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The Influence of Blade Types and Forward Speed on the Performance of the MURRAY-15.5hp Lawn Mower

A.R.H.A. Mashhadani, S.B.S.A. Badri

Department of Agriculture Machines and Equipment, College of Agriculture Engineering Sciences, University of Baghdad, Iraq, abd.ahmed2103m@coagri.uobaghdad.edu.iq,
Department of Agriculture Machines and Equipment, College of Agriculture Engineering Sciences, University of Baghdad, Iraq, samir.albadri@coagri.uobaghdad.edu

THE INFLUENCE OF BLADE TYPES AND FORWARD SPEED ON THE PERFORMANCE OF THE MURRAY-15.5HP LAWN MOWER

Abstract: A field experiment was conducted to design, implement, and test the effects of blade type represented by cutting angle and forward speed on the performance of a MURRAY-15.5hp lawn mower machine. Three types of blades with cutting angles of 20o, 25o, and a straight angle with three forward speeds of 2.99, 4.32, and 5.60 km h-1. The slippage percentage, field and cutting efficiencies, and fuel consumption were also studied. The results indicate that decreasing the cutting angle from 25o to 20 o and then to a straight angle considerably decreases the slippage percentage and significantly decreases fuel consumption. In addition, there was a significant increase in field and cutting efficiency. Increasing the forward speed resulted in a significant increase in the slippage percentage and decrease in the field and cutting efficiencies. The interaction between the straight blade type and the forward speed at 2.99 km h-1 led to the lowest slippage at 8.34%, the highest field efficiency at 81.56% and the highest cutting efficiency at 40.00%, whereas the interaction between the straight blade type and forward speed 5.60 km h-1 resulted in the lowest fuel consumption at 4.33 liters ha-1.

Keywords: Blade, Cutting efficiency, Forword speed, Fuel consumption, Field efficiency, Lawn Mower, Slippage percentage.

Introduction

Gardens consider the lungs of the city because it is necessary to keep them nice and clean by trimming them. In the past humans did this work, but today machines do that because the green areas occupy a large space in any garden, reaching up to 70% or more depending on the type of garden and its purpose. Most plants in these gardens belong to the Gramineae family and differ in shape and characteristics. They may be annual or perennial, creeping or standing and growing alongside each other with dense branches and leaves that spread quickly to cover all the ground on which they grow, forming green spaces (Al-Qaii & Alamuddin, 2004). However, they share some characteristics that enable them to withstand agricultural treatments, such as pruning and levelling, because the area of growth and extension in the leaves is concentrated in their lower parts, enabling the plant to grow and compensate for what has been due to cutting (Shaheen, 2008).

Therefore, agricultural machinery, including lawn mowers, has gained importance. It is one of the sections of animal production machinery and has been used to cut green areas.for ornamental and aesthetic purposes and for the development of recreational places (Jassem, 2021). Machines are produced specifically for cutting fodder crops and grasses in green areas. These cutting devices have been diversified and developed according to the nature and needs of the farmers, including several designs and shapes, each with technical and engineering specifications. One such device is the rotary mower, a type of cutting machine that includes the following components:
Cutter-Bar Mower: A type of hay mower that uses a reciprocating blade to cut grass or hay. 2- Disc Mower: This type of hay mower has been used in recent years for its features, including ease of use due to the absence of complex regulations specific to it, as well as ease of maintenance and transmission and its high productivity rates (Al-Ani, Al-Ani & Al-Khafaf, 2006).

Edwin Budding, an English textile worker who lived in Thrupp, created the first lawnmower in 1827. The budding mower was constructed to mow grass on vast gardens and sports grounds (Bellis, 2010). The cutting section is the most important factor for determining the cutting process (Anonymous, 2011). A serrated edge blade will drag up most of the vine and the stem to the mower and then slash them, which is advantageous for clearing the area for the digger and making it easy to harvest (Kakahy *et al.*, 2014). Knives with worn or outdated blades may have diminished power (El-Baily, 2022). The impact of gas emissions from burned fuel into the atmosphere and the ongoing rise in the price of gasoline when operating an engine (Soyoye, 2021). This may be related to hardness edges which impact wear (Tekeste *et al.*, 2022) and corrosion (Alwan, Fayyadh & Khalid, 2019), leading to vibration of the machine during operation (Abbood, Abbood & Jasim, 2018).One type of agricultural equipment that can consume excessive amounts of energy is the lawnmower (Hosseini & Shamsi, 2012). When the lawn is dry before mowing, more grass can be cut with less effort (Nkakini & Yabefa, 2014).

As stated in, (Al-Azzy, 1980) and (Al-Khaffaf & Hassan, 1975) mentioned that when agricultural machinery is not used, the operating costs of such machinery constitute a significant proportion of total agricultural costs. Research objectives: To determine the best combination of blade type and forward speed for the MURRAY 15.5hp grass mower to reduce fuel consumption.

Materials and Methods

1- *Materials*:

The following materials were used in the field experiment:

1-1- Riding Mower: A MURRAY-15.5hp American-made reel mower model 2010 was used, as shown in Figure (1).

1-2- Cutting blades: The cutting blades were fabricated at different angles from the standard blade angles. The first blade, which is the standard blade available for the lawn mower, has a slanted cutting angle (25^o), referred to as T1. The second blade had a slanted cutting angle (20^o), referred to as T2. The third blade had a straight cutting angle and was referred to as (T3). The blades of both types T2, T3 were fabricated locally in a blacksmith workshop under the supervision of a specialized blacksmith with precise measurements. The blades were fabricated using the same steel used for the standard blade, as shown in Figure (2).

1-3- Fuel Consumption Measurement Device

The fuel consumption measurement device consisted of a graduated plastic cylinder (1000 ml) equipped with a valve and set of rubber tubes, as shown in figure (3). This device was connected to a lawn mower and attached to the main fuel pump through tubes.

Figure 1: The MURRAY -15.5 mower which was used in the experiment.

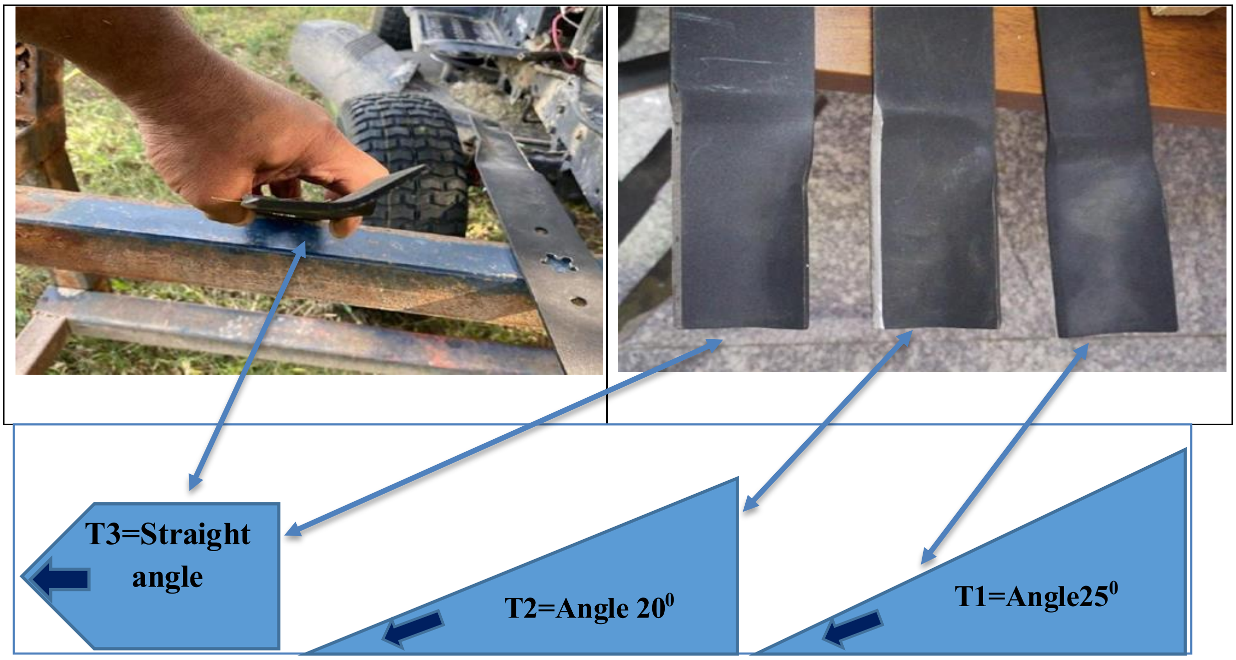

Figure 2: The shapes and angles of the blades of the cutting knives in the mower which was used in the experiment.

Figure 3: Fuel consumption device

Table 1: Specifications of the lawn mower used.

Type, Made, Year	Murray, USA, 2010
Serial no.	072610 C001224
Cylinder no.	1
Cooling system	Air
Engine power H. P	15.5
Starting system	Key switch - super glow

Fuel tank (L)	Gasoline 5
Type suspension seat	Mechanical spring
Speeds no.	6 forward and 1 rear
Cutting width (inch)	42
Tires front size	15. 6.00-6 NHS
Tires front and rear pressure (psi)	20
Tires rear size	20. 8.00-8NHS

2- *Work methods*

2-1- Experimental field:

The experiment was conducted via a Split-Plot arrangement according to the randomized complete block design (RCBD). Three replicates were used. The three blade types were allocated to the main plot, and forward speeds were allocated to the sub-plots. The averages of the treatments were compared using the least significant difference (LSD) test at a probability of 0.05.

This study was conducted at Al-Bustan Park, one of the gardens of the Umm Al-Qura Mosque site, locate in Al-Ghazaliyah district, Baghdad governorate, for the summer season of 2022 in the tenth month of the green lawn, which is composed of American Bermuda grass (*Cynodon dactylon*), with a 4500 square meter space. A 3200 square meter plot of ground that was 80 meters long and 40 meters wide was used as an experimental field. The experimental field was divided into blocks of 3x20 m

2-2- Experimental Design:

Two factors were used: the first factor represented a main plot with blades of three angles:

1- The standard blade was tilted at an angle of 25^{o} represented as T1.
2- The standard blade was tilted at an angle of 20^{o}, locally adjusted, and represented as T2.
3- The manufactured blade with a straight angle is represented as T3.

The second factor was the forward speed of the lawn mower machine, as a secondary factor with three selected levels of gear speed, which were measured after the engine rotation speed was fixed at the highest rotational speed 3160 revolutions per minute:

1- The first speed with number 3, which was 2.99 km h^{-1}, was represented as S1.
2- The fourth speed, which was 4.32 km h^{-1}, was represented as S2.
3- The fifth speed, which was 5.60 km h^{-1}, was represented as S3.

The experiment included nine treatments, which were 3x3 with three replicates, resulting in 27 experimental units. The length of each unit was 80m, and with three replicates, the length of each replicate was 20 m. The experimental unit's area was 60 m2, including leaving a 5m space at the beginning and end of each replication to acquire the specified speed for the lawn mower during work, as shown in the general experimental design. The data were analyzed using the (SAS) 2010 program (Elsahooki & Waheeb, 1990)

2-3- Experimental Execution Method:

1- The fuel consumption device was installed and connected to the fuel system, and the engine's rotation speed was set to 3160 RPM by the manual fuel regulator located on the left of the steering regulator and the tachometer device.
2- The theoretical time was then measured for each speed for the selected numbers 3,4, and 5 fixed on the driver's seat straight by the speed change regulator for the gearbox in sequence, ranging from 1-6, inside the experimental field on the grass.
3- The practical time for each treatment was then measured after starting the cutting blade, was the total time using the same previous method to measure the theoretical time and the amount of consumed fuel.

3-Theoretical calculations for the studied properties:

3-1- Percentage: The percentage slip ratio was calculated using the following equations (AL Binaa, 1990) (Taha & Taha, 2019),and (Aboud, 1980):

S = (Vt - VP/VT) × 100 ……………… (1).
Where: S: Slippage percentage
VT: Theoretical speed (km h^{-1})
VP: Actual Speed (km h^{-1})
The theoretical speed of the mower (VT):
VT = St ÷ Tt × 3.6……….km hr^{-1}…………. (2)
where: St: distance (m)
Tt: Theoretical Time
The actual speed of the mower (Vp):
VP= Sp ÷ Tp × 3.6……….km hr^{-1}………… (3)
where: Sp: distance (m)
Tp: Actual Time (s)

3-2- Field efficiency: was calculated by using the following equation proposed by by *(Al-Tahan, et al*., 1991), (Jasim , *et al*., 2017):

FE = Pp ÷ Pt × 100% …………… (4)
where: FE: field efficiency
Pp: actual machine productivity (EFC)
Pt: theoretical machine productivity (TFC)

3-3- Height and cutting efficiency.

The cutting efficiency was calculated according to measuring the length of the stem before and after cutting used the following equation: (Atallah، 2013)
Cutting efficiency (η %) = [(Lb. – La.) / Lb] x 100……………. (5)
where: η: cutting efficiency (percentage)

Lb: Length before cutting - grass height above the ground before cutting in cm.

La: Length after cutting - grass height above the ground after cutting in cm.

3-4- Fuel consumption

It was calculated via the following equation which found at: (AL-Badri & AL-hadithy, 2011; Al-Hashemi, , 2012)

FQ = Q × 10000/TL × Wp × 1000……………. (6)

where: FQ: fuel consumption per hectare (L/ha)

Q: fuel consumption during operation (mL)

TL: length of operation (m)

Wp: actual width of machine or tillage (m)

Results

Percentage of Slippage:

The results indicate a significant difference between the average cutting angles in Table 2, where the highest was 14.00 % and the lowest was 10.71 % for both treatments T3 and T1. A larger blade angle leads to an increase in the required cutting force, which in turn increases the overall resistance of the mechanical unit leading to an increase in the percentage of slippage. Additionally, this is achieved by a straight blade, which requires fewer cutting forces. There was a significant difference in the average speed, with T3, which had the highest speed of 5.60, and T1, which had the lowest speed of 2.99. The reason for that may be related to the slippage rate being less than 15% of the allowed limits.

Table (2) shows an increase in slippage with increasing selected speed for all types of blades used, with values of 2.99, 4.33, and 5.60. The lowest slippage rate was recorded when the straightT3 blade was used, and the lowest forward speed S1was 8.34%. This is due to the low cutting force required for the blade, which reduces the total resistance of the cut and thus reduces the slippage in the driving wheel. The highest slippage was recorded when the standard T1 blade was used and the highest selected forward speed S3, was 14.90%. The reason behind this is that forward speed and slippage have a positive relationship, which is with agreement with (AL-Ahmad & Ibrahim، 2016), (Al-Khaldi، 2006), (Nafawaah & Mageed, 2019), (Jasim & Saadoon, 2020) , (Chancellor , 1988), and (Jabr & Al-Sayah, 2017).

Table 2: Effects of blade type represented by the cutting angle and ground speed on the percentage of slippage.

Cutting angle	Selected Speed			Mean cutting angle
	S1	S2	S3	
T1	12.49	14.61	14.90	14.00[a]
T2	11.30	12.86	13.25	12.47[b]
T3	8.34	10.83	12.95	10.71[c]
LSD*		1.05		0.87
Mean	10.71[c]	12.77[b]	13.70[a]	
LSD		0.58		

**LSD (least significant difference) is the value at a particular level of statistical probability (e.g., P≤0.05- means with 95% accuracy).*

Field Efficiency:

The results in Table 3 show a significant difference between the means for the cutting angles, where the highest was recorded for the straight blade 70.14 and the lowest was for the standard blade 67.53, The reason for this may be due to the type of straight blade used. Also, results show that there is a significant difference between the different speeds S1, S2, and S3 and the reason is attributed to the fact that there is an inverse relationship between the practical speed of the mechanical unit and the field efficiency. When the mower operates at a forward speed of 2.99, 4.33, and 5.60. There was a noticeable decrease in the field efficiency averages for the three speeds of 79.40, 68.08, and 58.54.

Table 3 shows an increase in field efficiency as the selected speed decreases for all types of blades used. The highest field efficiency was recorded when the straight blade T3 was used with the lowest forward speed S1, which was 81.56 %. This was due to the lower force required for cutting, which led to a reduction in the overall resistance to mowing, thus reducing the slipping that occured in the driving wheel and increasing the field efficiency. The lowest field efficiency was recorded when the standard blade T1 when used the highest forward speed 57.98%, which is attributed to the inverse relationship between the forward speed and the field efficiency, which is consistent with (El-Sharabasy, , 2013), (Al-Azzawi & Zain Al-Din, 2022),and (Al-Ani, *et al.*, 2006)

Table 3: The effect of blade type represented by the cutting angle and ground speed on field efficiency.

Cutting angle	Selected Speed			Mean cutting angle
	S1	S2	S3	
T1	78.15	66.47	57.98	67.53[b]
T2	78.49	67.97	58.56	68.34[b]
T3	81.56	69.79	59.08	70.14[a]
LSD*		3.65		1.74
Mean	79.40[a]	68.08[b]	58.54[c]	
LSD		2.46		

**LSD (least significant difference) is the value at a particular level of statistical probability (e.g., P≤0.05- means with 95% accuracy).*

Efficiency of Cutting: The results indicated a significant difference between the means of the cutting angles (Table 4), where the highest value was recorded for the straight blade 38.67 and the lowest value was for the standard blade 36.42 for T1 and T3, which reached 36.42. The reason behind this might be that with increased speed, there were uncut or irregularly cut stems, as well as the type of straight blade used. Additionally, the results showed significant differences between the forward speeds S1, S2, and S3, because there is an inverse relationship between the practical speed of the machinery unit and the cutting efficiency. Considering the results, when working with a practical speed from 2.99 - 5.60, there was a noticeable decrease in the field efficiency means for the three speeds which reached 38.48, 37.63, and 36.63 % respectively. Table (4) shows an increase in the cutting efficiency when the selects lower speeds, for all types of blades. The highest field efficiency was recorded when the straight blade T3 was used with the lowest practical speed S1, which reached 40.0 %, whereas the lowest cutting efficiency was recorded when the standard blade T1 with the highest practical speed S3,was used, which is consistent with (Ahmed & Dosoky, 2009), (Tabatabaee, 2006).

Table 4: Effect of blade type represented by the cutting angle and ground speed on cutting efficiency.

Cutting angle	Selected Speed			Mean cutting angle
	S1	S2	S3	
T1	37.27	36.83	35.17	36.42[c]
T2	38.17	37.90	36.90	37.66[b]
T3	40.00	38.17	37.83	38.67[a]
LSD*		1.12 [N.S]		0.88
Mean	38.48[a]	37.63[b]	36.63[c]	
LSD		0.65		

**LSD (least significant difference) is the value at a particular level of statistical probability (e.g., P≤0.05- means with 95% accuracy).*

Fuel consumption:

The results indicate a significant difference between the average of the cutting angles Table (5), with the highest value for the standard blade T1, and the lowest value for the straight blade 6.48 litters ha-1 which may be related to the increase in the speed of the unit due to less cutting effort, thus consuming energy in the shortest possible time, which was achieved with the type of straight blade used. The results also revealed a significant difference between speeds S1, S2, and S3, because of the inverse relationship between the practical speed of the unit and fuel consumption, which was matches the results [36]. Considering the results, when working at forward speeds of 2.99, 4.33, and 5.60 km h-1, there was a noticeable decrease in the average of fuel consumption for the three speeds 8.08 ,5.79, and 4.55 litters ha 1.

Additionally, Table (5) shows that there was a decrease in fuel consumption with an increase in the selected speed for all types of blades. The highest fuel consumption was recorded when the standard blade T1was used and the lowest forward speed S1was used, which amounted to 8.61 litters ha-1. The reason for this is the increase in energy consumed per unit of time with a decrease in actual productivity, and thus an increase in fuel requirements for mowing. This is contrary to what was recorded for the lowest fuel consumption in the interaction of the straight blade T3 and the highest selected forward speed for grass mowing S3, which amounted to 4.33 litters ha-1. This is attributed to the inverse relationship between the forward speed and fuel consumption, which is matches results obtained by (Tekeste *et al.*, 2022), (Hamid, 2013), (Sadeq & Al-Obaidi, 2019), and (Omar, Sadeq & Al-Ani, 2021), (Al Mashhadani & Al-Badri, 2023).

Table 5; Effect of blade type represented by the cutting angle and ground speed on fuel consumption (litter ha-1).

Cutting angle	Selected Speed			Mean cutting angle
	S1	S2	S3	
T1	8.61	6.11	4.72	6.48[a]
T2	7.92	5.69	4.58	6.06[ab]
T3	7.72	5.56	4.33	5.87[b]
LSD*		0.63		0.37
Mean	8.08[a]	5.79[b]	4.55[c]	
LSD		0.41		

**LSD (least significant difference) is the value at a particular level of statistical probability (e.g., P≤0.05- means with 95% accuracy).*

Discussion and Future Work

Conclusions:

The decrease in the cutting angle of the blade type from 25o to 20o, and then to the straight angle, results in a significant decrease in the average slippage and fuel consumption, and an increase in the average field efficiency and cutting efficiency. On the other hand, the increase in the forward speed of the grass cutting machine led to an increase in slippage. However, the opposite effect was observed for field efficiency, cutting efficiency, and fuel consumption, where the increase in forward speed led to a noticeable decrease in these parameters.

The study showed that the blade type represented by the straight cutting angle T3, which was designed in the workshop, proved to be efficient in achieving the study's goal. It has the best technical specifications for evaluating the performance of the Murray 2010 lawn mower and all types of mowers within the selected forward speed, engine rotation speed, and 15.5 horsepower capacity limits. It recorded the lowest fuel consumption rate and the highest field and cutting efficiency, leading to a reduction in the economic costs for the user, especially when working in large green areas.

Recommendations:

Researchers recommend the use of straight blades, especially in large areas, because of the significant differences in the studied technical properties. Further studies recommend to the use of straight blades in various types and shapes of lawn mower machines. Additionally, studying the use of straight blades with different cutting heights for lawn mower machines has been studied.

Finally, straight blade T3 with a speed 5.60 km hr-1 is recommended to achieve lower fuel consumption and straight blade T3 with a speed of 2.99 km hr-1 is recommended to achieve the highest cutting and field efficiency and the lowest slippage ratio. For future study smart technology implementation by using sensors that can adjust blade height or speed based on real-time grass condation.

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