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EXPLOITATIONAL AND TECHNICAL-ECONOMIC EXAMINATION OF TRACTOR LAWN MOWERS
EKSPLOATACIONA I TEHNOEKONOMSKA ISPITIVANJA TRAKTORSKIH KOSAČICA

Abstract

Sawn grasslands are an important source of bulk fodder, which is becoming more relevant not just because of the increased overall demands for cattle feed, but also because of higher yields and better food quality.

Mowing represents the first phase in managing green grass mass, which is to be performed within an optimum agro-technical period and in the shortest time interval possible.

A three-year study of tractor lawn mowers was held in the Zeta area, Podgorica region, in the period form 2004-2006. The program included an examination of oscillating lawn mowers with two mobile blades, rotary lawn mowers with reels, and rotary lawn mowers with disc-shaped functional units.

Researched oscillating lawn mowers with two mobile blades, with an average functional speed of 4.4 km/h, achieved technical productivity of 0.4 ha/h. Rotary lawn mowers with reels, with an average functional speed of 7.9 km/h, achieved technical productivity of 0.68 ha/h. Rotary lawn mowers with functional disc-shaped units, with an average functional speed of 6.5 km/h, achieved technical productivity of 0.77 ha/h.

Key words: lawn-mower, lucerne, hay, productivity, energy

Izvod

Sijani travnjaci su značajan izvor kvalitetne kabaste stočne hrane, koja dobija sve veći značaj, ne samo zbog porasta ukupnih potreba u ishrani stoke, već i radi većih prinosa i boljeg kvaliteta hrane.

Košenje predstavlja prvu fazu u procesu sređivanja zelene travne mase, koju treba obaviti u optimalnom agrotehničkom roku i u što kraćem vremenskom intervalu.

Trogodišnja ispitivanja traktorskih travokosačica obavljena su na području Zete, u okolini Podgorice u periodu 2004-2006. godina. Programom su obuhvaćena ispitivanja: oscilatorna kosačica sa dva pokretna noža, rotaciona kosačica sa bubnjevima i rotaciona kosačica sa radnim organima u obliku diska. Ispitivana oscilatorna kosačica sa dva pokretna noža, prosječnom radnom

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brzinom agregata od v= 4,4 km/h, ostvarila je tehničku proizvodnost od Wt= 0,4 ha/h.

Rotaciona kosačica sa bubnjevima u radu agregata sa prosječnom radnom brzinom od v=7,9 km/h, ostvarila je tehničku proizvodnost od Wt= 0,68 ha/h. Rotaciona kosačica sa radnim organima u obliku diska u agregatu sa prosječnom radnom brzinom od v= 6,5 km/h, ostvarila je tehničku proizvodnost od Wt= 0,77 ha/h.

Ključne riječi: kosačica, lucerka, sijeno, proizvodnost, energija

INTRODUCTION

Natural conditions and economic factors affecting the organisation of agricultural production in Montenegro are rather diversified and complicated because Montenegro is an exceptionally hilly-mountainous area with a small percent of flat terrain. Natural grasslands and lawns, as regards to the area where they abound, as well as the form of production done on them, take an important role in production of bulk cattle feed. Lawns are used without application of agro-technical measures or improvement to floristic composition. The mentioned reasons are cause of low yields of 0.5 t/ha – 1.6 t/ha, with lower share of nutritive matters **(Mitrović, Irić, 2004)**.

Small significance is given to the hay preparation. Usual thinking is that it is important to mow green mass and then gather it (baling) or transport to the commercial yard in bulk condition.

Preparation of fodder includes different technological processes: mowing, drying, gathering, loading and transport, in different forms, such as green fodder, semi-dry hay, dry hay, silage, haylage (**Blagojević, 1979**). The final product can be lucerne flour or grass-clover mixture, with inclusion of a dehydrator in the technological process.

In developed and highly mechanized technologies, preparation of bulky fodder takes place on larger production surfaces; machines that are more complex are used, which perform several functional operations (mowing + compression), (mowing + cutting + transport to trailer) in one walkthrough (**Barčić, 1985**).

Under the existing conditions, there are numbers of unsolved problems, mainly economic, energy or environmental in character. Due to the aforementioned reasons, in future a higher engagement of main connected machines for preparation of bulk fodder (hay) is expected. Their selection and categorization depends on the size of household (arable land area), terrain configuration, production orientation and economic capacities of the households (**Lulo, 1995**).

MATERIALS AND METHOD

A three-year study (2004-2006) was performed in the Zeta area, Podgorica region. Research was performed on the lucerne production area of 0.35 ha with sort legend and sawing was completed in 2002.

The work program included research on oscillating lawn mowers with two mobile blades, rotational lawn mowers with reels, and rotational lawn mowers with disc-shaped functional units.

Experimental research included examination of main power units and connected machines according to the research methods of the Institute for Agricultural Economics of the Faculty of Agriculture in Belgrade.

For testing the significant differences in examined parameter average values, the t-test was used: (te < tt 0.05) difference is not statistically relevant; (tt 0.05 < te < tt 0.01) difference is statistically relevant (*); (te > tt 0.01) statistically relevant high difference (**).

Exploitational analysis of the aggregate

Working speed (v) was determined by the chronography method, by measuring the aggregate walkthrough on the route of 50 m distance, in five repetitions. Working width of the aggregate (B) was determined by measuring the working width in five repetitions. Productivity (Wt) was determined by the data processing method on the basis of working speed, working width, and use of working time (n).

Technical-economic analysis of the aggregate

Technical productivity (Wt) was determined by the calculation method for data processing with application of the equation:.

$$\mathbf{Wt = 0{,}1 \cdot B \cdot v \cdot n \quad (ha/\ h)}$$

Fuel consumption (Qt) of the power unit was determined by the volume method, measuring the fuel consumption (l/h). Specific fuel consumption was determined from the ratio:

$$\mathbf{Qha = Qt/Wt;\ Qt = l/h.}$$

Energy consumption was determined using:

$$\mathbf{E = Q/ha \cdot g \ \ (MJ/ha)};$$

g-fuel energetic value;

$$\mathbf{g = 41MJ/l};$$

coefficient of the aggregate time consumption:

$$\mathbf{n = Wt/Wth},$$

where Wt = technical productivity and Wth = theoretical productivity.

For assessment of the machine suitability, the following parameters were examined:

- green mass and dry matter yield, sampling, square method, from the area of 1 m^2
- technical characteristics of tested machines in the aggregate of pull-drive machines
- technological characteristics of tested machines
- work quality of tested machines (failures, malfunctions…)

RESULTS AND DISCUSSION

For mowing winter crops, grass-leguminous mixtures, corn silage and other crops, lawn mowers of different technical-technological solutions are being used.

In mowing lawns of clover-grass mixtures and lucerne, basically two types of machines are being used depending on the devices for mowing, and these are oscillating and rotary lawn mowers.

Oscillating Mower with two Mobile Blades

The oscillating mower with two mobile blades has simple construction and can be quickly and simply aggregated to the power unit. This type of mower has two mobile cutting blades and does not have double fingers on its cutter bar for protection of blade segments. For this reason, it is more sensitive to shock and is not recommended for plots with grass-leguminous mixtures that are uneven and unmanaged.

The technological working process of lawn mowers is based on the scissors-principle. Mobile cutting blades move in opposite directions and, in that way, cut the grass stalks. Such movement of mobile cutting blades provides high dynamic balance of the cutting device, since the unbalanced forces are mainly neutralised.

Operational safety of the lawn mower is secured by two systems of breakers, a system for unpredicted, sudden obstacles, as well as the possibility of V-belt slip, so that the blades not break.

Exploitational analyses of mowers with two mobile blades were performed on production areas of grass-clover mixture in the Pljevlja region in 2002.

Tested mower IMT-627.794 operated with the aggregate of machine power of 29 kW, having the number of revolutions of the connected shaft of 540 min^{-1}.

The yield of fresh green mowed grass-clover mixture amounted to a mass of around 1.60 kg/m^2, or 16,000 kg/ha, and the dry hay yield was 2100 kg/ha.

Technical characteristics of the examined oscillating law-mower with two mobile blades (IMT-627.794)

Working width ..... 1.6 m
Working speed ..... 4-6 km/h
Required number of revolutions of the connected shaft ..... 540-580 min^{-1}
Required power ..... 18 kW
Weight ..... 165 kg

Average working width of the aggregate in operation amounted to B=1.50 m and average working speed was v = 4.40 km/h. Average working speed of v =

4.40 km/h and working width of B = 1.50 m and working time utilization coefficient n = 0.6 resulted in the achieved technical productivity of the Wt = 0.40 ha/h.

$$\mathbf{Wt=0.1 \cdot B \cdot V \cdot n\ (ha/h)}$$

$$\mathbf{Wt= 0.1 \cdot 1.50 \cdot 4.40 \cdot 0.6}$$

$$\mathbf{Wt= 0.40\ ha/h}$$

$$\mathbf{Q/ha= Qt/Wt}$$

$$\mathbf{Q/ha= 7.50\ l/ha}$$

Table 1. Exploitational and techno-economic indicators of oscillating lawn mower with two mobile blades IMT – 627.794

Tabela. 1. Eksploatacioni i tehnoekonomski pokazatelji rada oscilatorne travo-kosačice sa dva pokretna noža IMT – 627.794

		Year 2004						
Walk through hs	Walk through length (m)	Walk through time (s)	Walk through width (m)	Walk through speed (km/h)	Technical productivity (ha/h)	Fuel consumption (l/h)	Specific fuel consumption (l/ha)	Working time utilization coefficient (n)
I	50	38.00	1.50	4.70	0.42	3.00	7.10	0.6
II	50	38.00	1.55	4.70	0.44	3.00	6.80	0.6
III	50	42.00	1.55	4.30	0.40	3.00	7.50	0.6
IV	50	43.00	1.50	4.20	0.38	3.00	8.00	0.6
V	50	45.00	1.55	4.00	0.38	3.00	8.10	0.6
Xs	50	41.00	1.50	4.40	0.40	3.00	7.50	0.6

During the operations of the examined mower, the mowed plants (stalks) were not damaged in respect to the plane sections. The height of the cut after the aggregate walkthrough amounted to an average of 4.0 cm. No un-mowed grass mass stalks remained. After the aggregate walkthrough, the mowed grass mass stayed in a single swath and there were no failures during the operations.

The mentioned mower represents the latest technical-technological solution in the domestic industry; therefore, it deserves this brief analysis of its operations, although it was not envisaged by the research program.

According to the test results of **Brčić** (1984), under the operations of oscillating side-mounted mowers in lucerne fields, leaf and stalk losses amounted up to 25% depending on crop condition and grass mass elasticity.

Rotary mowers with reels

The author and constructor of the rotary mowing system for grass mixtures (rotary mowers) is Dutch, Zweegers. He used three main elements in his construction:

- sharp and simple blades, easily replaceable
- mowing of grass mass without anti-scalp plates,
- higher orbital blade speeds from 60 to 80 m/s.

The most recent lawnmowers with reels are rather simple, robust and reliable in work. They are produced with 2, 4 and 6 reels. Each reel has three blades, which are easily replaceable after 8 to 10 hours of operations. The working width of the mower is from 1.35 m to 3.00 m. The drive requires power units of 20 to 35 kW/m. They have rather high weights, from 220 to 350 kg/m, which represents the disadvantage of these mowers (**Koprivica, 1995**).

Technical characteristics of the examined rotary lawnmower with reels (Sip-RK-135)

Working width ..... 1350 mm
Transport width ..... 1150 mm
Weight.....300 kg
Required power of the drive machine .....30 kW
Number of movable reels 2
Number of blades per reel 3
Required number of revelations of the connected shaft..... 540 min^{-1}

The examined rotary lawnmower with reels (Sip-RK-135) is a mounted machine. Power for the reels with blades is obtained from the connected shaft of the engine drive, through the power take-off, with 540 min^{-1}.

Under the technological process of work, cutting of grass mass occurs through the impact of sharp blade edges to the stalks, where the inertia occurs as the counterforce; this type of cutting is known as the “free cut”. Furthermore, the orbital blade speed on the reel is from 60 - 80 m/s and average power consumption is from 20 - 25 kW/m for the mower working width.

Table 2. Techno-economical indicators of rotational lawn mower with reels (Sip-RK-135)
Tabela.2. Tehnoekonomski pokazatelji rada trvokosačice RK-135

No	Examined parameters	Research year			Average values X
		2004	2005	2006	
1	Working speed v= (km/h)	6.55	9.40	7.80	7.90
2	Working width B=(m)	1.31	1.20	1.25	1.25
3	Working time utilization coefficient (n)	0.70	0.70	0.70	0.70
4	Technical productivity (ha/h)	0.60	0.78	0.68	0.68
5	Fuel consumption (l/h)	3.20	3.80	3.60	3.53
6	Specific fuel consumption (l/ha)	5.33	4.87	5.30	5.17
7	Energy consumption (MJ/ha)	205.0	199.0	217.0	207.00

Working speed of aggregate in mowing lucerne (v) varied from 6.55 km/h to 9.40 km/h, for an average of 7.90 km/h, which can be considered as the optimum working speed of the examined aggregate.

Technical productivity (Wt) ha/h varied from 0.60 ha/h to 0.78 ha/h. Technical productivity of the examined aggregate was influenced by the condition of the culture (lucerne), its yield, working speed and working width.

In parallel with the technical productivity of the examined aggregate (engine power of 29 kW + rotary mower), fuel consumption amounted to 3.20 l/h - 3.80 l/h. Under the technical productivity of the aggregate amounting to 0.78 ha/l, fuel consumption was 3.80 l/h and specific fuel consumption was 4.87 l/ha.

Within the technological process of its work, the examined rotary mower with reels (Sip-RK-135) gathered mowed grass mass in a single swath. Average cut height amounted to 6.0 cm, which is considered advantageous in order to minimise damage to the roots of the lucerne stalks. Mowing was performed in the early morning with the average stalk moisture of around 72%. Remains of un-mowed plants were negligible, as was damage to the lucerne leaves and stalks.

Rotary mowers with disc-shaped functional devices

Rotary mowers with disk-shaped functional devices are manufactured using the latest technology or technical-technological solutions. These mowers are usually equipped with three, four and six disks, with two cutting blades per disk and a hydraulic lifting system. Transfer of power from the power unit is obtained from the power take-off through DC coupling and a set of V-belts connected to the multiplier. Reels are removed from this mower and only lower rotary parts with blades remain, which reduced the weight, as well as the drive power of 15 kW/m (**Kusovt, 1990**).

The examined rotary mower with disk-shaped functional devices (IMT 267.716) with active disks operated in the aggregate of 29 kW engine power.

Technical characteristics of the rotary mower with disks (IMT 627.716)

Working width ..... 1650 mm
Number of revolutions of the connected shaft 540 min-1
Number of revolutions of active disks 3000 min-1
Number of disks 4
Number of blades .....8(4x2)
Mower weight .....290 kg
Required power .....30 kW

The examined rotary mower with disk-shaped functional units (4) disks, represents a more recent technical-technological solution in the power transfer process of active disks with respect to mowing machines.

Specific features of this lawnmower is that a device for further processing of mowed mass can be attached thereto, where the mowed plant mass is being ground and shattered, thereby improving the drying time (process).

Table 3. Techno-economical indicators of rotary disk-shape functional mower
Tabela 3. Tehnoekonomski pokazatelji rada rotacione travokosačice

No	Examined parameters	Research year			Average values X
		2004	2005	2006	
1	Working speed v= (km/h)	5.50	7.10	7.00	6.50
2	Working width B=(m)	1.60	1.60	1.60	1.60
3	Working time utilization coefficient (n)	0.70	0.70	0.70	0.70
4	Technical productivity (ha/h)	0.73	0.80	0.78	0.77
5	Fuel consumption (l/h)	3.50	3.80	3.80	3.70
6	Specific fuel consumption (l/ha)	4.80	4.75	4.87	4.80
7	Energy consumption (MJ/ha)	197.0	195.0	200.0	197.30

The examined lawnmower with disk-shaped functional units with an aggregate of 29 kW power drive, achieved technical productivity of 0.77 ha/h. Specific fuel consumption amounted to 4.80 l/ha.

During the analysis of the aggregate, there were no failures or malfunctions. Considering that the examined mower had several active disks, (four) it made more swaths (three), thereby achieving better drying effects for mowed grass mass. Average cut height amounted to 6 cm and an important feature of this mower is that it does not damage the plant stem system and the cuts of mowed grass are even**.**

Table 4. Researched lawn mowers benchmark
Tabela 4. Uporedni rezultati ispitivanih kosačica

No	Parameters	Oscillating mower with two mobile blades IMT-627.794 **(A)**	Rotary mower with reels Sip-RK-135 **(B)**	Rotary mower with discs IMT-627.716 **(C)**
1	Working speed (km/h)	4.40	7.90	6.50
2	Technical productivity (ha/h)	0.40	0.68	0.77
3	Specific fuel consumption (l/ha)	7.50	5.17	4.80
4	Required power (kW/m)	8	15	16
5	Quality of work (cuts)	even cut	uneven cut	uneven cut
6	Swath quality	single swath	single swath	several swaths
7	Operational reliability	unreliable	reliable	reliable
8	Maintenance costs	higher	lower	lower
9	Production costs	low	high	high
10	Grass mass drying time	long	long	short
11	Failures in work	high	no failures	no failures
12	Leaf losses	inconsiderable	high	high
13	Damages to the plant stem	without damages	high damages	low damages

Absolute and relative differences in values of examined parameters

No	Parameters	Measuring units	A	B	Absolute	Relative
1	Working speed	km/h	4.40	7.90	3.50 **	79.50
2	Tech productivity	ha/h	0.40	0.68	0.28 **	70.00
3	Spec. fuel cons.	l/ha	7.50	5.17	2.33 *	70.00
4	Req. tractor power	kW/m	8	15	7.00 **	87.50

No	Parameters	Measuring units	A	B	Absolute	Relative
1	Working speed	km/h	4.40	6.50	2.10 **	48.00
2	Tech productivity	ha/h	0.40	0.77	0.37 **	92.00
3	Spec. fuel cons.	l/ha	7.50	4.80	2.70 *	36.00
4	Req. tractor power	kW/m	8	16	8.00 **	100.00

No	Parameters	Measuring units	A	B	Absolute	Relative
1	Working speed	km/h	7.90	6.50	1.40 *	18.00
2	Tech productivity	ha/h	0.68	0.77	0.09	13.00
3	Spec. fuel cons.	l/ha	5.17	4.80	0.37	7.20
4	Req. tractor power	kW/m	15	16	1.00	6.70

CONCLUSION

1. **The examined oscillating mower with two mobile blades (IMT-627.794)** with the aggregate 29 kW engine drive and the average working speed of 4.4 km/h, achieved productivity of 0.4 ha/h and fuel consumption of 7.5 l/ha. There were no failures during the test operations; it does not damage plant stem, and leaf losses from the stalk are negligible. With regard to the fact that these mowers do not have section fingers, they require an even surface without the presence of rocks.

2. **The rotary mower with reels (Sip-RK-135)** with the aggregate of the drive engine averaging a working speed of 7.9 km/h achieved a productivity of 0.68 ha/h. In comparison to the previously described mower, this mower achieved higher productivity.

3. **The rotary lawnmower with discs (IMT-627.716)** with the aggregate of the drive engine averaging a working speed of 6.5 km/h achieved a productivity of 0.77 ha/h. There were no failures during the test operations and the characteristic of this mower's technological work process is that it makes several swaths, increasing the drying effect for the mowed grass mass.

4. The examined mowers are applied in production practice, and as regards the selection, the limiting factors are: quality of operations, productivity, damages to the plant stem, leaf losses, grass mass drying effect and production price. Taking into account all of the aforementioned facts, we believe that the rotary lawnmower with discs is best positioned, due to its technical-technological solutions.

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by

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Summary

Sawn grasslands are an important source of bulk fodder, which is becoming more relevant not just because of the increased overall demands for cattle feed, but also because of higher yields and better food quality.

Mowing represents the first phase in managing green grass mass, which is to be performed within an optimum agro-technical period and in the shortest time interval possible.

A three-year study of tractor lawn mowers was held in the Zeta area, Podgorica region, in the period form 2004-2006. The program included an examination of oscillating lawn mowers with two mobile blades, rotary lawn mowers with reels, and rotary lawn mowers with disc-shaped functional units.

The examined oscillating mower with two mobile blades (IMT-627.794) with the aggregate 29 kW engine drive and the average working speed of 4.4 km/h, achieved productivity of 0.4 ha/h and fuel consumption of 7.5 l/ha. There were no failures during the test operations; it does not damage plant stem, and leaf losses from the stalk are negligible. With regard to the fact that these mowers do not have section fingers, they require an even surface without the presence of rocks.

The rotary mower with reels (Sip-RK-135) with the aggregate of the drive engine averaging a working speed of 7.9 km/h achieved a productivity of 0.68 ha/h. In comparison to the previously described mower, this mower achieved higher productivity.

The rotary lawnmower with discs (IMT-627.716) with the aggregate of the drive engine averaging a working speed of 6.5 km/h achieved a productivity of 0.77 ha/h. There were no failures during the test operations and the characteristic of this mower's technological work process is that it makes several swaths, increasing the drying effect for the mowed grass mass.

The examined mowers are applied in production practice, and as regards the selection, the limiting factors are: quality of operations, productivity, damages to the plant stem, leaf losses, grass mass drying effect and production price. Taking into account all of the aforementioned facts, we believe that the rotary lawnmower with discs is best positioned, due to its technical-technological solutions.