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SUITABILITY OF USING MECHANIZATION MEANS FOR THE MAINTENANCE OF GRASS STANDS BY THE METHOD OF MULCHING

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Abstract

This study aims to provide comprehensive and practical information on particular mechanization means used in the maintenance of permanent grass stands, namely grass cutting technologies without the collection of cut grass biomass – mulching. A sample consisting of six machines classified into three categories (uniaxial tool carriers, single-axle small tractors, cutting machines with a zero turning radius) was tested in practice and functional and operational aspects of the machines were studied on different localities of permanent grass stands. Data measured in the individual machines were used to calculate consumption [l/ha], consumption [l/mth], consumption [l/l of cut biomass] or performance [ha/hour]. The measurements took place on two sites: a site with the permanent grass stand unkempt for a long time and a site regularly maintained by mulching. The study was conducted in the cadastral area of Ostrava City situated in the NE part of the Czech Republic.

Results of the study show that the total fuel consumption [l/ha] in the individual mowing machines always at all times higher on plots that were unkempt for a long time. The overall comparison of fuel consumption [l/mth] of the individual types of cutting machines between the localities showed that nearly all tested cutting machines had a higher consumption on sites with permanent grass stands unkempt for a long time. The performance [ha/h] of all cutting machines was higher on the sites that were regularly maintained by mulching in the past.

Keywords: grass cutting, mulching, maintenance of grass stands, permanent grass stand, grass stand, grass mower

INTRODUCTION

Today, when the people increasingly deal with their professional lives, a problem occurs for them to find enough time for the maintenance and treatment of their lawns (Jankowski *et al.,* 2012a; Jankowski *et al.,* 2012b). An opinion that has become popular in recent years is that lawns around residential houses and in areas neighbouring with various companies and firms create a positive image about the standard of living of their owners or their high performance in business (Czeluściński *et al.,* 2017; Jankowski *et al.,* 2017). The size of green areas and grass stands in them increases with the increasing size of built-up areas in towns and villages. These permanent grass stands have to be maintained by cutting and measures have to be taken to prevent the cut grass from spreading to other land properties.

Grass stands are easy to grow, they can readily adapt to extreme conditions and are also pleasant to look at. Grasses that are known for having many advantages must be suitable for maintenance to have ideal appearance and survive for many years (Kara *et al.,* 2020). At the same time, the cutting helps to retain biological diversity and the species composition of grass stands by reducing the competition of tall grass species with high nutrient requirements (Hansson and Fogelfors, 2000; Huhta *et al.*, 2001).

Cutting is a widely available option of trimming grass stands (Shimoda, 2017) and one of the most important grassland maintenance operations. In the process of cutting, time and cutting height play an important role at determining the turfgrass quality (Turgeon, 1991). The cutting height affects the turfgrass adaptability in particular (Shimoda, 2017). The selection of appropriate cutting technology supports the uniform grass growth, too (Gonzalez and Loreau, 2009) as plants respond to the removal of biomass by regrowth from dormant meristems. If a sufficient care and more time are given to the maintenance of lawns, grass can have a slower growth rate (Domański and Andrzejewska, 2011; Prończuk and Prończuk, 2006). Slow growth of grass considerably reduces the frequency of cutting, which directly reflects in lower turfgrass maintenance costs (Prończuk and Prończuk, 2008).

Methods for the growing and maintenance of grass stands were modernized in the last century. In the past, permanent grasslands were cut using scythes (Liira *et al.,* 2009). Nevertheless, mechanization means became more common in recent tens of years (Humbert *et al.,* 2009). The reason is their time and cost effectiveness (Tälle *et al.,* 2014) as well as the fact that experts consider the cutting by machines better than the use of other mechanical tools which tear off the plant material (Tälle *et al.,* 2014). To have the turfgrass maintenance as simple as possible, solutions should be adopted that are focused on the reduced amount of work or on work simplification. This can be achieved also by the correct choice of grass mowers.

One of technologies used in the maintenance of permanent grass stands is the technology without the collection of cut grass – mulching (grass cutting and grinding into tiny parts that are left on the soil surface). Mechanization means which can be used for such maintenance of permanent grass stands are subject of this study. Machines for measurements and their comparison at work were chosen to be intended for the maintenance of a wide spectrum of surfaces (regularly maintained surfaces in the built-up areas of municipalities, irregularly maintained surfaces and neglected surfaces) and to provide for a meaningful comparison after their classification into groups.

MATERIALS AND METHODS

The research dealt with a comparison of three uniaxial tool carriers of different categories with various types of mulching systems and thee professional large-scale cutting machines.

The measured tool carriers included Agria 5900 Taifun made by Agria-Werke GmbH, fitted with a four-stroke Briggs & Stratton Vanguard 22 spark-ignition engine cooled by air and performance 22 HP (16.4 kW) at 3600 RPM. The cutting mulching system of the machine (Safety mulcher SME-125 with a working width of 125 cm) was produced by Humus Maschinenfabrik Bermatingen GmbH & Co (Agria, 2002; Agrocar, 2021a). The second type was Rapid Euro 4 made by Rapid and fitted with the two-cylinder Briggs & Stratton Vanguard spark-ignition engine cooled by air and performance 21 HP (15.7 kW) at 3600 RPM. This machine was aggregated with the Humus SMK/E 105 (working width 105 cm) hammer mulching cutting system with the horizontal axis of rotation (Agrocar, 2021b; Rapid Technic AG, 2014; Agrocar, 2021c). The third type was Robot Komunal from TIP spol. s. r. o. aggregated with the B-750 mulcher of own production with a working width of 75 cm and the horizontal shaft. This type was fitted with the Briggs & Stratton Intek engine 13.5 HP (9.8 kW) at 3100 RPM (Tip Spol, 2021; Tip Spol, 2012; Briggs & Stratton AG, 2012). A detailed description of basic technical parameters, the tool carriers and the cutting mulching systems is presented in Tab. I.

The professional large-scale cutting machines were made by SCAG Power Equipment and characterized by a zero turning radius, so-called „zeroturnmowers“. Although all thee cutting machines are made by the same manufacturer, all have different engines and two different types of mulching system. It is a model series called Turf Tiger, namely the STT61V-29DF1-SS type with a two-cylinder, spark-ignition engine cooled by water with the direct fuel injection Kawasaki FD791D and performance 29 HP (21.3 kW) at 2800 RPM, and with the rotating thee-blade mulching system with the vertical blade shaft and a working width of 155 cm (SCAG, 2021a, SCAG, 2021b; SCAG, 2008a). The type STWC52V-26KA-LC was equipped with a weaker two-cylinder, also by water cooled, engine Kawasaki FH731V with the performance of 26 HP (19.4 kW) and the same cutting system a working width of which was 132 cm (SCAG, 2010). The last STT-SM58-28CAT-SS type was equipped with the four-stroke, water cooled, thee-cylinder, spark-ignition Caterpillar CAT C.1.1 engine with a performance of 28 HP (20.9 kW) at 3200 RPM, mowing system with the horizontal axis of shaft rotation and Safety blades with a working width of 147 cm (Agrocar, 2021a; SCAG, 2008b). This machine has a zero turning radius but thanks to the Safety cutting system, it is determined for extensively maintained permanent grasslands, which is why it is combined with tool carriers with cutting mulching systems on large areas or can fully replace them. Basic technical parameters of the above-mentioned cutting machines with a zero turning radius and cutting systems are presented in Tab. II.

Each machine was retested on two plots of each locality. In order to have results for the comparison as accurate as possible, all machines were tested within a short time. Prior to the measurements, all sites were inspected and a botanical survey was made of the most frequently occurring grass and herb species. Grass stands were measured, classified in dominant altitudinal zones, and the zones were expressed in percent according to their cover. For this altitudinal classification, four sample plots of

I: *Basic technical parameters of measured tool carriers and cutting mulching systems*

Power unit	Agria 5900 Taifun	Rapid Euro 4	Robot Komunal
Engine	Briggs & Stratton Vanguard 22 HP	Briggs & Stratton Vanguard 21 HP	Briggs & Stratton Intek 13,5 HP
Number of cylinders	2	2	1
Fuel	BA 95	BA 95	BA 95
Performance [kW/HP]	16.4/22	15.7/21	9.8/13.5
Capacity [cm^3]	627	627	344
Specific consumption [g/kW/h]	329	329	262
Tank volume [l]	8.0	15.0	2.6
Transmission	hydrostatic	hydrostatic	mechanical
Number of gears	-	-	6+2
Speeds forward/reverse [km/h]	0–7.0/0–3.6	0.0–8.0/0.0–4.0	1.0–11.0/1.2–3.3
Travel axle	Rotary hydraulic motors	Rotary hydraulic motors	with differential
Differential lock	no	no	yes
Steering/Control	active hydraulic/ by turning handlebars	hydraulic/ by levers on handlebars	by wheel brakes
PTO shaft rotations [RPM]	805	700/1000	3000
Cutting mulching system	Humus SME 125	Humus SMK/E 105	B 750
Working width [cm]	125	105	75
Blade shaft	HH	HH	HH
Blades	Safety segments	smooth hammers	loose “Y”
Number of blades	18	18	12
Adjustment of cutting height from/to [cm]	5.0–9.0	5.0–9.0	5.0–10.0
Machine dimensions l × w × h [mm]	2 310 × 1 370 × 1 150	2 279 × 1 220 × 870	2 150 × 760 × 1 100
Weight of the set	218 + 185	225 + 185	145 + 72
Slope accessibility of the set [°]	45	45	30
Possibility of further accessories	yes	yes	yes

II: *Basic technical parameters of measured cutting machines with a zero turning radius and cutting systems*

	Scag STT 61V-29DFI-SS	Scag STWC 52V-26KA-LC	Scag STT-SM 58 - 28CAT-SS
Engine	Kawasaki FD791D	Kawasaki FH731V	CAT 28 HP, typ C1.1
Number of cylinders	2	2	3
Fuel	BA 95	BA 95	diesel
Performance [kW/HP]	19.4/26	19.4/26	20.9/28
Capacity [cm3]	745	675	1131
Specific consumption[g/kW/h]	309	246	259
Tank volume [l]	38	30.3	38
Travel speed forward/reverse [km/h]	0–19/0–8	0–16/0–8	0–19/0–8
Steering	hydrostatic, by levers	hydrostatic, by levers	hydrostatic, by levers
Mulching adapter	SMST-61V	SMST-52V	STTSM-58
Working width [cm]	155	132	147
Blade shaft	VH	VH	HH

	Scag STT 61V-29DFI-SS	Scag STWC 52V-26KA-LC	Scag STT-SM 58 - 28CAT-SS
Blades	mulching Hurricane	mulching Hurricane	Safety
Number of blades [pc]	3	3	21
Adjustment of cutting height from/to [cm]	2.5–16.0	3.0–15.0	2.5–16.0
Machine dimensions l × w × h [mm]	2 290 × 1 640 × 1 730 **	2 030 × 1 400 × 1 670 **	2 330 × 1 600 × 1 750 **
Machine weight [kg]	620	495	710

HH – shaft with horizontal turning axis, VH – shaft with vertical turning axis, * – without cutting mechanism, ** – height with ROPS frame

1 m^2 (1 × 1 m) were distinguished in each locality, on which the data were collected and then translated to the whole plot. On each site, sample plots were set out for the individual machines, on which the measurements and research took place. The plots were measured using a distance measuring wheel and their corners were fixed with wooden pegs whose upper parts were painted with the reflex orange spray for better visibility. Both localities are situated in the cadastral area of Petřkovice village (district Ostrava – City, Moravian-Silesian Region, Czech Republic).

Site 1 – Permanent grass stand unkempt for a long time. Sample plots sized 20 × 15 m (300 m^2, i.e. 0.03 ha). Average stand height (representation in percent) – 80 cm (80%), 120 cm (15%), 140 cm (5%).

Site 2 – Grassed area regularly maintained by mulching. Sample plots sized 15 × 10 m (150 m^2, i.e. 0.015 ha) with respect to spatial possibilities. Average stand height (representation in percent) – 20 cm (85%), 35 cm (10%), 65 cm (5%).

Field Measurements

Parameters measured in the practical testing of machines were as follows: time required for cutting the sample plot, fuel consumption, stubble height, mean height of individual mulch components and volume of cut biomass. Parameters measured in the machines included the range of adjusted cutting height, and the range and continuity of speed and direction change.

The time needed for cutting the sample plot was measured using a stopwatch. The machine engine was prepared for the start, the stopwatch was switched on, the engine was started, the mulching system power unit was switched on and the cutting was commenced. As soon as the plot had been cut, the stopwatch was stopped and the time was recorded.

Fuel consumption was measured by adding fuel up to the tank neck by means of graduated jar (500 ml). Upon the machine arrival to the selected place of sample plot (flat area on the sample plot) the engine was switched off, the tank was opened and filled with fuel up to the neck. When the mowing on the sample plot was ended, the machine was put at the same place, the engine was switched off and the tank was refuelled up to the neck again using the graduated jar. The value was recorded.

Stubble height was measured on selected points across the sample plot by using a metal sheet angle scale. At the selected place, the mulch layer was removed from the surface and the stubble was measured by the scale. The procedure was repeated several times across the sample plot. All values were recorded and an average value was calculated by arithmetic mean rounded to whole centimetres, which was then recorded.

Average length of individual mulch components was measured by the metal sheet angle scale, too. The measuring procedure was similar as in measuring the stubble height. The only difference was a random measurement of the length of several parts of the mulch; the value of arithmetically calculated mean was recorded.

The layer of mulch was measured by the metal sheet angle scale at several places across the sample plot too. At the places, the mulch layer was picked up, placed on a mat and measured. Arithmetic means of all values were recorded.

The volume of biomass cut from the selected characteristic points was measured using a graduated bucket. An area of 1 × 1 m was set out using a measuring tape, metal sheet angle scale and pegs. The layer of mulch was dug out, placed in the bucket, compacted, and its value was read in litres. If the amount of cut biomass was larger than the bucket, the measurement was repeated and the values were summed up and recorded. The measurement was only indicative and its purpose was informative as on some plots the stand was either thinner or denser, which affected other measured parameters. This measurement was also considered a certain indicator of extent to which the mulching system can crush the cut biomass into tiny particles (which cannot be raked out any more).

Field Results and Their Processing

The measurement of the given parameters took place repeatedly, therefore the values used were based on the arithmetic average of the measured data, when the degree of variability of the measured data was also determined by the standard deviation. The results were evaluated in the Statistics program.

Due to time losses in handling the machines, the measured time results were multiplied by a conversion coefficient. The testing of machines was attended by another person who measured the time spent for activities other than proper mowing (turning, cleaning of the working space of cutting systems). Then a coefficient of losses was calculated for each measured machine and the arithmetic mean of all these coefficients gave an overall coefficient of 0.7 for the uniaxial tool carriers with the cutting mulching systems. The cutting mulching machines with a zero turning radius had a coefficient of 0.6.

Then the measured values were converted from the sample plots to 1 ha and from them, time data per 1 hour were determined. Formulas used for the conversions were as follows:

$$M_{ha} = \frac{V_p \times 10\,000}{S}, \quad (1)$$

where:
M_{ha}....fuel consumption [l/ha],
V_p ......fuel consumption at measurements [l],
S ....sample plot size [m^2].

$$M_h = \frac{V_p \times 60}{t}, \quad (2)$$

where:
M_h .....fuel consumption [l/mth],
V_p ......fuel consumption at measurements [l],
t ....time of sample plot cutting [min].

$$M_{bio} = \frac{V_p}{V_{bio}}, \quad (3)$$

where:
M_{bio} ...fuel consumption [l/l of cut biomass],
V_p ......fuel consumption at measurements [l],
V_{bio} ....volume of cut biomass [l].

$$W_n = \frac{S \times 60}{t \times 10\,000}, \quad (4)$$

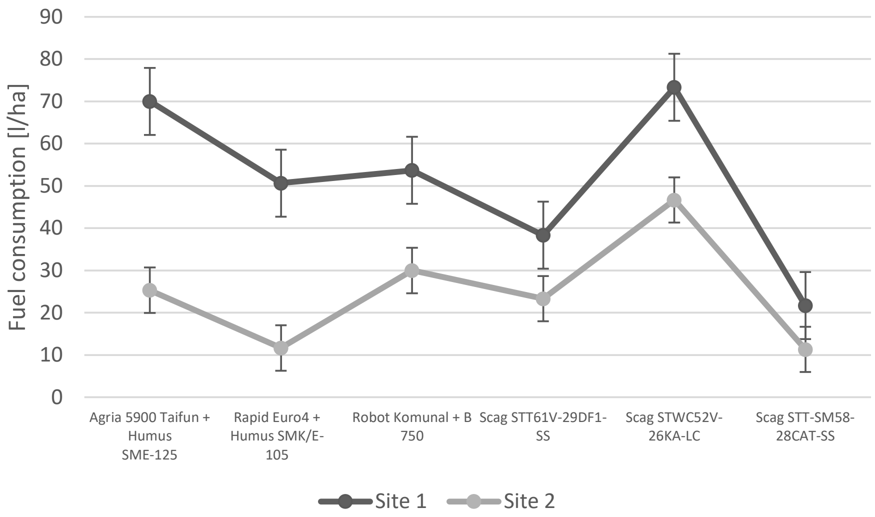
where:
W_n.....measured performance [ha/hour],
S ....sample plot size [m^2],
t ....time of sample plot cutting [min].

RESULTS

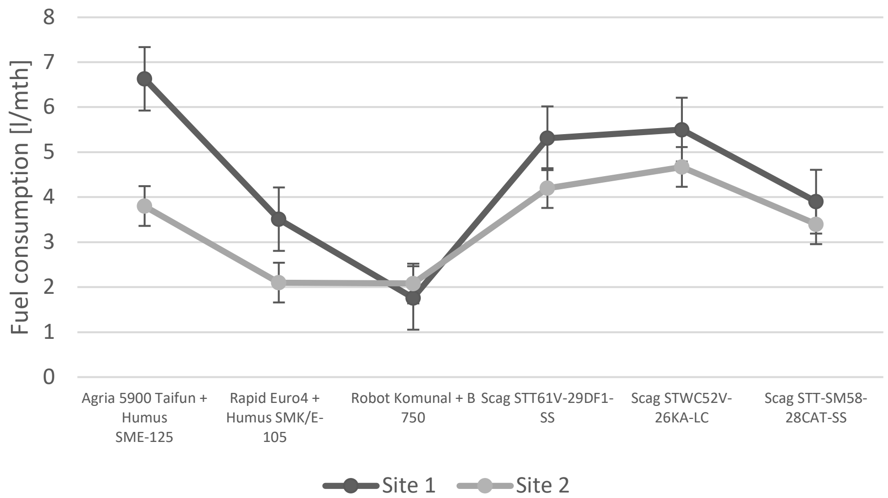
As specified in the Methodology chapter, there were six machines that were tested and the measured data from them were converted. Results and evaluated data are presented in Tab. III and Figs. 1, 2, 3, 4.

Fig. 1 shows that the total fuel consumption [l/ha] in the individual mowing machines was at all times heigher on plots that were unkempt for a long time. In both types of localities, the Scag STWC52V-26KA-LC was evaluated as a cutting machine with the highest consumption. On the other hand, the Scag STT-SM58-28CAT-SS exhibited the lowest fuel consumption on both site types. The biggest difference in fuel consumption [l/ha] between the two sites was recorded in the Agria 5900 Taifun and the smallest difference in this parameter was observed in the Scag STT-SM58-28CAT-SS.

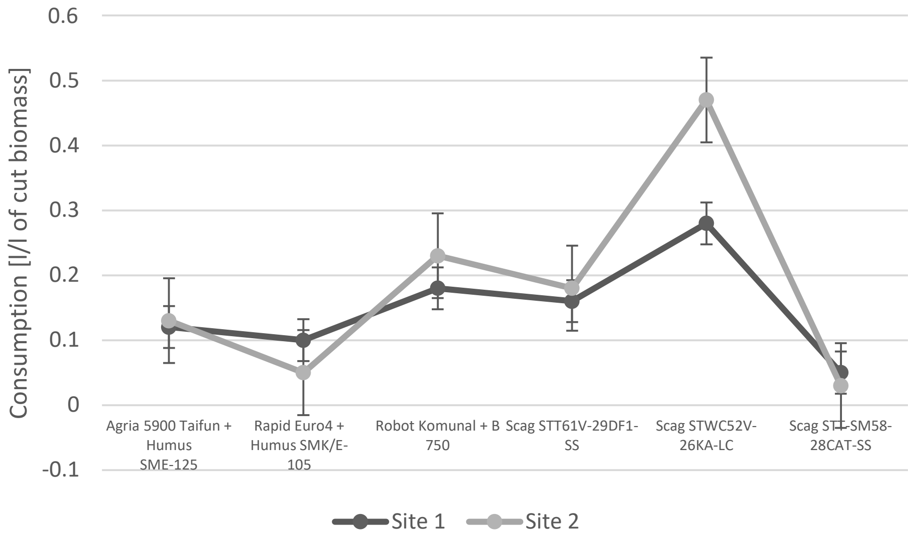
The overall comparison of fuel consumption [l/mth] of the individual types of cutting machines between the localities (Fig. 2) showed that nearly all tested cutting machines had a higher consumption on sites with permanent grass stands unkempt for a long time, only the Robot Komunal was measured to have a higher consumption on the site regularly maintained by mulching. The cutting machine exhibited the lowest fuel consumption in both types of the tested sites. The highest consumption on the permanent grass stand unkempt for a long time was recorded in the Agria 5900 Taifun. By contrast, the highest consumption on the site regularly maintained by mulching was observed in the Scag STWC52V-26KA-LC.



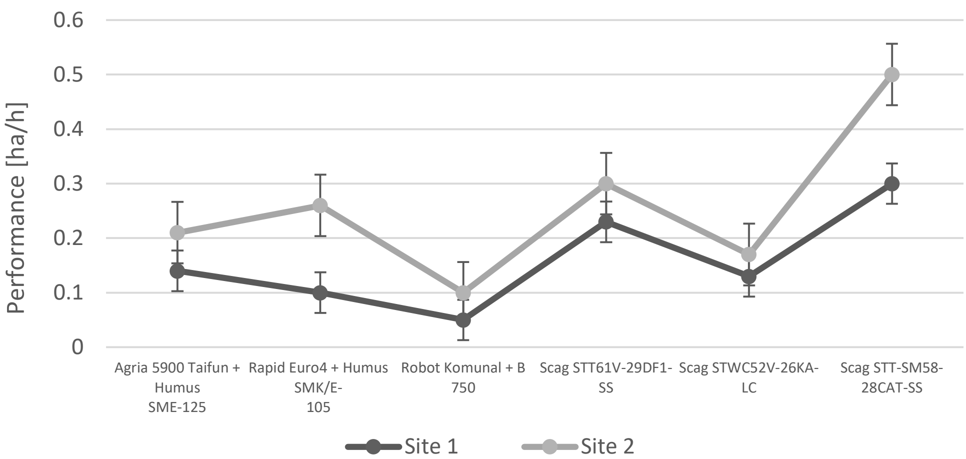
1: *Fuel consumption of the individual types of cutting machines [l/ha] on the two sites*



2: *Fuel consumption of the individual types of cutting machines [l/mth] on the two sites*



3: *Fuel consumption of the individual types of cutting machines [l/l of cut biomass] on the two sites*



4: *Performance of the individual types of cutting machines [ha/h] on the two sites*

III: *Operating parameters measured in the tested machines*

Machine	Agria 5900 Taifun + Humus SME-125		Rapid Euro4 + Humus SMK/E-105		Robot Komunal + B 750		Scag STT61V-29DF1-SS		Scag STWC52V-26KA-LC		Scag STT-SM58-28CAT-SS	
Plot no.	1	2	1	2	1	2	1	2	1	2	1	2
Sample plot size [m^2]	300	150	300	150	300	150	300	150	300	150	300	150
Average stubble height [cm]	10	10	14	8	10	13	9	9	10	7,5	9	9
Average stubble height (Standard deviation) [cm]	1.79	1.04	1.58	1.2	1.62	1.11	1.39	1.09	1.42	1.18	1.51	1.3
Average volume of cut biomass [l]	17.0	3.0	16.0	3.5	9.0	2.0	7.0	2.0	8.0	1.5	12.0	5.5
Average volume of cut biomass (Standard deviation) [cm]	2.09	1.52	1.89	1.43	1.39	1.13	1.63	1.14	1.76	1.21	1.89	1.34
Average length of crushed biomass [cm]	10	10	12	12	8	13	9	9	3	3	11	11
Average length of crushed biomass (Standard deviation) [cm]	1.56	1.12	1.63	1.07	1.41	1.28	1.9	1.07	1.78	1.11	1.63	1.15
Average height of mulch layer [cm]	7	3.5	7	3.5	6	2.5	3.5	1	4	1	5.5	3
Average height of mulch layer (Standard deviation) [cm]	1.56	1.12	1.62	1.34	1.58	1.19	1.48	1.21	1.71	1.23	1.99	1.36
Average fuel consumption (sample plot)) [l]	2.1	0.38	1.52	0.175	1.61	0.45	1.15	0.35	2.2	0.7	0.65	0.17
Average time of cutting sample plot) [min]	19	6	26	5	55	13	13	5	24	9	10	3
Conversion coefficient	0.70	0.60										
Cutting time sample plot [min]	13	4	18	4	39	9	8	3	14	5	6	2
Consumption [l/ha]	70.00	25.33	50.67	11.67	53.67	30.00	38.33	23.33	73.33	46.67	21.67	11.33
Consumption [l/mth]	6.63	3.80	3.51	2.10	1.76	2.08	5.31	4.20	5.50	4.67	3.90	3.40
Consumption [l/l of cut biomass]	0.12	0.13	0.10	0.05	0.18	0.23	0.16	0.18	0.28	0.47	0.05	0.03
Performance [ha/hour]	0.14	0.21	0.10	0.26	0.05	0.10	0.23	0.30	0.13	0.17	0.29	0.50

Fig. 3 shows that at measuring fuel consumption [l/l of cut biomass] in the individual cutting machines on the two different sites, the Scag STWC52V-26KA-LC had the highest consumption on both measured localities. The same cutting machine had the biggest difference in consumption [l/l of cut biomass] between the two localities. By contrast, the Scag STT-SM58-28CAT-SS cutting machine had the lowest consumption on both sites. The Agria 5900 Taifun cutting machine had the smallest difference between the tested sites.

Fig. 4 shows that the performance [ha/h] of all tested cutting machines was higher on the sites that were regularly maintained by mulching in the past. On the sites with the permanent grass stands unkempt for a long time, all tested cutting machines exhibited a lower performance [ha/h]. The biggest difference in the performance [ha/h] between the two tested sites was recorded in the Scag STT-SM58-28CAT-SS cutting machine. The smallest difference in the performance [ha/h] between the two sites was recorded in the Scag STWC52V-26KA-LC cutting machine. It can be stated that compared with the uniaxial tool carriers, the professional large-scale mowing machines achieved a higher performance [ha/h] in both localities with the exception of Scag STWC52V-26KA-LC in which 0.13 ha/h was recorded on Site 1 and 0.14 ha/h was measured in the Agria 5900 Taifun uniaxial tool carrier.

The research results indicate that work productivity depends on the working width of cutting mulching systems, used blades and their wear, engine performance, travel speed and size of mulched area.

As the plots on Site 1 (permanent grass stand unkempt for a long time) were overgrown mainly with the herbaceous vegetation and grasses, some significant conclusions can be drawn. Less suitable on these plots appeared to be mulching systems with the vertical axis of rotation or systems used at the measurement, in which the size of entrance into the working space of blades was not optimal. The reason was that taller grasses and herbs were laid down and the blades had no chance to cut and crush their biomass properly. The neglected grass stand had to be treated by the cutting machine at least two times, for the second time in the direction opposite to the first one. The lying thick grass was a problem for all types of the cutting mulching systems. The only exception was the Safety type. The mulching mechanism with the "Y" blades and hammers exhibited the winding up of grass, and several times the working space became completely congested. This problem was observed in the Robot Komunal tool carrier in which a continuous adjustment of travel speed was impossible. Working space clearing impaired the work productivity of cutting systems.

The sample plots on Site 2 (grass stand regularly maintained by mulching) did not show any problems. In terms of work productivity, the most suitable mulching systems for the regularly treated grass stands are those with the vertical rotation axis.

DISCUSSION

As to work quality on the studied plots (permanent grass stand unkempt for a long time and permanent grass stand regularly maintained by mulching), the suitability of individual types of mulching systems for different terrain conditions was clearly demonstrated. There were also apparent differences between the individual studied plots. Fuel consumption on the sites unkempt for a long time [l/ha] was considerably higher than on the sites regularly maintained by mulching in the past. It should be emphasized that the performance [ha/h] of all tested grass cutting machines was higher on the sites regularly maintained by mulching in the past. It was also found out that of the six measured machines, the STT-SM58-28CAT-SS machine had the best economic characteristics which exhibited the lowest fuel consumption per hectare of cut biomass (Fig. 1) and at the same time the highest performance per hour (Fig. 4) as compared with the other machines.

The Safety mulching systems appeared universal in relation to the quality of cutting. The machines are equipped with a helix with fixed blades (segments) thanks to which the grass stand was cut evenly, biomass was very well ground and evenly distributed across the cut area even when the grass was lying. Their disadvantage was revealed only in thinner and drier stands. As the helix created a whirl in the working space of the cutting system and the cut biomass had nothing to lean on, the grass was bent and the stand was not cut evenly. As to the mulching systems with the horizontal axis of rotation, a relatively straight cut was recorded also in the mulching system with hammers. However, the cut biomass was not ground sufficiently. The cutting mulching system with the loose "Y" blades did not exhibit a sufficiently straight plane of cut but could properly grind the cut biomass thanks to the fact that the surface area of blades is larger than the surface area of hammers. In terms of cutting quality, mulching systems with the horizontal rotation axis are more appropriate for extensively cut areas. As to work quality, both types (horizontal and vertical rotation axes) are suitable for regularly treated grass surfaces with the most important factor being the sharpness of blades and the necessary number of rotations of the working roller with blades (hammers). An important factor in the relation of tool carrier and operator as to the influence on work quality is to find an optimum travel speed. If the work speed is too high, the machine can neither cut the biomass nor to grind it. Rather frequent is the congestion of the working space of the mulching system. Very important is also the correct adjustment of stubble height and good terrain copying because the cutting height differs in dependence on the intended use and type of cutting machine (Lee *et al.,* 2011). An important factor that will show only in critical situations or in unfavourable terrain conditions are tires of drive wheels. Therefore, machines for grass cutting should preferrably have wide tires with an optimal tread pattern.

In addition to cutting itself, a significant side effect of cutting is the removal of cut material (Ruprecht *et al.,* 2010). One of possibilities is mulching, i.e. cutting of grass stands without the collection of grass which can be used for the maintenance of grasslands where grass is not intended to serve as fodder. Regular mulching (two or thee times a year) has a similar effect on the composition of stands as cutting, i.e. an increased number of plant species. There are records on an increased biodiversity index comparable with that of grass stands managed by cutting (two times a year) with the removal of biomass (Heckman *et al.,* 1999; Knot, 2013). Advantage of the technology without biomass collection at regular cutting is a shorter cutting time. Disadvantage is however a more frequent cutting to prevent the grass stand overgrowing (Wilson and Koski, 1998). Compared with the technology combined with the collection of cut biomass, mulching represents the saving of costs for loading, transport and storage or disposal of the cut material (Knot *et al.,* 2017). Cutting of grass stands with the removal of cut biomass means the removal of nutrients from the grass stands (Marrs *et al.,* 1998). Nevertheless, if a large stand is cut, the layer of mulch is too thick, which is undesirable and might suppress the grass stand (Wilson and Koski, 1998). Loydi *et al.* (2013) and Kelemen *et al.* (2014) have a similar opinion claiming that excessive accumulation of non-decomposed biomass on the soil surface has a negative impact.

It is also necessary to choose a proper time for mulching. The date of cut and hence the cut quality can be influenced by many factors. If we go for a late cut (July), some grass species will ripen. The grass may lie down, which will significantly affect the quality of mulching as plants will not be cut completely. On the other hand, this may be positive for water retention and protection from evaporation (Kaźmierczakowa, 1999). The selected date of mulching may also affect the quality of cut biomass decomposition. Bussiere and Cellier (1994) and Chung and Horton (1987) and Mohamoud and Ewing (1999) agree that an indisputable advantage of mulching is the insulation of the soil surface by which resistance increases to heat transfer and evaporation. Mulching also helps to improve the quality of soil humus, water content and temperature (Movahedi Naeni and Cook, 2000).

Čedík and Pexa (2015) observed during the mulching a direct proportion between the fuel consumption and the volume or weight of cut biomass. This trend we focused on in our study, too. It was the highest in the Scag STWC52V-26KA-LC machine whose fuel consumption was the highest in both studied sites. The Scag STT-SM58-28CAT-SS machine exhibited the lowest fuel consumption with the difference more perceptible in Site 1 as compared with the other machines. Čedík and Pexa (2015) point out that mulching is an energy intensive operation and that the machine performance for the activity of mulching has to be on average 22.6 $kW.m^{-1}$ with respect to the type of the mulching system. Srivastava *et al.* (2006) state that the performance of these machines is from 11 to 16 $kW. m^{-1}$, which corresponds to values declared by the manufacturers of machines studied in this research.

There are thee technologies that can be used to manage grass stands by cutting without grass collection: rotary cutting machines, spindle cutting machine and flail cutting machines (Munshaw, 2013). The advantage of all these cutters is that their operators can use them with hardly any previous practice. Main factors in grass cutting are machine quality, cutting efficiency and reliability of machine work. Rotary cutting machines cut grass using just one rotating blade and are the most effective for cutting tall grasses. They are however not suitable for cutting low grasses, and undercutting often happens if they are used (Munshaw, 2013). Spindle cutting machines are predominantly used to cut maintained grass stands such as golf greens where their higher quality of cut is utilized (compared with the rotary cutters) as well as a low stubble (below 2.5 cm) where the stand could be ripped out if a rotary cutter is used (Beard and Eaton, 1973; Munshaw, 2013). It is also necessary to have the cutting system properly maintained. Cutting or mulching with unsharpened blades could result in the tearing of plant stems instead of their cutting, which is undesirable in respect of grass stand quality (Johansson and Hedin, 1991). Priest *et al.* (2004) and Chistensen *et al.* (2001) point out that activities connected with the turfgrass care such as grass cutting are most frequently performed using machines with small engines and that two- and four-stroke petrol engines are used in grass cutting machines, which significantly contribute to the contamination of the urban environment with the gaseous phases and particles of hydrocarbons and with other contaminants, e.g. CH_4, CO, NO_X. Junker *et al.* (2000) have a similar opinion and claim that in addition to emissions associated with the grass cutter, grass cutting generates a range of emissions connected with the process of grass cutting itself. One type of them are mechanically generated particles such as remainders of plants or swirling soil dust. Another type are gaseous emissions of volatile organic compounds from plants, which occur due to leaf injuries (Karl *et al.,* 2001; Kirstine *et al.,* 1998). These vapours are responsible for the typical smell of the freshly cut grass (Karl *et al.,* 2001).

A technique of cutting grass stands without the collection of cut biomass can also be represented by the application of autonomous cutters. They have a number of benefits such as savings of time, energy, low noisiness etc. (Hicks and Hall, 2000; Ragonese and Marx, 2015). They are powered by batteries and do not need an operator for cutting. They are usually programmed for everyday cutting which ensures that tiny pieces of biomass fall though into the turfgrass and a layer of cut grass is not formed on the stubble surface (Brede, 2000). Compared with the rotary cutting machines, the autonomous cutters exhibit the high quality turfgrass (Grossi *et al.,* 2016; Pirchio *et al.,* 2018), which however applies only to regularly managed grass stands.

Intensive management of grassed areas leads to the decrease of seminatural, unmanaged grass stands (Johansson *et al.,* 2008; Dengler *et al.,* 2014). Regular cutting eliminates and controls allochthonous annual grass and weed species (Prevéy *et al.,* 2014; Valliere *et al.,* 2019). Svensson *et al.* (2009) state in their study that regular grass cutting has not apparently negative effects on the flora but can lead to the elimination of some animal species that are dependent on the sites and may consequently become rare or endangered (Tälle *et al.,* 2014; Gärdenfors *et al.,* 2010). On the other hand, (Marrs *et al.,* 1998) claim that cutting, i.e. the removal of above-ground biomass, means the removal of nutrients. The recommended technique of cutting grass stands should however preserve a high diversity of plant and animal species as well as rare and endangered species depending on the site (Wahlman and Milberg, 2002; Milberg *et al.,* 2014).

In many European countries, grass is usually mown without its collection, namely at municipal maintenance. In those countries, grass cutting with its collection is not so usual for maintaining built-up areas as it is in the Czech Republic. At maintaining grass stands, considerations should be given to the site where they are situated. If they are situated in the built-up area of a municipality or a town, their management has to comply with the local legislation. There should also be ecological, economic and societal compromises. Technical literature does not include much information about using grass cutting machines in combination with mulching. This is why the goal of this paper was to examine and compare them because the intensive cultivation of turfgrass areas brings about also a greater emphasis on their maintenance.

CONCLUSION

This study aimed at a monitoring of functional and operational parameters of uniaxial tool carriers, single-axle small tractors and cutting machines with a zero turning radius on their selected samples. The mechanization means were tested in practice and experimental results were analyzed.

Practical measurements were taken on two sites of which the first one was a permanent grass stand unkempt for a long time and the second one was a permanent grass stand regularly maintained by mulching. Machines used in the measurements included the uniaxial tool carriers Agria 5900 Taifun with the Safety mulcher Humus SME-125, Rapid EURO 4 with the hammer mulching system Humus SMK/E-105, the single-axle small tractor ROBOT with the B 750 cutting mulching system with the horizontal axis of blade shaft rotation, the cutting machines with a zero turning radius Scag STT61V-29DF1-SS, Scag STWC52V-26KA-LC, both with the thee-blade cutting mulching system and the vertical axis of blade shaft rotation, and Scag STT-SM58-28CAT-SS with the Safety Humus mulching system. This machine was introduced as specific because in spite of the fact that it is classified as a cutting machine with a zero turning radius, thanks to the Safety cutting system it is intended for extensively managed permanent grass stands and can efficiently complement or even replace tool carriers with the cutting mulching systems on large areas. As the machines used in our experiment featured different cutting system types, an overview could be made of the possibilities for using the individual assemblies, cutting qualities and suitability of the machines for various surfaces, based on the measured, monitored and calculated data.

The research demonstrated that uniaxial tool carriers are suited for cutting poorly accessible rugged surfaces and slopes more than cutting machines with a zero turning radius. They are primarily used for the extensive maintenance of permanent grass stands by the technology without collection (mulching). Single axle small tractors are determined primarily for work in agriculture and gardening, particularly at places where cutting is not a dominant work of these machines. Results of the research further indicated that cutting machines with a zero turning radius are determined for the intensive maintenance of more extensive and continuous permanent grass stands.

The technology of maintaining permanent grass stands by cutting without the collection of biomass and its subsequent crushing and leaving on the site (mulching) is very progressive. It is gradually winning the ground also in the built-up areas of towns where grassed areas used to be traditionally managed by cutting with the collection of cut biomass so far. Main reasons are that it is a low-cost method with a very favourable influence on the turfgrass provided that all rules are followed.

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