Agronomy Research **15**(5), 1890–1896, 2017
https://doi.org/10.15159/AR.17.049

Qualitative classification of mulchers

R. Hnilica[1,*], M. Kotus[2,*], M. Jankovský[3], M. Hnilicová[4] and M. Dado[1]

[1]Department of Manufacturing Technology and Quality Management, Faculty of Environmental and Manufacturing Technology, Technical University in Zvolen, Študentská 26, SK960 53 Zvolen, Slovak Republic
[2]Department of Quality and Engineering Technologies, Faculty of Engineering, Slovak University of Agriculture, Tr.A. Hlinku 2, SK949 76 Nitra, Slovak Republic
[3]Department of Forestry Technologies and Construction, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, CZ165 21 Prague 6 – Suchdol, Czech Republic
[4]Department of Forest Harvesting, Logistics and Ameliorations, Faculty of Forestry, Technical University in Zvolen, T.G. Masaryka 24, SK960 53 Zvolen, Slovak Republic
[*]Correspondence: hnilica@tuzvo.sk; martin.kotus@uniag.sk

Abstract. Mulchers are helpful in forest establishment and tending. Numerous mulchers are available, so buyers can become disoriented when choosing one. This paper was aimed at creating a classification of mulchers based on the evaluation of the most important parameters: weight, required engine performance, and mulching diameter. Through ANOVA, and regression and correlation analyses of our database, we created six machine classes, devised their upper limits, and assigned mulchers to the classes. Class K1 (weight up to 1,300 kilograms; performance up to 75 kilowatts; mulching diameter up to 22 centimetres) was the most popular one with 88 mulchers. It was followed by class K2 (1,800 kilograms; 100 kilowatts; 27 centimetres) with 61 mulchers, class K4 (3,200 kilograms; 175 kilowatts; 41 centimetres) with 44 mulchers, class K3 (2,300 kilograms; 125 kilowatts; 31 centimetres) with 34 mulchers, class K5 (4,100 kilograms; 225 kilowatts; 51 centimetres) with 18 mulchers, and class K6 (no upper limit) with nine mulchers.

Key words: mulchers, mulching diameter, engine performance, weight, classification.

INTRODUCTION

Machinery producers have broad product ranges to satisfy the specific needs of their customers. They use the latest scientific knowledge in design, technology, materials and other fields of research to keep up with the competition. However, they cannot meet the needs of every single potential client, as this could theoretically cause the production of an almost infinite number of machine types, thus significantly increasing production costs. Sloboda et al. (2008) and Majdan et al. (2012) described the process of selecting machines suitable for various applications. They state that one of the most important factors in product innovation and production economics improvement is the optimisation of the product range, reflected in a finite number of machine classes. This enables producers to apply unification in design, contributes to cost effectiveness, and increases customer satisfaction. Producers need to know, which machines (or machine classes) are the most marketable to be able to focus their resources on effectively.

Bukoveczky et al. (2007) and Štollman & Slugeň (2009) focused on the classification of forestry machines. They devised their classification systems for different kinds of machines however, and their classifications are not fully applicable to forestry mulchers. They approached the classification of forestry machines and mechanisms only through evaluating two variables (performance and weight). They did not consider the joint effects of technical (e.g. weight of the machine), and operational (e.g. required engine performance of the machine, diameter of the processed growth, etc.) parameters. Furthermore, they designed their classification system for machinery used in forest harvesting. In our article, we have tried to consider both the technical and operational parameters simultaneously, because we believe that dividing machines in this manner provides valuable information for the consumers and the producers.

Rao (1992) described the possibilities of using mathematical data processing in creating models, such as classifications. Their work gives one valuable information on what statistical analyses to use. Forestry mulchers and their most important characteristics came into the focus of Eisenbarth (2000), who determined the most influential parameters for the quality of their work. He evaluated two mulchers during the maintenance and construction of forest roads. Based on measurements from 145 newly constructed roads he determined that the performance, costs and technique influence the quality of the work of the mulcher the most. Zemánek et al. (2004) evaluated the innovation of machines based on their technical and economical parameters.

Čedík et al. (2016) and Kumhála et al. (2016) define of mulching is among energy intensive crop harvesting operations. It is therefore interesting to deal with mulching energy demands in more details. The energy intensity of mulching or shredding of plant material is dependent on the type of processed crop, parameters of the cut (mass performance, cutting speed etc.) and shape and condition of the cutting tool (Syrový et al., 2008; Hosseini & Shamsi, 2012; Kronbergs et al., 2013; Pecenka & Hoffmann, 2015).

Mulchers are multipurpose machines. The wide range of their shapes and sizes documents this fact. Despite the variety of the machines, no classification of mulchers was found when the literature survey for this paper was carried out. This article is aimed at creating a classification of mulchers with mechanical drives according to their main technical and operational parameters – required performance of the base machine, the diameter of the processed growths, and the weight of the mulcher.

MATERIALS AND METHODS

The proposed classification of mulchers with mechanical drives is based on a method described by Bukoveczky et al. (2007). The method was modified to meet the needs of this study. To elaborate the classification of mulchers, a comprehensive database of mulchers with mechanical drives was created, statistical analyses were carried out, and the criteria for dividing mulchers into classes were devised.

The comprehensive database (statistical sample) of mulchers with mechanical drives produced globally was created according to the method described by Hnilica et al. (2012). Each database entry contained information on the brand, mulcher designation, weight, required performance of the base machine (furthermore: required performance), power torque output of the mulcher, and the maximal diameter of processed growth (furthermore: mulching diameter).

The analysis of variance (ANOVA) was used to prove whether the required performance had a significant influence on the weight and mulching diameter. The relationship between the required performance and weight, and between the required performance and mulching diameter was studied further through a regression and correlation analysis. Individual mulchers were divided into groups and categories through a frequency analysis, i.e. the detection and characterization of the distribution of the crushers' abundance in terms of performance, weight and average growth.

An orthogonal projection of the individual database entries (mulchers) to a regression line was created. This lead to the creation of 10 orthogonal groups (I to X). The mulchers were divided into orthogonal groups according to the following criteria: (i) weight of the mulcher; (ii) mulching diameter; (iii) required performance, as provided by the producers of the individual mulchers.

The producers did not have a consistent method of stating the required performance of the mulchers they produce. Mulcher producers stated the required performance in four different ways. If producers provided the upper and lower performance limits, their mean was calculated and then the mulcher was assigned to the corresponding orthogonal group. If the producers provided the required performance as one value, this value was used to assign the mulcher to the corresponding group. If the producers provided the minimal required performance, the number was multiplied by a coefficient of 1.2 and then the mulcher was assigned to the corresponding group. If the producers provided the maximal required performance, the number was multiplied by a coefficient of 0.8 and then used to assign the machine to the corresponding group.

The frequency p1 to p10 was determined in every orthogonal group and a frequency diagram was constructed. The length of the class intervals for the required performance (Scheer & Sedmák, 2010) was set, and the orthogonal groups were divided into classes K1 to Kn. Each class consisted of three groups maximally, and contained as many mulchers as possible.

RESULTS AND DISCUSSION

A database containing 254 mulchers from 17 different producers was created. Table 1 shows a sample of the database. The complete database is available from the authors upon request.

The data from the database was divided according to the relationship between the weight and the required performance and the relationship between the mulching diameter and the required performance. ANOVA proved a statistically significant effect upon the required performance on the weight (F: 1,211.67; p: < 0,001). The regression and correlation analysis showed a strong correlation between the required performance and the weight (R: 0.91; R2: 0.83; standard deviation – SD: 0.44; p: < 0.001). A ten kilowatt increase in the required performance resulted in a 190 kg (95% confidence interval – CI: 180–200 kg) increase in weight. The variability of the required performance explained

83% of the variability in weight. Fig. 1, a shows the graphic depiction of the relationship. It also shows that most mulchers in the database were in the 50 to 150 kW required performance range and weighed 500 to 2,200 kg.

Table 1. A Sample from the Comprehensive Database of Mulchers with Mechanical Drives

Brand	Mulcher designation	Weight (kg)	Required performance (kW)	PTO (rpm)	Grinding diameter (cm)
FAE	UML/SS 150	970	45–82	540/1,000	20
FERRI	MC 180	545	41–52	540	6
AHWI	M700	4,350	185–300	1,000	30
SERRAT	FX3 T-1200	580	32–44	540	8
MERI	MJS-2.0 DT	1,610	82–135	1,000	25
FAE	UMH 175	2,910	97–112	1,000	40
SERRAT	FX5 T-2000	2,470	110–150	1,000	20
VENTURA	TFVJ 130	625	*min* 30	540	18
TEAGLE	EKR/S250	645	45–60	540/1,000	3
OSMA	TLPF 220	1,290	89–104	1,000	25
FAE	SSH 225	4,581	164–261	1,000	69
FECON	BH200	2,449	104–336	1,000	50
SEPPI M_	FORST M	4,900	125	1,000	30
RYETEC	TRB 180	1,220	60–82	1,000	15
BUGNOT	BFO 1800	2,560	*max* 186	1,000	50

PTO – power torque output; kg – kilograms; kW – kilowatt; rpm – revolutions per minute; cm – centimeter.

ANOVA proved that the required performance significantly affected the mulching diameter too (F: 384.62; p: < 0.001). The correlation between the mulching diameter and the performance proved to be strong as well (R: 0.78; R2: 0.60; SD: 8.05; p: < 0.001). A ten kilowatt increase in the required performance resulted in a 1.95 cm (95% CI 1.75–2.14 cm) increase in the mulching diameter. The variability in the required performance explained 60% of the variability in the mulching diameter. Fig. 1, b shows the graphical depiction of the relationship and that less than 50% of the mulchers can process growths thicker than 35 cm.

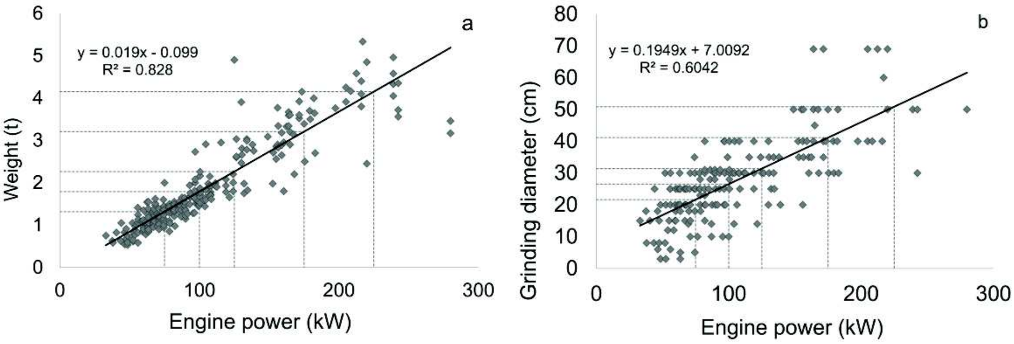

Figure 1. Relationship between the weight of the mulchers and their required performance (a) and the mulching diameter of the mulchers and their required performance (b); dashed lines denote the individual classes.

The mulchers were assigned into orthogonal groups based on their parameters and a frequency diagram of the mulchers in individual groups was constructed (Fig. 2, a). The orthogonal groups were divided into six classes K1 to K6. Class K1 contained groups I and II, K2 contained group III, K3 contained group IV, K4 contained groups V and VI, K5 contained groups VII and VIII, and K6 contained groups IX and X.

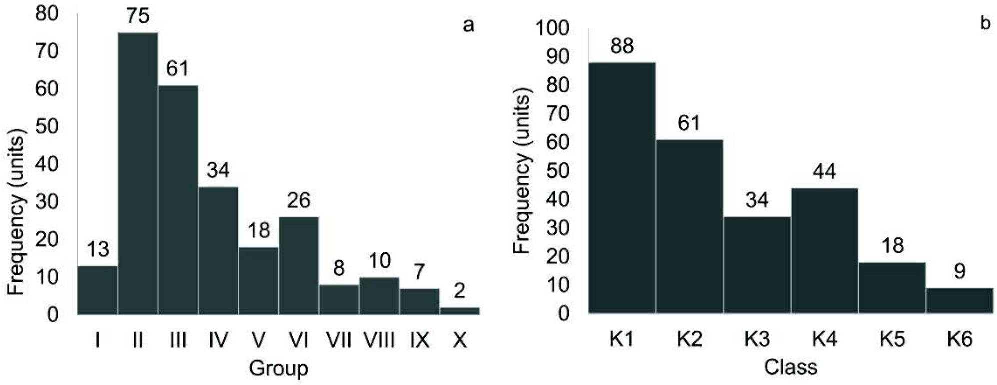

Figure 2. Frequency diagrams of the mulchers assigned to the individual orthogonal groups (a) and classes (b).

The class upper limits for weight, required performance, and mulching diameter were determined from the corresponding regression lines (Fig. 1). Table 2 shows the characteristics of each class. Fig. 2, b shows the population of each class. Classes K1 to K4 are the most relevant for producers. Mulchers in the K1 class are the most frequently used in practice. Classes K5 and K6 contain high performance mulchers with lower production quantities. Mulchers included in these classes are produced almost exclusively on demand and are optimised for the specific needs of the individual customers.

Table 2. Specification of lower and upper class limits for required engine performance, weight, and mulching diameter of mulchers with mechanical drives

Parameter	K_1^*	K_2^*	K_3^*	K_4^*	K_5^*	K_6^*
Engine performance (kW[a])	0–75	76–100	101–25	126–175	176–225	over 225
Weight (kg[b])	0–1,300	1,400–1,800	1,900–2,300	2,400–3,200	3,300–4,100	over 4,100
Mulching diameter (cm[c])	0–22	23–27	28–31	32–41	42–51	over 51

$^*K_i$ – class designation; [a]kW – kilowatt; [b]kg – kilogram; [c]cm – centimeter.

Classifications of machinery based on more than two parameters are common in practice. Eisenbarth (2000) stated that performance, costs, and technique influence the quality of terrain preparation the most. This information validates the parameters we chose for the proposed classification – mulcher performance (defined by the mulching diameter) and weight (the quality and quantity of material used throughout the machine production affects its price). Zemánek et al. (2004) evaluated the innovation of machines based on their technical and economical parameters. They also considered the technological process when selecting appropriate machines. Incorporating economic parameters of mulchers into the classification is problematic, because the price is not a fixed value and depends on the time of the purchase and the accessories of the mulchers. Operational economic parameters of mulchers, such as variable costs, also change with the conditions in which the mulchers operate (e.g. terrain, base machine, processed material, natural conditions in which the mulchers are used, etc.).

We shall further verify the proposed classification of mulchers by including new types of mulchers and expanding the database. We shall remain focused on the area of machines used in forest establishment and tending.

CONCLUSIONS

This classification reflects the needs of forestry in practice. It can serve as a lead for machine producers when they optimise their product range. Meeting the market demand with minimum product types is especially important for the economics of machine production and the unification of machine parts. After assigning mulchers into classes, one can see the popularity of each class. This is beneficial to the producers of mulchers, as they will have valuable information about the state of the market and their competitors. This categorization reflects customer specifications (forestry) after crushers these dimensional types and can be for machine producers support in determining the of optimal construction crushers series. Meet market demand with the minimum number of types is especially important for the producer in economic terms and in view of unification the construction. They can reach an informed decision on what types of mulchers to produce. The proposed classification can also improve the decision-making process of consumers. They will simultaneously acquire information on which mulcher they can mount on the base machines they already own and whether it is going to be sufficiently powerful for their intended purposes.

ACKNOWLEDGEMENTS. This paper was elaborated as a part of the scientific grant project APVV-0145-10 'Utilization and development of adapters for mechanization of works on forest establishment and timber stand improvement' and scientific grant project VEGA 1/0531/15 'Increasing the life of tools and components of the mechanisms used in forestry technology'.

REFERENCES

Bukoveczky, J., Gulan, L., Zajacová, Ľ. & Schmidtová, C. 2007. Určenie veľkostného radu skupiny mobilných pracovných strojov (Determination of size range of mobile machines). In: *Zborník MVK Mobilné energetické prostriedky – Hydraulika – Životné prostredie – Ergonómia mobilných strojov*, FEVT, Zvolen (2007).

Čedík, J., Pexa, M., Chyba, J., Vondrášek, Z. & Pražan, R. 2016. Influence of blade shape on mulcher blade air resistance. In: *Agronomy Research* **14**(2), 337–344.

Eisenbarth, E. 2000. Mulchgerate im Praxisvergleich (A comparison of mulching machines). AFZ/Der Wald **55**, 518–522.

Gitlow, H. 1989. *Tools and Methods for the Improvement of Quality*. Richard D. Irwin, INC., Homewood, Illinois, 603 pp.

Hnilica, R., Mesingerová, V., Hnilicová, M. & Stanovský, M. 2012. Drviče nežiadúcich nárastov s mechanickým prenosom energie (Mulchers of undesirable advance growth with mechanical transmission of energy). In: *Les. Pr.* **92**, 152–158.

Hosseini, S.S. & Shamsi, M. 2012. Performance optimization of a rotary mower using Taguchi method. In: *Agronomy Research* **10**(1), 49–54.

Kronbergs, A., Kronbergs, E. & Repsa, E. 2013. Evaluation of reed canary grass shredding and compacting properties. In: *Agronomy research* **11**(1), 61–66.

Kumhála, F., Chyba, J., Pexa, M. & Čedík, J. 2016. Measurement of mulcher power input in relation to yield. In: *Agronomy Research* **14**(4), 1380–1385.

Majdan, R., Tkáč, Z., Abrahám, R. & Kosiba, J. 2012. Teória a konštrukcia traktorov (Theory and construction of tractors) Slovak University of Agriculture in Nitra, Nitra Slovakia, 100 pp.

Pecenka, R. & Hoffmann, T. 2015. Harvest technology for short rotation coppices and costs of harvest, transport and storage. In: *Agronomy Research* **13**(2), 361–371.

Rao, S. 1992. Reliability-Based Design. McGraw Hill, New York, 569 pp.

Scheer, Ľ. & Sedmák, R. 2007. *Biometria* (Biometry). Technická univerzita vo Zvolene, Zvolen, Slovakia, 333 pp.

Sloboda, A., Ferencey, V., Hlavňa, V., Tkáč, Z., Spišák, E., Piľa, J., Sloboda, A., Rojko, E., Močkoř, R., Isteník, R., Labuda, R., Sojčák, D., Žikla, A., Jablonický, J. & Abrahám, R. 2008. *Konštrukcia kolesových a pásových vozidiel: teória, konštrukcia, riziká*. (The design of wheeled and crawler-type vehicles). Vienala, Košice, 547 pp.

Syrový, O., Bauer, F., Gerndtová, I., Holubová, V., Hůla, J., Kovaříček, P., Krouhlík, M., Kumhála, F., Kvíz, Z., Mašek, J., Pastorek, Z., Podpěra, V., Rybka, A., Sedlák, P., Skalický, J. & Šmerda, T. 2008. Energy savings in crop production technologies. In: *Research Institute of Agricultural Engineering*, p.r.i., Prague, 101 pp.

Štollmann, V. & Slugeň, J. 2009. Návrh novej kategorizácie harvesterov na základe analýzy hmotnostných a výkonových parametrov (A proposal of new classification of harvesters based on weight and performance parameters). In: *Acta Facult. For*. **51**, 101–109.

Zemánek, P., Abrham, Z. & Burg, P. 2004. Economic effectiveness of mulching machines operations. In: *Hortic. Sci*. **31**, 76–80.