of 8.316 acre per hour, 6.821 acre per hour, and 4.703 acre per hour respectively (Figure 2.6). The detailed results of M-NH for all three cuttings are elaborated in Table 2.

Table 2. Fuel consumed by M-NH during raking of Rhodes grass at different speed of field operation.

S. No	Fuel Consumption of Massy Ferguson 375 (75hp) tractor (New Holland 260 Hay Rake Implement)								
	1st Cutting			2nd Cutting			3rd Cutting		
Speed of Field Operation	Lit / hr	Lit/ acre	Acre/hr	Lit / hr	Lit/ acre	Acre/hr	Lit / hr	Lit/ acre	Acre/hr
1/3rd	3.216	0.677	4.750	2.902	0.643	4.513	3.152	0.670	4.703
2/3rd	5.719	0.830	6.890	5.161	0.789	6.546	5.605	0.822	6.821
Full	8.685	1.171	7.417	7.838	1.112	7.046	8.512	1.159	7.343
Mean	5.873	0.893	6.352	5.301	0.848	6.035	5.756	0.884	6.289

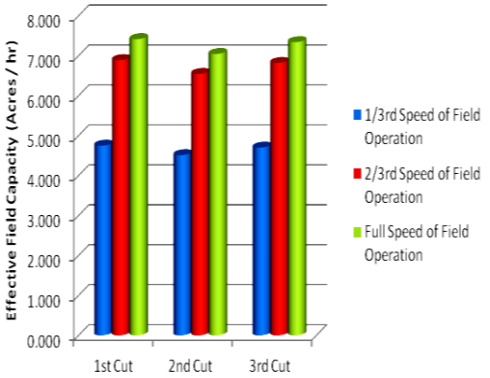

Figure 2.6. Comparison of Effective Field Capacity (Acres / hr) of M-NH at different speed of field operations

3. M-C (Massy Ferguson 120 hp tractor with Challenger LB 34 Series Big Baler Implement)

According to the results obtained it has been observed that the average fuel consumption during bales packaging operation for M-C at 1/3rd was (1.559 liter per acre and 4.540 liter per hour), at 2/3rd (1.993 liter per acre and 7.322 liter per hour) and at full speed (2.842 liter per acre and 11.076 liter per hour) respectively. Throughout the bales packaging operation the moisture was kept under 15%. The fuel consumption trend was increasing from 1/3rd engine speed to 2/3rd engine speed and full speed (Figure 2.7 and Figure 2.8). The overall minimum fuel consumed with 1/3rd of engine speed but time consumption was found more. As baler implement is a very expansive implement therefore, if it is operated with full speed for baling huge number of area the durability of the implement may suffers. It has also observed that with 1/3rd and 2/3rd engine speed the bales produced with strong and proper tinning while, with full engine speed loose bales was observed. Once again the most economical engine speed was found to be 2/3rd as with this speed fuel consumption was found less and produced more tons of hay per hour.

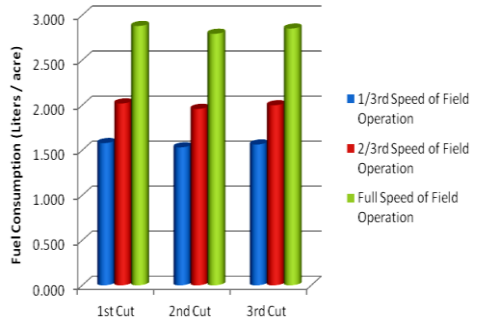

Figure 2.7. Comparison of fuel consumption (liter per acre) of M-C at different speed of field operations

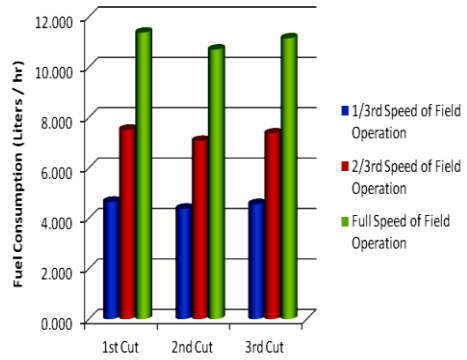

Figure 2.8. Comparison of fuel consumption (liter per hour) of M-C at different speed of field operations

The effective field capacity of M-C was calculated through the actual field data i.e. the number of tons of hay baled per hour. It has been observed that an area of 1 acre (1/3rd, 2/3rd, and full speed) was baled in the average time of 19.423 minutes, 16.783 minutes, and 14.510 minutes and produced the (EFC) 3.089 tons per hour, 3.587 tons per hour, and 4.135 tons per hour respectively (Figure 2.9). The overall average weight of bales in all cutting was observed to be 1.061 tons per acre. The detailed results of M-C for all three cuttings are elaborated in Table 03. These results were according to the observation of [12, 13], who also observed the variation of fuel consumption in Rhodes grass for the dry fodder yield.

Table 3. Fuel consumed by M-C during baling of Rhodes grass at different speed of field operation.

S. No	Fuel Consumption of Massy Ferguson 120hp Tractor (Challenger LB 34 Series Big Baler Implement)											
	1st Cutting				2nd Cutting				3rd Cutting			
Speed of Field Operation	Lit / hr	Lit/ acre	Acre/hr	*Bales Produce Tons / hr	Lit / hr	Lit/ acre	Acre/hr	*Bales Produce Tons / hr	Lit / hr	Lit/ acre	Acre/hr	*Bales Produce Tons / hr
1/3rd	4.663	1.580	2.951	3.131	4.387	1.533	2.862	3.037	4.570	1.564	2.921	3.100
2/3rd	7.520	2.202	3.415	3.623	7.075	2.136	3.313	3.515	7.370	2.180	3.381	3.587
Full	11.376	2.880	3.950	4.191	10.704	2.794	3.832	4.065	11.150	2.851	3.911	4.149
Mean	7.853	2.221	3.439	3.648	7.389	2.154	3.336	3.539	7.697	2.198	3.404	3.612

*Overall average weight of bales per acre was recorded 1.061 tons/ acre in all three cuttings.

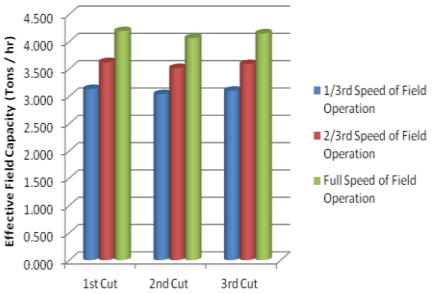

Figure 2.9. Comparison of bales produced during baling (Tons / hr) of M-C at different speed of field operations

CONCLUSIONS

On the basis of results obtained throughout the research period for C-NH, M-NH, and M-C; it can be concluded that for all cases increase in engine speed decreased the time requirement of the specific field operation however, the fuel consumption was recorded more. Among the three discussed scenarios the engine speed of 2/3rd was found more economical to harvest Rhodes grass as it save good amount of fuel and time respectively. While harvesting large area i.e. more than 100 acres per day, the tractors should not be driven with 1/3rd of speed just to save fuel as time requirement to finish the operation within the specific time is considerably greater. Likewise, as baler implement is a very expansive implement therefore, if it is operated with full speed for baling huge number of area the durability of implement may suffers and chances of having loose bales will be more. In the light of above findings it is suggested to the Rhodes grass growers that harvesting of Rhodes grass should be done at 2/3rd of the engine speed in all field operations as this speed will save fuel and time respectively.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Jam Farms, Tando Adam representatives especially to Mr. Jam Madad Ali the owner of the farm for allowing this research to be carried out on his farm, and Mr. Jam Zaheer Ali for his kind assistance throughout the research study; and all other individuals who have been source of help throughout the research period.

REFERENCES

[1] Zane, R. H. "Fuel Requirements and Energy Savings Tips for Field Operations". *A fact sheet, presented by Rutgers, Cooperative Extension Station N.J Agricultural Experiment Station, New Jersey,* 1-4 (2007).

[2] Goyal, S., S. Samsher, S. Chandra. "A Study on Fuel Consumption and Work Performance of different Tractors with Tillage Implements". *Journal of Agricultural Engineering,* **50**(2): 270-274 (2010).

[3] Kepner, R. A., R. Baine, E. L. Bager. "Principles of Farm Machinery". *A technical article published by C.B.S. Publishers and Distributors, New Delhi,* **1**(1): 26-37 (2000).

[4] Goyal, S., I. Mani, U. Singh, V. Upendra. "Fuel Consumption Pattern of Tractor-Implement System at Pat Loads under Different Field Conditions". *Journal of Agricultural Engineering,* **43**(3): 66-70 (2006).

[5] Adewoyin, A. O. "Fuel Consumption Evaluation of Some Commonly Used Farm Tractors for Ploughing Operations on the Sandy-loam soil of Oyo State, Nigeria". *Research Journal of Applied Sciences, Engineering and Technology,* **6**(15): 2865-2871 (2013).

[6] McLaughlin, N.B., L.C. Heslop, D.J. Buckley, G.R.St. Amour, B.A. Compton, A.M. Jones, P. Van Bodegom. "A General Purpose Tractor Instrumentation and Data Logging System". *Trans. Journal of American Society of Agricultural Engineers*, **36**(2): 65-273 (1993).

[7] Barnes, R.F., C.J. Nelson, M. Collings, K.J. Moore. "Forages - An Introduction to Grassland Agriculture". *Iowa State Press. Ames, IA,* (2003).

[8] Adewuyi, S.A., O. F. Ashaolu, I. A. Ayinde and S. O. Ogundele. "Determinants of Farm Mechanization among Arable Crop Farmers in Ibarapa Zone, Oyo State, Nigeria". *Moor J. Agric. Res.*, **7**(1): 49-55 (2006).

[9] Arshad, I. "Performance of Different Rhodes Grass Varieties under the Agro-Climatic Conditions of Sindh, Pakistan". *International Journal of Research and Applied Science and Engineering and Technolgy*, **3**(7): 145-151 (2015).

[10] Arshad, I., W. Ali, Z. A. Khan, W.A. Bhayo. "Effect of Nitrogen and Phosphorus on the Growth and Yield of Alfalfa (Medicago sativa L.) under Agro-Climatic Conditions of Tando Adam". *PSM Biol. Res.*, **1**(2): 69-73 (2016).

[11] Shah, A. R., T. Mashooque, L. Mahmood, S. M. Ali, A. Memon, S. A. Shakeel, S. Majeeduddin. "Fuel Consumption and Operational Cost of Various Tillage Implements". *Sci.Int. (Lahore)*, **28**(3): 2651-2653 (2016).

[12] Al-Suhaibani, S.A., A. E. Ghaly. "Effect of Ploughing Depth of Tillage and Forward Speed on the Performance of a Medium Size Chiesel Plow Operating In a Sandy Soil". *Am. J. Agric. Biol. Sci.*, **5**(3): 247-255 (2010).

[13] Arshad, I., W. Ali, Z. A. Khan, W. A. Bhayo. "Effect of Water Stress on the Growth and Yield of Rhodes Grass (Chloris gayana. L. Kunth.)". *PSM Biol. Res.*, **1**(2): 58-61 (2016).