BIOSCIENCE JOURNAL

HOW DOES THE INITIAL SWARD HEIGHT AND THE GRAZING PERIOD INFLUENCE THE SPATIAL VARIABILITY OF VEGETATION IN DEFERRED SIGNAL GRASS PASTURES?

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How to cite: SANTOS, M.E.R., et al. How does the initial sward height and the grazing period influence the spatial variability of vegetation in deferred signal grass pastures? *Bioscience Journal*. 2022, **38**, e38019. https://doi.org/10.14393/BJ-v38n0a2022-53878

Abstract

The objective of this study was to evaluate the spatial variability of structural characteristics of deferred pastures of *Brachiaria decumbens* cv. Basilisk (signal grass) subjected to associations of sward heights (10, 20, 30, and 40 cm) at the beginning of deferment and grazing periods (1, 28, 56, 85, and 113 days). The experiment was arranged in a split-plot and completely randomized-block design with two replicates. Pastures remained deferred from March to June 2010. From June to the beginning of October 2010, deferred pastures were utilized by steers under continuous grazing and at a fixed initial stocking rate of 3.5 AU ha^{-1}. At the beginning of the deferment, the coefficient of variation (CV) for pasture height was reduced linearly with the pasture height. During the grazing period, in the winter, the CV for pasture height was not influenced by initial pasture height; however, it responded quadratically to the grazing period, with a maximum value of 36.4% at 71 days of the period of utilization. The CV for tiller height was reduced linearly with pasture height at the beginning of deferment but increased linearly along with the grazing period. The initial pasture height did not change the CV of the falling index. However, the latter was quadratically influenced by the grazing period, with a maximum value of 59.5% at 67 days of the utilization period. Signal grass pastures deferred at a lower height have a higher spatial variability of the vegetation. In the grazing period, there are changes in the spatial variability of the vegetation of the deferred signal grass.

Keywords: *Brachiaria decumbens* syn. Coefficient of variation. Falling index. Sward height. *Urochloa decumbens.*

1. Introduction

The deferment of pasture usage is a management strategy that guarantees a forage stock for the dry period, and, with this, it can minimize the negative effects of the production seasonality of tropical-climate forages on animal production (Euclides et al. 2007; Santos et al. 2009a; Shio et al. 2011).

Among the factors that determine the quantity and quality of the forage produced in deferred pastures, the forage species stand out. It should present high forage production during the fall, low natural height, and slender stem (Fonseca and Santos 2009), which are characteristics found in *Brachiaria decumbens* cv. Basilisk.

In addition, the height of a pasture at the beginning of the deferment period also has effects on the structure of the deferred pasture in the winter (Sousa et al. 2012). Because the pasture structure influences the plant and animal productions simultaneously (Carvalho et al. 2001), it is important to evaluate the effects of pasture height at the beginning of the deferment period on the descriptive features of the pasture, such as height and lodging rate.

In research studies, the characterization of pasture structure is mostly relative to the vertical variations of the canopy (Palhano et al. 2005; Gonçalves et al. 2009). In contrast, variations in the horizontal structure or the spatial variability of the vegetation, which are caused by the animal over time, where a few locations of the pasture show higher defoliation frequency than others, are, in general, not well studied. However, the horizontal structure is important on all scales of the plant-animal interaction, whereas the vertical structure is relevant on the lower scales of this interaction (Carvalho et al. 2001).

The existing vegetation on the pasture is naturally heterogeneous. Even in monospecific pastures, there is a broad range of descriptive characteristics of the pasture structure. This spatial variability of pasture can be quantified by the coefficient of variation of the values of its descriptive traits (Hirata 2002; Santos et al. 2010a). However, there is not much information about the horizontal structure of deferred tropical-climate pastures (Santos et al. 2010a).

This experiment was conducted to evaluate the effects of initial canopy height and grazing period on the spatial variability of the vegetation in deferred *Brachiaria decumbens* cv. Basilisk pastures.

2. Material and Methods

The experiment was conducted in the Forage Sector of the Department of Animal Science of Universidade Federal de Viçosa on a *Brachiaria decumbens* Stapf. cv. Basilisk (signal grass) pasture planted in 1997. The pasture was divided into eight paddocks, whose areas varied between 0.25 and 0.40 ha. The climate, according to the Köppen (1948) classification, is a Cwa type with well-defined dry (May to October) and rainy (November to April) seasons. The average annual precipitation is 1,340 mm, with average relative air humidity of 80% and average annual temperature of 19 ºC, oscillating between the maximum mean of 22.1 ºC and the minimum mean of 15 ºC. During the experimental period, from March to October 2010, climate data were recorded at the Meteorological Station of UFV (Table 1).

Table 1. Average daily temperature, insolation, and rainfall during the experimental period (March to October 2010).

Month	Average daily temperature (°C)	Insolation (hour day^{-1})	Rainfall (mm)
March	22.9	6.3	192.5
April	20.4	6.2	18.3
May	18.2	5.7	45.8
June	15.3	6.8	1.2
July	16.9	6.4	0.0
August	16.5	8.4	0.0
September	18.5	7.4	22.8
October	20.6	3.7	158.8

The soil of the experimental area, classified as a moderately undulated Red-Yellow Latosol of clayey texture, showed the following chemical characteristics in its 0-20 cm layer, in a sampling conducted in November 2009: pH in H_2O: 5.3; P: 3.8 (Mehlich-1), and K: 102 mg dm^{-3}; Ca^{2+}: 1.3; Mg^{2+}: 0.5 and Al^{3+}: 0.3 cmol$_c$ dm^{-3} (KCl 1 mol L^{-1}); organic matter: 3.0 dag kg^{-1}; remaining P: 31.8 mg L^{-1}.

Because of the results of the soil analysis, the soil was fertilized with phosphate for maintenance of fertility with the application of 40 kg P_2O_5 ha^{-1} on the cover, on October 15, 2009, in the form of simple superphosphate. Nitrogen and potassium fertilization was always applied in the late afternoon, on 11/15/2009 and 12/17/2009. Because of the data at the beginning of the deferment (3rd week of March 2010), also in the late afternoon, the soil was fertilized for the third time, but only with nitrogen (70 kg ha^{-1}), using urea on the cover, in each experimental unit.

We studied associations between four average pasture heights at the beginning of the deferment period (10, 20, 30, and 40 cm) and five grazing periods (1, 28, 56, 85, and 113 days). The experimental design was set in completely randomized blocks with two replications, in a split-plot arrangement. Average pasture heights at the beginning of deferment were randomized to the plots. Subplots consisted of measurements throughout the grazing period. To implement the average heights of 10, 20, 30, and 40 cm, the signal grass pastures that had been managed since November 2009 under continuous grazing with cattle and an average height of 25 cm (Santana 2011) had their stocking rates modified two weeks prior to the beginning of the deferment period for the desired average heights to be reached. The deferment period began on March 19 (2010) and ended on June 12 (2010). The grazing period started from the latter date; the periods assessed were 1, 28, 56, 85, and 113 days. These numbers corresponded to the occasions in which the evaluations were performed on the pasture, i.e., from the 1st day of grazing, and repeated every 28 days until the end of the experiment (10/16/2010).

From June to October 2010, pastures were managed under continuous grazing with a fixed stocking rate of 3.5 AU ha^{-1} in each paddock. We utilized crossbred steers with an initial weight of 190 kg. During the grazing period, animals received only mineral salt. Pastures deferred with initial average heights of 10, 20, 30, and 40 cm showed an average forage availability corresponding to 3.00, 3.32, 2.99, and 2.61 kg dry mass of forage per kg of animal, respectively.

In each experimental period (paddock), the pasture height, the height of the extended plant, and the falling index were measured in a zigzag pattern through the paddocks, with 30 points in total. Pasture height was measured in March 2010, after the cattle lowered the grass until the desired heights (10, 20, 30, and 40 cm) at the beginning of the deferment period. Subsequently, pasture height, the height of the extended plant, and the falling index were measured during the grazing period of the deferred pastures every 28 days. Pasture height was determined in each of the 30 points per paddock with a graduated ruler, having the distance between the horizon of leaves and the soil level as the criterion. Extended-plant height was measured by stretching the tillers of the grass vertically and recording the longest distance between the soil level and the apex of tillers. To objectively estimate the deferred-pasture falling degree, the pasture falling index was developed; this rate is calculated as the quotient between extended plant height and pasture height (Santos et al. 2009b). The evaluation of the dispersion of these measures was performed through their coefficient of variation (Hirata 2002).

For each trait, variance analysis and subsequent regression analysis were performed. For pasture height after its lowering at the beginning of the deferment period, the greatest response-surface model tested as a function of the means of the treatment was as follows: $Y_i = \beta_0 + \beta_1 H_i + \beta_2 H_i^2 + e_i$. Where: Y_i = response variable; H_i = average pasture height at the beginning of the deferment period; β_0, β_1, β_2 = parameters to be estimated; and e_i = experimental error.

For the response variables measured during the grazing period, the greatest response-surface model tested as a function of the means of treatments was as follows: $Y_i = \beta_0 + \beta_1 A_i + \beta_2 H_i^2 + \beta_3 P_i + \beta_4 P_i^2 + \beta_5 HiPi + e_i$. Where Y_i = response variable; H_i = average pasture height at the beginning of the deferment period; P_i = grazing period; β_0, β_1, β_2, β_3, β_4, β_5 = parameters to be estimated; and e_i = experimental error.

The model-fitting degree was evaluated by the coefficient of variation and by the significance of the regression coefficients, tested by the t-test corrected based on the residues from the variance analysis. All statistical analyses were performed at a significance level of up to 10% of probability.

3. Results and Discussion

For all the response variables, there was no interaction effect between average sward height at the beginning of the deferment period and the grazing period. Therefore, the effects of these factors were analyzed in isolation.

At the beginning of the deferment period, the spatial variability of the pasture, expressed by the coefficient of variation, reduced linearly ($p<0.05$) along with the average pasture height (Figure 1). Before the deferment, pastures were managed under continuous grazing. In this grazing method and under the same environmental conditions, the pasture with the greatest average height characterizes a condition of lower stocking, intensity, and grazing-frequency rates (Flores et al. 2008; Casagrande et al. 2011; Fagundes et al. 2011), contrarily to those kept lower. Thus, the effects of animals (e.g., deposition of feces and urine, trampling and grazing) on the vegetation in the pasture are minimized when the pasture is managed higher, which results in the less spatial variability of the height values of the plants in the pasture.

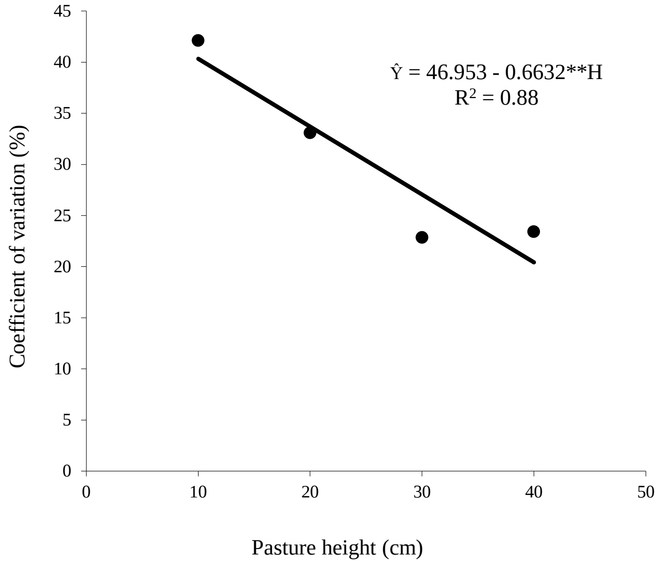

Figure 1. Coefficient of variation of pasture height as a function of the average pasture height (H) at the beginning of the period of deferment of signal grass. ** Significant according to the t-test ($p<0.05$). The minimum, maximum, mean, and standard deviation values of plant height were 5; 22; 10.4 and 4.4 for the 10 cm average height pasture, respectively; 10.5; 45; 21.9 and 7.3 for the 20 cm average height pasture, respectively; 23; 41.5; 28.3 and 6.5 for the 30 cm average height pasture, respectively; and 25; 57; 41.8 and 9.8 for the 40 cm average height pasture, respectively.

On the other hand, in the pasture managed lower (10 cm) at the beginning of the deferment period, there was the need to elevate the stocking rate, and thus, the effects of cattle on the spatial variability of the vegetation increased. In this sense, as an example, we can infer that in lower pastures, the higher stocking rate implied greater return of nutrients to the pasture via feces and urine (Dubeux et al. 2007). One of the main effects of cattle manure on pasture consists of greater growth of the plants close to the stools, as compared to those distant (Santos et al. 2011a), which happens, among other factors, according to their rejection during grazing by animals (Santos et al. 2012).

Some other research studies (Schwartz et al. 2003; Santos et al. 2010a) have shown that lower pastures usually have more homogeneous vegetation (lower coefficient of variation for pasture height) than the higher ones. In the latter, the forage availability is higher, and so the cattle tend to concentrate their grazing activity on certain areas of the pasture, and at the same time, reject others, which increases the spatial heterogeneity of the vegetation in the pasture. However, in the present study, this response pattern was not true. This indicates that the high instantaneous stocking rate (up to 16 AU ha^{-1}) employed to lower the pastures in a short period (about 15 days) before the deferment period has a preponderant effect on the spatial variability of the vegetation when compared with the typical condition of higher forage availability of higher pastures.

In contrast, the average pasture height did not affect ($p>0.10$) the coefficient of variation of pasture height after the deferment period, which was when the deferred pastures were utilized by cattle. However, in this period, the coefficient of variation for pasture height was quadratically influenced ($P<0.01$) by the period of pasture utilization (Figure 2), with a maximum value of 36.4% at 71 days of utilization.

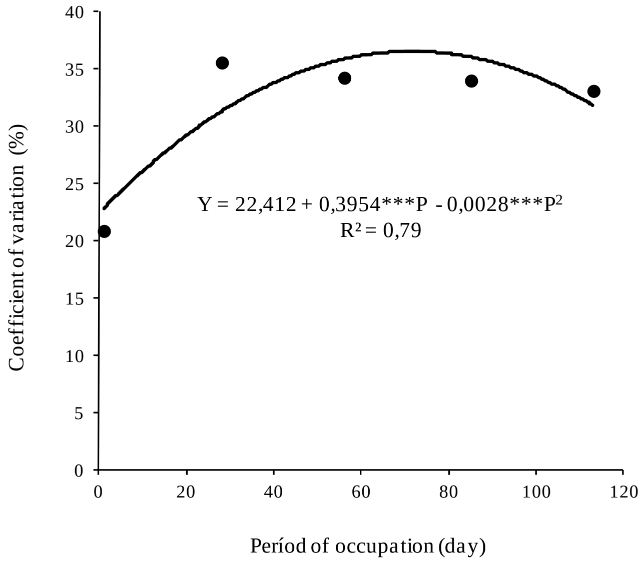

Figure 2. Coefficient of variation of pasture height according to the period (P) of occupation of signal grass pasture. *** Significant according to the t-test (p<0.01). The minimum, maximum, mean, and standard deviation values of plant height were 21; 91; 66.5 and 13.1 on the 1st day of the grazing period, respectively; 7; 64; 39 and 11 on the 28th day of the grazing period, respectively; 7; 49; 31.5 and 8.5 on the 56th day of the grazing period, respectively; 5; 40; 25 and 7.2 on the 85th day of the grazing period, respectively; and 5; 36; 23 and 5.3 on the 113th day of the grazing period, respectively.

The high coefficient of variation of pasture height at the beginning of the deferment period in lower pastures (Figure 1) did not cause the same response pattern during the period of use of the deferred pastures (Figure 2). The fact that higher signal grass plants fell due to animal trampling during grazing probably stopped the manifestation of this effect.

The coefficient of variation for pasture height was higher in the intermediate phase of the period of use of deferred pastures in relation to its beginning and end (Figure 2). Initially, there was lower spatial variability of plant heights because the effects of the cattle on the pasture (e.g., selective grazing, trampling, and excretion of feces and urine) were still incipient, due to the shorter time of pasture use. Nevertheless, these effects became stronger over the grazing period, which resulted in the lower spatial variability of the height of plants close to the 70 days of utilization.

Moreover, the decrease in the coefficient of variation of pasture height from the middle to the end of the period of pasture utilization was probably caused by the regrowth of signal grass in this period. From the end of September (approximately 100 days of grazing), the first rainfalls of spring started (Table 1). With this, it is possible that the plants at the lower portions of the same pastures - due to the more intensive and frequent grazing that occurred previously, presented a higher growth rate in comparison with those of higher places, which were grazed more leniently. Thus, there was more homogeneity of plants in the same pasture, which decreased the coefficient of variation for pasture height (Figure 2).

This hypothesis is based on the fact that in low canopies the higher incidence of light at the base of plants stimulates tillering (Sbrissia and Da Silva 2008), especially when the environmental condition is once again favorable to the development of the plant, which happens at the end of the utilization of deferred pastures. In addition, a pasture with a lower average height in the winter has a lower leaf senescence rate (Santos et al. 2011b), which certainly reduces the number of dead tissues in the lower stratum of the pasture, providing more luminosity on the basal buds, and consequently, stimulating tillering in the spring. Corroborating these arguments, Santos et al. (2011b) verified that when the pasture is lower in the winter it presents better regrowth conditions in the subsequent seasons, especially in the spring.

As for the height of the extended plant during the grazing period, its coefficients of variation reduced linearly (p<0.01) as a function of the average pasture height at the beginning of the deferment period but increased linearly along with the grazing period ($\hat{Y}$ = 27,1238 – 0,2503***H + 0,1865***P, r^2 = 0,63). During the grazing period, the higher coefficient of variation of the height of the extended plant in lower pastures was a consequence of the higher variability of pasture height at the beginning of the deferment period (Figure 1), as previously described.

Furthermore, on all deferred pastures, there were vegetative and reproductive tillers, and the latter were longer. However, on pastures deferred at a greater initial height, vegetative tillers also had longer stems, similar to the reproductive ones. Thus, plants presented greater uniformity for height when their tillers were extended for the measurement of extended-plant height.

On the contrary, pastures deferred at a lower height had shorter vegetative tillers, with shorter stems in relation to the reproductive tillers. This might have been the cause of the higher heterogeneity of extended-plant height of pastures deferred at a lower height, given that areas of the pasture with more occurrences of reproductive tillers showed higher extended-plant height, whereas those with a predominance of vegetative tillers showed lower extended-plant height.

The positive effect of the grazing period on the variability of the extended-plant height values of the deferred signal grass is due to the increased time of permanence of cattle on the paddocks, which exacerbated the deposition of feces and urine on the pasture, selective grazing, and trampling, which are determinant factors of the spatial heterogeneity of the vegetation (Salton and Carvalho 2007).

The coefficient of variation of signal grass lodging rate was quadratically influenced ($p<0.01$) by the period of pasture use (Figure 3), with a maximum value of 59.5% at 67 days of the utilization period. This indicates that the variability in the measures of pasture lodging rate was lower in the extreme periods of its utilization. Pastures at the beginning of the period of use virtually did not have fallen plants, hence why their lower variability for lodging rate. Pastures under extensively long periods of use, in turn, were characterized by having many fallen plants, where the lodging rate was high and uniform. On the other hand, in pastures under intermediate utilization periods, the heterogeneity of the lodging rates was high due to the higher diversity of areas with and without plant lodging.

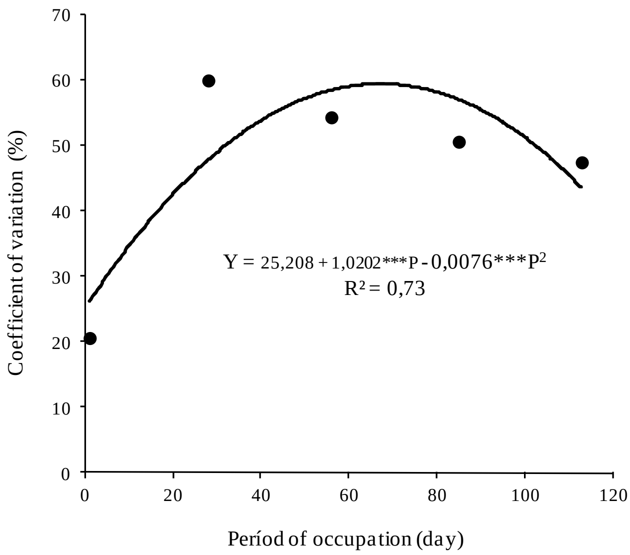

Figure 3. Coefficient of variation of lodging rate as a function of the period (P) of occupation of the signal grass pasture. ***Significant according to the t-test ($p<0.01$). The minimum, maximum, mean, and standard deviation values of the falling index were 1; 2.9; 2.5 and 0.31 on the 1st day of the grazing period, respectively; 1; 10.3; 6.1 and 1.67 on the 28th day of the grazing period, respectively; 1; 8.6; 5.3 and 1.75 on the 56th day of the grazing period, respectively; 1; 11.10; 6.6 and 2.0 on the 85th day of the grazing period, respectively; and 1; 6.7; 4.4 and 1.3 on the 113th day of the grazing period, respectively.

Regardless of the average height of the deferred pastures and their period of utilization, there was always a spatial variation of the vegetation, because the coefficients of variation were never null (Figures 1, 2, and 3). Even in monospecific pastures, the heterogeneous distribution of the vegetation is inevitable, because the proportion of forage removed at every bite of the animal is significantly larger in relation to that which should be removed in order to maintain the pasture uniformity (Parsons and Chapman 2000), notably in deferred pastures, which are usually utilized during the winter period, when the climate conditions are restrictive to plant growth.

If we consider that pasture height, extended-plant height, and lodging rate are strongly associated with other characteristics of the deferred pasture like the numbers of the different classes of tillers and the nutritional value traits (Santos et al. 2010b), we can assume that the average pasture height at the beginning of the deferment period and the grazing period also modified the spatial variability of these and other characteristics.

It can also be inferred that the spatial variability in pasture height and extended-plant values and lodging rate results in differentiated microclimates (temperature, ventilation, shading, among others) in the deferred signal grass canopy, which can affect important processes in the pasture ecosystem such as growth, senescence and tillering in a heterogeneous manner. This makes the pasture heterogeneity persist for a longer period, contributing to its inherent and dynamic horizontal variability (Santos et al. 2010a).

Besides, the diversity of plants of varying heights on the same pasture tends to be beneficial because plants with different structural characteristics and consequent specific physiologies have distinct abilities to occupy the many ecological niches, which would lead to more complete and optimized use of the environmental resources (Spehn et al. 2005).

It is important that, in studies with tropical forage grasses, researchers evaluate the coefficients of variation of the features describing the pasture condition like height, so as to characterize the horizontal structure of the pasture. This would make it possible to quantify and understand the effects of several factors of pasture management such as nitrogen fertilization, average pasture height, the season of the year, pasture supplementation, and grazing methods on the variation in the structural characteristics of the pasture in its horizontal plane. We stress that, in plenty of studies (Flores et al. 2008; Moreira et al. 2009; Casagrande et al. 2011; Fagundes et al. 2011), plant height is monitored to ensure the maintenance of pastures within the targets desired and thus, the calculation of the coefficients of variations of the precise measures of plant height could be quantified and discussed with little additional work or time.

It is also recommendable to conduct studies to relate and elucidate the effects of spatial variability of a region on the primary and secondary pasture productivities. This assertion is important in as much as, for example, there are pastures with similar average height, but different horizontal structures, which in theory would modify the ingestive behavior and the performance of an animal as well as plant development and consequently the production of forage of a pasture (Salton and Carvalho 2007).

4. Conclusions

During the grazing period, there is spatial variability of the vegetations on *Brachiaria decumbens* cv. Basilisk pastures managed with different heights at the beginning of the deferment period. Signal grass pastures deferred at a lower height presents higher spatial variability of the vegetation, which is modified during the grazing period.

Authors' Contributions: SANTOS, M.E.R.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article, and critical review of important intellectual content; SILVERIRA, M.C.T.: analysis and interpretation of data, drafting the article, and critical review of important intellectual content; FONSECA, D.M.: analysis and interpretation of data, and critical review of important intellectual content; CLEEF, F.O.S.: drafting the article; CARVALHO, B.H.R.: acquisition of data; ROCHA, G.O.: acquisition of data, analysis and interpretation of data, and critical review of important intellectual content. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Not applicable.

Acknowledgments: The authors would like to thank the Group of Hypothesis Testing in Forage of Federal University of Uberlândia for aid during the conduct of the research.

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Received: 17 April 2020 | **Accepted:** 22 September 2021 | **Published:** 31 March 2022