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EFFECTIVE OPERATIONAL CAPACITY OF BRUSHCUTTER WITH DIFFERENT CUTTING TOOLS

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ABSTRACT

Brushcutters use different cutting tools with variations in operating capacity. Thus, the present study evaluate the effective operational capacity of a brushcutter equipped with different cutting tools in different areas of plant cover. It was subdivided into three experiments with 44 replicates of 4m^2 each. The first was carried out in an area with plants cover with wheat and ryegrass, with blades of triple and double discs, and double wire. The second was carried out in another area with a cover composed of wheat, ryegrass, and fallow (composed of different species plants), with double- and triple-discs blades. The last experiment was carried out in a fallow area, with all cutting tools, except for the double wire. The results indicate that the brushcutter equipped with the triple-disc blade had greater operational capacity compared to the other cutting tools. For a working day of 8 h.day^{-1}, the highest amount of mowed biomass was obtained with the triple-disc blade in areas with ryegrass and wheat cover, while for the fallow area, there is no significant difference between the double- and triple-disc blades. The adequate selection of the cutting tool contributes to the increase of the cut biomass in a shorter time, reducing the exposition of the operator to the vibrations and noise produced by the machine.

Palavras-chaves:
Lâmina
Operação
Roçada
Rendimento
Vegetação

CAPACIDADE OPERACIONAL EFETIVA DE MOTORROÇADORA COM DIFERENTES FERRAMENTAS DE CORTE

RESUMO

As motorroçadoras utilizam diferentes ferramentas de corte com variações na capacidade operacional. Assim, o presente estudo avalia a capacidade operacional efetiva de uma motorroçadora equipada com diferentes ferramentas de corte em áreas com distintas coberturas vegetais. Foi subdividido em três experimentos com 44 repetições de 4 m² cada. O primeiro foi conduzido em área com cobertura vegetal de trigo e azevém, com lâminas de três e de duas pontas, e fio duplo. O segundo foi conduzido em outra área com cobertura composta por trigo, azevém e pousio (composto por diferentes espécies vegetais), com lâminas de duas e três pontas. O último experimento foi realizado em área de pousio, com todas as ferramentas de corte, com exceção do fio duplo. Os resultados indicam que a motorroçadora equipada com a lâmina de três pontas apresentou maior capacidade operacional em relação às demais ferramentas de corte. Para uma jornada de 8 h.dia^{-1}, a maior quantidade de biomassa roçada foi obtida com lâmina de três pontas nas áreas com cobertura de azevém e trigo, enquanto no pousio não existe diferença significativa entre lâminas de duas e três pontas. A seleção adequada da ferramenta de corte contribui para o aumento de biomassa roçada em menor tempo, reduzindo a exposição do operador às vibrações e ruídos produzidos pela máquina.

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INTRODUCTION

The performance of mechanized operations in small farms has become an interesting alternative for many farmers whose objective is to reduce the time to carry out the activities, as well as the physical wear when compared to work using manual tools. Many of these operations are carried out Using small or semi-mechanized machines. In this sense, the use of mechanization as a production tool allows for greater efficiency in operations and cost reduction (CUNHA *et al*., 2016). Thus, according to Carvalho (1999), Márquez (2004), and COTF (2013), machines such as brushcutters are used in cleaning operations, especially where mechanization is limited (areas of difficult access) and in small areas (due to the low operational capacity).

A brushcutter is a machine consisting of a cutting tool at the end of a rod, through which the movement is transmitted to activate it (MÁRQUEZ, 2004). This machine is attached to two handles, one for each hand, and hung from operator support (COTF, 2013). At the near-ground end, the cutting element is positioned so that it reaches the understory vegetation at an appropriate angle of attack.

The operational capacity of a machine depends on the time worked and the time losses that occur due to machine obstructions, refueling, machine preparation, interruptions during the workday, among others (BALASTREIRE, 2005). Therefore, Mialhe (1974) clarifies that the operational capacity of machines and implements deals with the amount of work they can perform in a unit of time.

Corroborating studies such as those developed by the authors Silva *et al*. (2014); Bertollo *et al*. (2019); Franco *et al*. (2019); Nagaoka *et al*. (2019); Tavares *et al*. (2019); Savioli *et al*. (2020) demonstrate the importance of operational performance in optimizing the use of machines and reduction in the costs.

As the semi-mechanized mowing operation is performed by man-machine interaction, its productivity is directly proportional to the operator's work rate. Oliveira *et al*. (2014), classify the operation with a brushcutter as moderately heavy after biomechanical evaluation. For Novais (2016), the choice of cutting element is dependent on the type of work to be performed. Therefore, it is necessary to characterize the operation performed and brief analysis of the vegetation to define the appropriate tool.

In this context, the performance indicator is a useful tool to enable improvements in the operation. Thus, the objective of this work was to evaluate the effective operational capacity of a brushcutter equipped with different cutting tools in areas with different vegetation cover.

MATERIAL AND METHODS

The study was carried out in September 2020 in the municipality of Santa Maria, state of Rio Grande do Sul, southern Brazil (29º42'56.84 S, 53º43'59.56 W) in an area at an altitude of 118 m. According to the Köppen's classification, the climate of the region is Cfa-type (humid subtropical), characterized by an average air temperature in the coldest month between -3 and 18°C and in the hottest month above 22°C, average annual rainfall of 1,769 mm, with rainfall well distributed throughout the year (ALVARES *et al*., 2013).

The air temperature and the average monthly rainfall during the experimental period were 15.8°C and 108.8 mm, respectively (BDMEP, 2020). The soil is classified as Paleudalf, characterized as an undulating plain with good drainage (HELDWEIN *et al*., 2009).

The study was subdivided into three experiments. Each one had 44 replicates of 2 x 2 m (width x length), totaling an area of 4 m² per plot. Each treatment had a mowing width strip of 2 x 88 m in length, totaling an area of 176 m² per experimental unit.

The first experiment was characterized in a two-factor statistical design (2 x 3), conducted in two types of vegetation cover and three cutting tools. The second experiment was characterized in a two-factor statistical design (3 x 2), covering three types of vegetation cover, and two cutting tools. The third experiment was characterized in a one-factor statistical design conducted in a fallow area composed of different plant species, and four cutting tools (Table 1).

Table 1. Cutting tools and plant cover types in each experiment

Experiment	Species	Cutting tools
1	*Triticum* spp. (wheat) and *Lolium multiflorum* (ryegrass)	Triple-disc blade; two-disc blade and double-wire cutting set
2	*Triticum* spp. (wheat) and *Lolium multiflorum* (ryegrass) *and fallow area*	Triple-disc blade and two-disc blade
3	Fallow area	Triple-disc blade, two-disc blade, Standard cutting blade, and circular blade.

To characterize the vegetation cover at mowing, the average height was measured in centimeters using a graduated ruler from the ground to the apical bud. The average height of 0.50 m, 0.66 m, and 0.93 m was obtained for wheat, ryegrass, and fallow, respectively.

The following species were identified in the fallow area: *Bidens pilosa* (Black-jack); *Conyza bonariensis* (Buva); *Plantago major* (Tanchagem); *Andropogon bicornis* (Bustail Grass); *Solanum mauritianum* (Smoky); *Baccharis dracunculifolia* (Broom); *Eragrostis plana Nees* (Annoni grass); *Raphanus sativus* L. (Forage radish); *Lolium multiflorum* (ryegrass).

After cutting, the vegetation was collected and placed in packages for weighing on a digital scale and the green mass was determined in kg. To calculate the operational capacity of the machine ($m^2.h^{-1}$) with each cutting tool, the time of the mowing operation in a 4 m^2 space was timed.

Mowing operations were carried out with a 2-stroke Otto-cycle, gasoline-powered side brushcutter, with a power of 1.6 kW and a cylinder capacity of 40.2 cm^3. The machine has a mass of 7.3 kg, 2,800 revolutions per minute (RPM) at low gear, and 12,300 RPM at full speed. It has a multifunctional handle with a curved profile that allows wide movement and makes the commands available at the reach of the hands, and the machine used in this study has a system that allows the exchange of the cutting tool.

Each tool has technical specifications indicated by the manufacturer, which guides their selection, depending on the different types of vegetation that can be handled with this machine. Given this premise, the following cutting tools were used in the experiments:

A. Triple-disc blade: 300-mm, recommended for highly-difficult mowing with shrub-cutting with a maximum diameter of 2 cm (Figure 1A);

B. triple-disc blade: 300-mm diameter, recommended for cutting, cleaning, and maintenance work with low and medium difficulties (Figure 1B);

C. two-wire cutting set: the cutting wires are round, with a thickness of 2.5 mm, suitable for cleaning areas, cutting, and finishing with low execution difficulty (Figure 1C);

D. Standard cutting blade: 200-mm diameter, with sharp teeth and capacity of cutting shrubs of up to 7-cm in diameter (Figure 1D);

E. circular blade: 200 mm diameter, equipped with chisel teeth designed for cutting logs up to 7 cm (Figure 1E).

The mowing operation was carried out by a single operator, with a body mass of 86 kg and a height of 1.76 m, to guarantee the uniformity of the operation throughout the data collection. To understand the operational performance, the effective operational capacity was calculated through Equation 1 adapted from Mialhe (1974):

$$\text{Effective operational capacity } \left(\frac{kg}{h}\right) = \frac{\text{Managed mass (kg)}}{\text{Time unit (h)}} \quad (1)$$

Data were submitted to the Shapiro-Wilk statistical normality test and, when not normal, transformed $(x + 0.5)^{0.5}$. Subsequently, the data were submitted to the F test for analysis of variance and, when significant, the differences between the means were verified using the Tukey test at 5% of significance. All statistical calculations were performed using the Sisvar *software* (FERREIRA, 2014).

Figure 1. Cutting tools used in the experiments: triple-discs (A), two-discs (B), double-disc cutting set (C), Standard cutting blade (D), and circular blade (E)

RESULTS AND DISCUSSION

The interaction between the different cutting blades with the mowed vegetation cover was significant in experiments one and two, indicating that the mowing is influenced by the cutting tool used in the brushcutter. Furthermore, in the first experiment, the effective operational capacity of the brushcutter was significantly affected by the cutting tool and the type of vegetation cover being cut. The highest values for effective operational capacity were observed with the triple-disc blade and in the area with vegetation cover composed of ryegrass (Figure 2).

The triple-disc blade and the two-disc blade influenced the effective operational capacity of the brushcutter for the covers composed of ryegrass and wheat, resulting in a higher value for ryegrass when compared to wheat. This statistical difference in relation to the same vegetation cover does not occur for the double-wire cutting set (Figure 2). The effective operational capacity of the brushcutter with the triple-disc blade on ryegrass was 1.21 and 3.54 times greater than the two-disc blade and double-wire cutting set, respectively, in the same crop (Figure 2).

Considering only the cover composed of wheat, the highest values of effective operational capacity were observed with the triple-disc blade, being these values 1.27 and 2.71 times higher in relation to the double-disc blade and double-wire cutting sets, respectively.

In the semi-mechanized mowing of herbaceous-shrubby vegetation, Oliveira *et al*. (2014) obtained effective average productivity of 0.29 $ha.h^{-1}$, which exceeds the results obtained in the present work by approximately 300% for managed vegetation cover. Corroborating to that, Da Silva *et al*. (2018) state that the expansion of arable land in the country, especially in places with sloping terrain or difficult access, where mechanized operation is limited, the use of brushcutters plays an important role. In this sense, for cutting plant species such as wheat and ryegrass, the use of a triple-disc blade is more efficient.

Regarding experiment two, the effective operational capacity of the brushcutter was significantly affected by the cutting tool and the type of vegetation being cut. The highest values were observed with the triple-disc blade in the vegetation cover composed of ryegrass (Figure 3). In addition, the results demonstrate that the cutting set using a triple-disc blade differs in the effective operational capacity for ryegrass cover, not differing between wheat and fallow area.

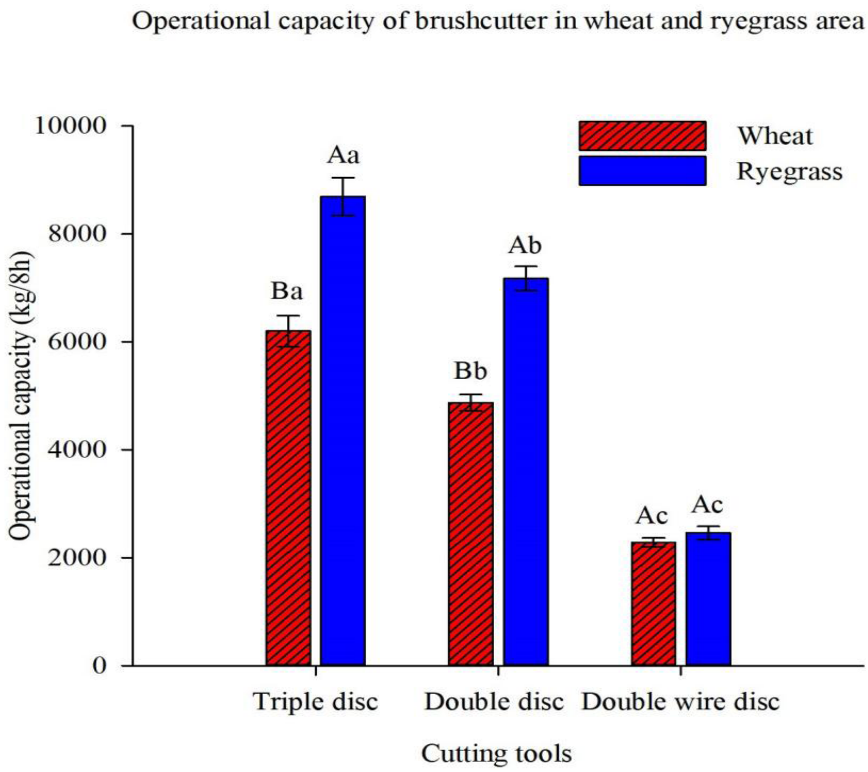

Figure 2. Effective operational capacity (kg biomass.8 h^{-1}) of the brushcutter, in wheat and ryegrass covers, using different cutting tools. Where: vertical bars represent the standard error of the means. Means followed by the same upper-case letter do not differ between covers on the same cutting tool, and the same lowercase letter does not differ among cutting tools in the same cover by the test of Tukey at 5% probability

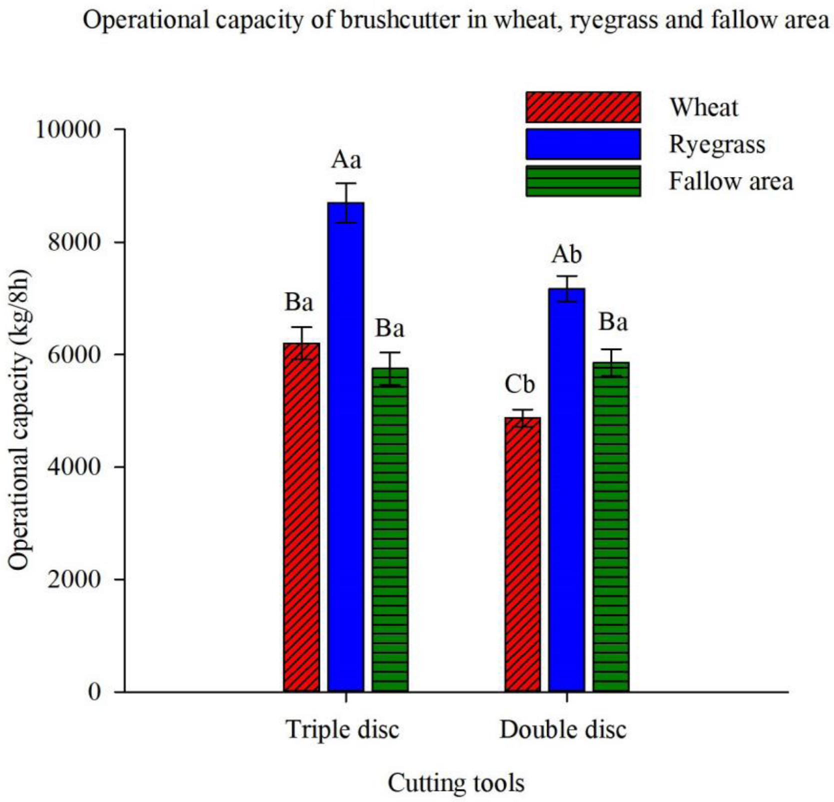

Figure 3. Effective operational capacity (kg biomass.8 h^{-1}) of brushcutter in wheat, ryegrass, and fallow areas, using different cutting tools. Where: vertical bars represent the standard error of the means. Means followed by the same capital letter do not differ between plant covers on the same cutting tool, and the same lowercase letter does not differ between cutting tools in the same cover by the test of Tukey at 5% probability

Considering the cutting set consisting of a double-disc blade, there were significant differences in the effective operational capacity of the brushcutter between the vegetation covers, resulting in decreasing values for the covers composed of ryegrass, fallow area, and wheat, respectively. The analysis in the cover formed by wheat allowed us to observe the highest values in the cutting set composed of a triple-disc blade, and for the fallow area, the values did not show a significant difference.

For experiment three, the highest effective operating capacity of the brushcutter in the fallow area was observed in the cutting tools with a triple-disc blade and with a double-disc blade, differing from the standard and circular blade cutting sets (Figure 4). In this sense, choosing between the triple-disc blade and the double-disc blade does not significantly change the effective operating capacity of the brushcutter in the fallow area. Similar behavior occurs in the standard cutting sets and the circular blade.

Based on the simulation of the 8-hour workday (Figure 5), it can be inferred that for the cutting of ryegrass and wheat cover species, the use of a triple-disc blade is recommended, as it has the greater effective operational capacity, providing greater biomass yield during the workday. It should be observed that there is no difference in the fallow area between the triple- and double-disc blades.

Considering the operational quality, Vatraz and Borges (2014) state that incorrect information on the volumetric biomass estimate may have a negative effect on management outcome. Therefore, semi-mechanized operations require planning to optimize resources, such as machines, tools, fuel, time, among other factors.

Also regarding the mowing operation, the aerial part of the plants is cut close to the ground (RAIMONDI *et al.*, 2019), so it is necessary to

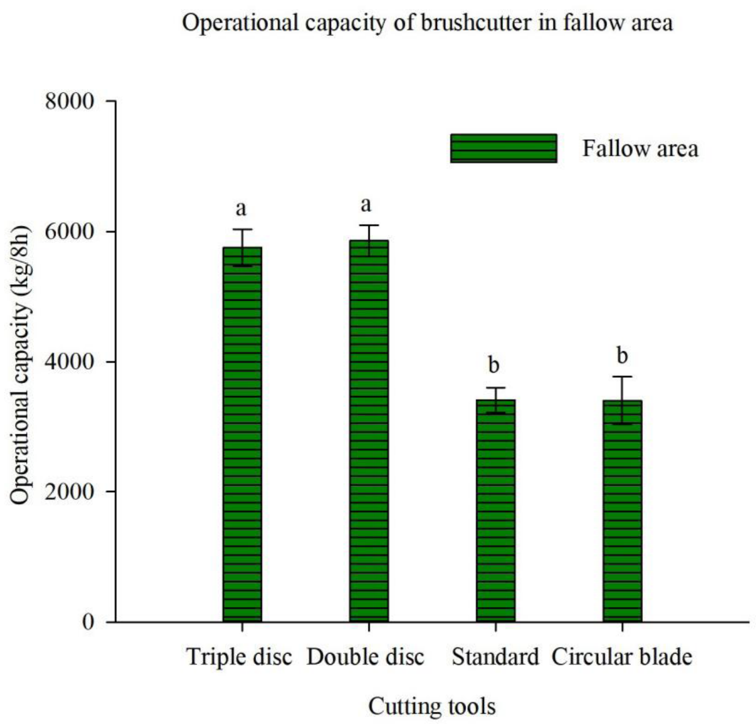

Figure 4. Effective operational capacity (kg biomass.8 h^{-1}) of brushcutter in fallow area, using different cutting tools. Where: vertical bars represent the standard error of the means. Means followed by the same lowercase letter do not differ among cutting tools in the same vegetation cover by the test of Tukey at 5% probability

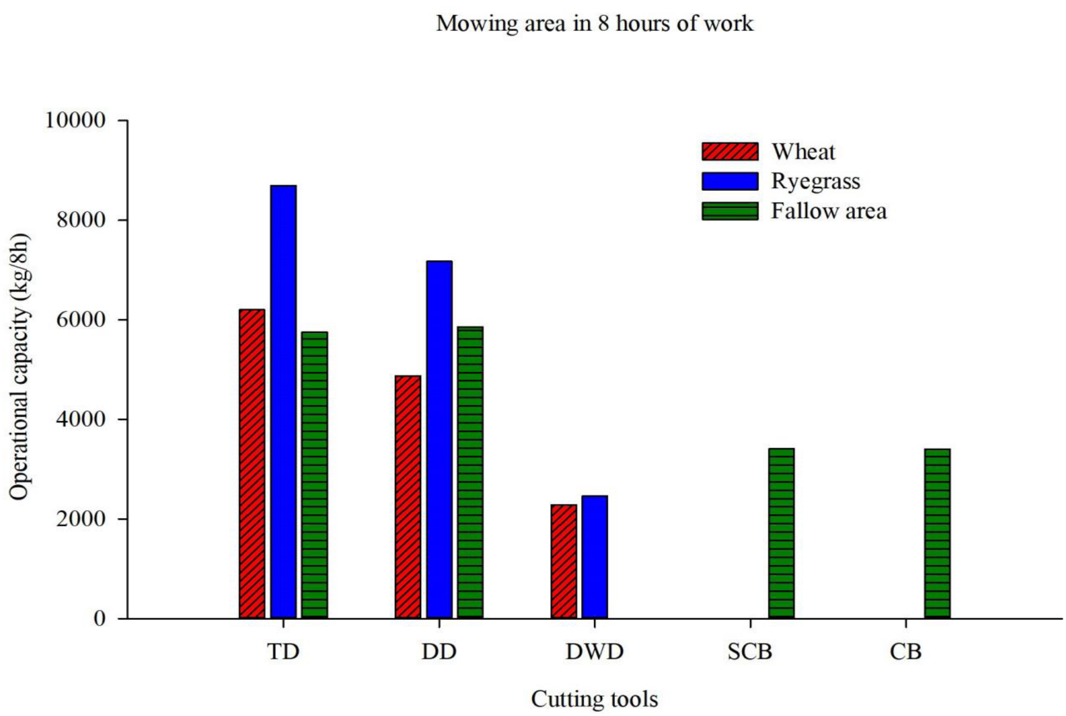

Figure 5. Biomass yield for the 8 h.day^{-1} work shift based on the study of times and movements of the brushcutter, for different vegetation cover and cutting tools. Where: triple-point blade (TD), double-disc (DD), double-wire cutting set (DWD), Standard cutting blade (SCB), and circular blade (CB)

fully understand the operating cycle so that it is possible to optimize the use of resources, in order to improve the productivity of the operation (MALINOVSKI, 2017).

To maximize efficiency, it is important to establish an adequate working methodology. Therefore, knowing and describing the steps of the operation performed in order to eliminate unnecessary and harmful factors to the activity is essential for maintaining the productivity of the mowing (DA SILVA *et al*., 2018). Trindade *et al*. (2012) emphasize that productivity in operational processes is understood as the relationship between results achieved and the resources used. According to Peinado and Graeml (2007), one of the most used methods for planning and standardizing work is the study of times and movements, making it possible, in a simple way, to detail the activities performed in a task and select the most appropriate method for its realization.

CONCLUSIONS

- Choosing the cutting tool to be used in the brushcutter operation depends on the existing vegetation cover in the area to be managed. The use of a triple-disc blade increases the effective operational capacity for cutting ryegrass and wheat, while for the fallow area, the use of a double- or triple-disc blade is indifferent.
- The proper selection of the cutting tool increases the amount of biomass (kg) mowed in less operating time, providing a reduction in exposing the operator to stress (noise and vibration) agents produced by the machine.

AUTHORSHIP CONTRIBUTION STATEMENT

PARCIANELLO, C.F.: Conceptualization, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing; **BRANDELERO, C.:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing; **WERNER, V.:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing; **BERTOLLO, G.M.:** Conceptualization, Formal Analysis, Methodology, Software, Writing – original draft; **SILVA, L.C.:** Conceptualization, Methodology, Visualization, Writing – original draft, Writing – review & editing; **RODRIGUES, L.A.:** Conceptualization, Methodology, Visualization, Writing – original draft, Writing – review & editing; **RUSSINI, A.:** Formal Analysis, Methodology, Software, Visualization, Writing – review & editing.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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