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MODELING BIOLOGICAL GROWTH OF *Lolium perenne* SPECIES UNDER CURRENT CLIMATE CHANGE CONDITIONS

Ionel SAMFIRA[1, 2], Nicolae Marinel HORABLAGA[1, 2], Ramona Loredana TOPORAN[1], Adina HORABLAGA[1], Saida FEIER DAVID[1], Cristian BOSTAN[2]

[1]University of Life Sciences "King Mihai I" from Timisoara, 119 Calea Aradului Street, Timisoara, Romania
[2]Agricultural Research and Development Station Lovrin, 200 Principala Street, Lovrin, Romania

Corresponding author email: cristian.bostan@scdalovrin.com

Abstract

The importance of knowing the impact of life factors is also supported by several specialized studies. Several measurements were made on 34 local biotopes collected from Almajului Mountains, Mehedinți Plateau and Blahniței Plain. During the vegetation period, recording was investigated: plant height, leaf dimensions, and leaf surface of the shoot, along five BBCH development codes. Depending on the bio-accumulations of essential life factors (sum of accumulated precipitation and temperatures), biological growth was estimated. The mathematical interpretation of the slopes of the lines represents the growth rate, which practically determines the influence of precipitation or temperatures on the studied characters. The results of the research in this work show that the determining factor in the dynamics of biological growth in perennial ryegrass is the amount of precipitation. Perennial ryegrass growth in the presence of precipitation is almost double that of the accumulation of an identical amount of temperature. Moreover, studies published in related research reveal that the major limiting factors are drought and high temperatures, factors that are accentuated by current climate change.

Key words: *perennial ryegrass, life factors, biological growth.*

INTRODUCTION

Previous studies have shown that current climate change will improve forage production conditions, as the growing season will be longer (1-3 months), with milder and rainier autumns and winters (Sampoux et al., 2011; Cui et al., 2018; Zhangab et al., 2019). It is demonstrated that in the last decade the climate has warmed by 1-2^{0}C, under these conditions the dominant plurispecific plant associations of perennial ryegrass will constitute one of the most valuable fodder resources (Nakamura et al., 2008; Blackmore et al., 2016; McDonagh et al., 2016; Giraldo et al., 2018).

The drought tolerance of this species is low, this fact limits the area of distribution especially in the current context of global climate change (Yates et al., 2019; Hatier et al., 2014; Westermeier et al., 2016).

In other words, the current global climate change characterized by expected seasonal changes in precipitation periods associated with increased frequencies of temporary drought periods will affect the production capacity of perennial ryegrass (Westermeier & Hartmann, 2016). The response to water stress in perennial ryegrass depends on the interactions between factors that ensure intraspecific community diversity such as soil properties, climatic conditions, and management practices (Buttler et al., 2019; De Swaef et al., 2021).

Drought causes a decrease in productivity, but the availability of certain productive characters can mitigate drought resistance, such as leaf size, bush diameter, plant height, leaf:stem ratio, root system architecture (Hofer et al., 2016; Lee et al., 2019).

Water and nutrients, especially nitrogen, are major limiting factors in forage crop species, influencing their efficiency in growth and development and, therefore, reducing biomass production. Limiting water availability in perennial ryegrass has the effect of reducing the availability of carbon assimilated from photosynthesis contributes to vegetative development through stomatal conductance. Under these conditions, limiting the amount of CO_2 in leaves slows down the respiration rate but also the water loss per unit area (Akmal & Janssens, 2004; Wagner et al., 2008).

According to numerous studies, the survival of perennial ryegrass under drought conditions has been associated with a series of traits: root length and mass, photosynthetic characteristics and water-soluble carbohydrate concentrations. It has been proven that water stress in this species decreases the photosynthetic capacity due to the reduction of the active leaf area, decreasing its efficiency depending on the rate of onset and extension of the stress caused by water shortage. Drought is an important environmental stress factor in agriculture worldwide, due to climate change by destabilizing production, affecting both yield and quality (Pearson et al., 2011; Jonavičienė et al., 2014; Kemesyte et al., 2017).

Temperature is also one of the limiting factors for the growth cycles of perennial ryegrass, throughout the entire vegetation period from planting to harvest (Calvache et al., 2021; Wei et al., 2023).

The low temperature resistance of the species is a complex trait meaning the ability to survive and grow at low temperatures, to acclimatize to cold, to tolerate wind, snow cover, etc. (Skøt et al., 2002; Höglind et al., 2011). Perennial ryegrass tolerates poorly drained soils, with a pH range between 5.0 and 8.3 and optimal growth occurs between 20 and 25^{0}C.

The plant's ability to adapt to extreme living conditions includes the ability to survive and grow at low temperatures, to acclimatize to cold, to tolerate wind and snow, etc. High temperatures limit performance in warmer and transitional regions (Schmidt et al., 2015; Skøt et al., 2002). Also, perennial ryegrass is a forage species that has a pronounced response to temperature and light and does not flower unless exposed to long periods of cold followed by long days with high temperatures (Ciannamea et al., 2007; Heineck et al., 2020). The flowering period of ryegrass is an important trait, as it determines the reproductive power of the plant because during evolution the species has adapted mechanisms to synchronize flowering and seed setting with favorable environmental conditions. Prolonged exposure to low temperatures, long/short photoperiods promote or repress flowering (Bergonzi & Albani, 2011; Butnariu & Cauni, 2013). In light of these considerations, we generally consider that heat stress is a major abiotic stress that affects the productivity and growth of forage plants by disrupting metabolic homeostasis and the activities of various biochemical processes, such as photosynthesis, respiration, and stress defense (Lei et al., 2022; Kemesyte et al., 1017).

Knowledge of the dynamics of productive characters such as leaf size, bush diameter, plant height, leaf: stem ratio is important because it influences the regeneration capacity after defoliation and allows the restoration of active photosynthesis and plant growth. As a result of the externalization of these characters, perennial ryegrass becomes one of the dominant species in temperate grasslands, ensuring a rapid establishment for this species, increased tolerance to defoliation, but also a production with high digestibility.

It is known that the productive traits of perennial ryegrass are influenced especially in the vegetative stage by factors such as the height of the vegetation cover, the frequency of defoliation or N fertilization (Meuriot et al., 2018). The frequency of defoliation influences the recovery of the species, moreover, frequent defoliation reduces the persistence and quality of the forage obtained from the harvest of perennial ryegrass (Calvache et al., 2020; Terán-Chaves et al., 2022).

These elements are important because monitoring the spatio-temporal dynamics of current climate change on the quality and quantity of aboveground biomass produced is important and contributes to adjusting the management decision-making process, such as the density of the vegetation cover, mowing time or fertilizer application rates (Pranga et al., 2021; Toporan, 2024).

MATERIALS AND METHODS

Biological material

The biological material was represented by 34 biotypes collected from 3 areas of differentiated altitudinal range: Almajului Mountains, Mehedinți Plateau and Blahniței Plain. These biotypes were collected from natural grassland habitats and then transferred to the germplasm collection field at the Lovrin Agricultural Research and Development Station, Timis, Romania, on an identical agro-background for all biotypes. The codes BBCH 31, BBCH 37, BBCH 55, BBCH 71, and BBCH 89 were mainly investigated, which correspond to the vegetative and generative growth stage.

The soil was a typical chernozem soil, considered representative of the Low Banat Plain area. The pH value indicated a weakly alkaline reaction in the range of 20-100 cm, to even strongly alkaline at depths of up to 200 cm (Bostan et al., 2024).

The purpose of the study

The purpose of the study was focused on the biological growth depending on the amounts of precipitation and temperatures accumulated by the plant during the vegetation period. For that the amounts of precipitation and daily temperatures were recorded, using descriptively their sum at each BBCH. With the help of this information, the mathematical quantification of the biological growth response of the main productive characters was represented: plant height, leaf dimensions, and leaf surface of the shoot.

Climatic conditions

The analysis of data on the rainfall regime in the period 2023-2024 registered at Lovrin Agricultural Research and Development Station, shows that it was an atypical year overall. The total amount of precipitation was 417.4 mm, with a negative deviation of 104 mm from the multiannual average. During the perennial ryegrass vegetation period, the amount of precipitation was 121.6 mm, with a negative deviation of 134.6 mm from the MMA.

The average annual temperature was 14.6^{0}C, 3.6^{0}C higher than the 70-year multiannual average. During the perennial ryegrass vegetation period, temperatures exceeded the multiannual average monthly. The largest deviations from the average were reported starting with February and until July. Thus, in February a positive deviation of +7^{0}C was recorded, in March + 4.3^{0}C, in April +3.1^{0}C, in June +3.8^{0}C, and in July +4.6^{0}C.

During the vegetation the perennial ryegrass biotopes accumulated the following climatic factors: the amount of precipitation was between 62.5 and 196.4 mm, and the sum of temperatures between 454.1 and 1061.8^{0}C. Since the increases at 1^{0}C, or 1 mm of precipitation are subunits, it is considered appropriate to express the dynamics of the studied characters at average accumulations of 10 ^{0}C or 10 mm of precipitation.

Statistical processing

The perennial ryegrass growth biological development was estimated, for this, both the experimental data and the regression lines associated with them were represented in the same coordinate system. The mathematical interpretation of the slopes of the lines represents the growth rate, which practically determines the influence of precipitation or temperatures on the studied characters.

To test the presence of a significant link between the biological growth of the selection biotope and the main growth factors, one-way ANOVA was also used.

The graphical representations were made with JASP version 0.18.3 (Goss-Sampson, 2018; Langsrud, 2003; Whitlock & Schluter, 2015).

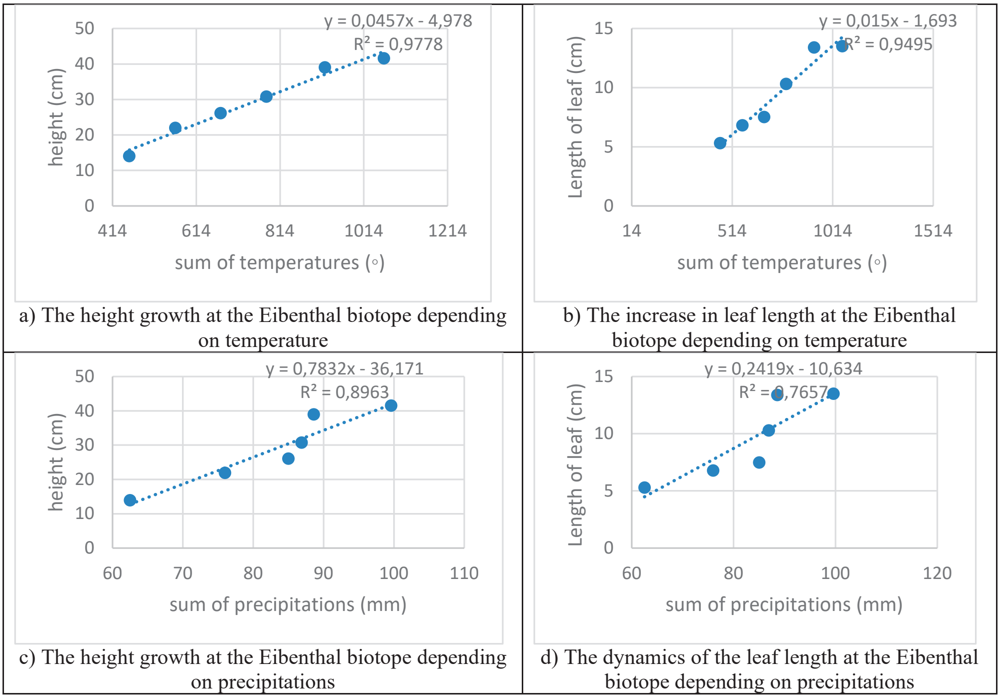
RESULTS AND DISCUSSIONS

To cope with current climate change, it is necessary to create new cultivars adapted to current abiotic conditions. From the analysis of climate conditions throughout 2024 with a non-uniform median distribution throughout the biological growth period, was performed the growth measurements in five BBCH development codes.

Biological growth of selected biotopes from the Montane area - Almaj Mountains

The altitudinal range of the collection was between 86 m and 740 meters. The orography is diverse, which primarily produces an edaphic differentiation, not identifying a common soil type for the five localities from where the biological material was collected.

The analysis of the growth dynamics of the biotopes collected from this area reveals a maximum increase in height at the accumulation of 10^{0}C in the case of the Eibenthal and Mraconia with 0.45 cm. At these biotopes, a response towards the maximum was also recorded, quantified with an increase of 0.79 cm at the accumulation of ten mm of precipitation.



a) The height growth at the Eibenthal biotope depending on temperature

b) The increase in leaf length at the Eibenthal biotope depending on temperature

c) The height growth at the Eibenthal biotope depending on precipitations

d) The dynamics of the leaf length at the Eibenthal biotope depending on precipitations

Figure 1. The graphical representation of biological growth at Eibenthal at accumulation depending on temperature and precipitation (a, b, c, d)

Biological growth of selected elites from the Mehedinți Plateau Area

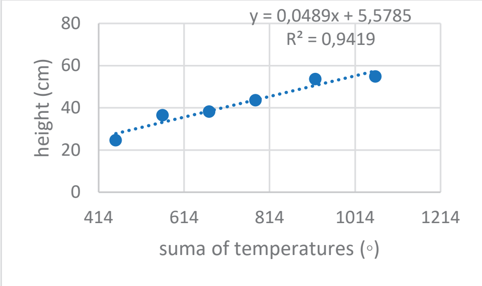
This area is characterized by an altitudinal range between 104 m and 654 meters, the dominant soil type is the typical districambosol soil. The analysis of the biological response to temperature accumulation is differentiated, the maximum increase in height was at Gornovița and Ponoarele biotopes where it is associated with an increase in leaf length of 0.079 cm at an accumulation of 10^0C (Figure 2).

The influence of precipitation on the dynamics of height growth was extremely differentiated. The maximum increases exceeding 0.9 cm are recorded at the Gornovița and Turbata biotopes followed by the Ponoarele with 0.84 cm.

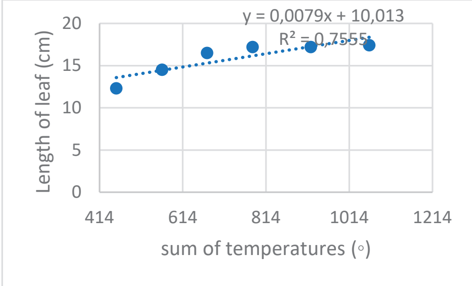
Biological growth of selected elites from the Câmpia Blahniței Area

This collection area had an altitudinal range between 49 m and 120 meters. The analysis of the biological response to temperature accumulation distinguishes the Cioroboreni and Burila Mare biotopes with an increase between 0.48-0.56 cm at the accumulation of 10^0C.

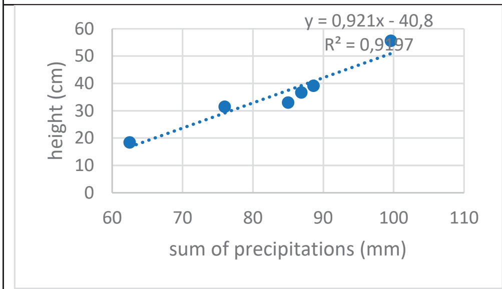
The influence of precipitation on the growth dynamics revealed that at the accumulation of 10 mm of precipitations the maximum increases was recorded at the same biotopes Cioroboreni at 0.96 cm, and Burila Mare at 0.82 cm (Figure 3).



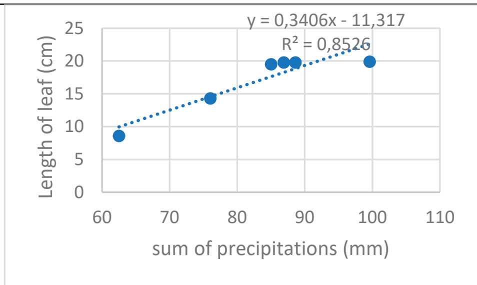
a) The dynamics of height growth at the Ponoarele biotope depending on temperature



b) The dynamics of the leaf length at the Ponoarele biotope depending on temperature

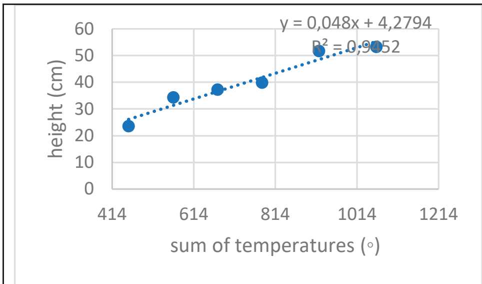


c) The dynamics of height growth at the Gornovița biotope depending on precipitation

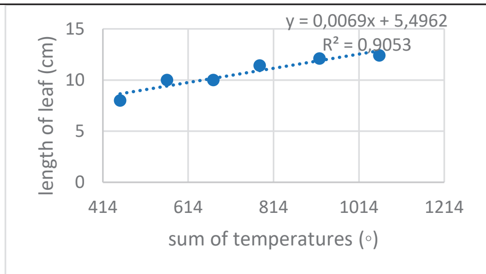


d) The dynamics of the leaf length at the Gornovița biotope depending on precipitation

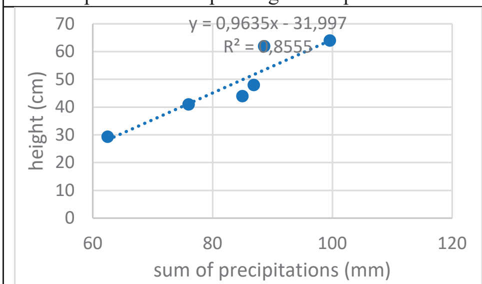
Figure 2. The graphical representation of biological growth at Ponoarele (a, b) and Gornovița (c, d) biotopes depending on temperature and precipitation



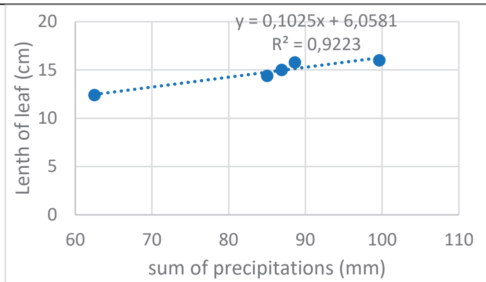
a) The dynamics of height growth at the Burila Mare provenance depending on temperature



b) The dynamics of the length at the Burila Mare biotope depending on temperature



c) The dynamics of height growth at the Cioroboreni biotope depending on precipitation



d) The dynamics of the leaf length at the Cioroboreni biotope depending on precipitation

Figure 3. The graphical representation of biological growth at Burula Mare (a, b) and Cioroboreni (c, d) biotopes depending on temperature and precipitation

Analysis of biological growth according to abiotic factors using the ANOVA test

Analysis of variance ANOVA was used as a statistical tool to analyze the means obtained between the groups of experimental data obtained. Thus, in this research, we analyzed the means obtained from the biological growth of short-crop ryegrass in order to establish the presence or absence of statistically significant interdependencies or differences between it and the major growth factors. We chose this type of test because it has the capacity to test two groups of experimental data to identify the connection between their means. Table 1 presents the one-way ANOVA analysis of variance on the biological growth of perennial ryegrass in height at the accumulation of 10^0C. In this case, the variability was due to the analysis of the differences between the data groups, namely the growth in height of perennial ryegrass at the accumulation of 10^0C.

In order to analyze the significance level of the P value, we compared the F value determined using the critical values from the previous distribution table. Thus, in this case the significance value of P is 0.60, which does not reject the null hypothesis and does not statistically assure us of the existence of a significant interdependence between the group means.

Table 1. One-way ANOVA on height growth at 10^0C

Groups	Count	Sum	Average	Variance		
Almajului Mountains	5	1.97	0.39	0.013		
Mehedinți Plateau	18	6.18	0.34	0.011		
Blahniței Plain	11	4.09	0.37	0.011		
Source of Variat.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.012	2	0.00	0.515	0.602	3.304
Within Groups	0.37	31	0.01			
Total	0.38	33				

ns p>0.05; * p≤0.05; ** p≤0.01; *** p≤0.001

In order to analyze the significance level of the P value, we compared the F value determined using the critical values from the previous distribution table. Thus, in this case the significance value of P is 0.60, which does not reject the null hypothesis and does not statistically assure us of the existence of a significant interdependence between the group means. As is known from specialized studies, there is a close connection between the persistence of perennial ryegrass and climatic factors. Thus, normal development of the foliar apparatus is considered to occur at 20^0C (Calvache et al., 2020).

Table 2 presents the one-way ANOVA analysis of variance on the height increase of local perennial ryegrass provenances in height upon accumulation of 10 mm of precipitation. Thus, in this case the significance value of P is 0.13 which does not reject the null hypothesis and does not statistically assure us of the existence of a significant interdependence between the group means.

Table 2. One-way ANOVA analysis of variance on height growth at 10 mm of rainfall

Groups	Count	Sum	Average	Variance		
Almajului Mountains	5	4.09	0.81	0.011		
Mehedinți Plateau	18	11.24	0.62	0.04		
Blahniței Plain	11	7.7	0.7	0.02		
Source of Variat.	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.15	2	0.07	2.14	0.13	3.30
Within Groups	1.11	31	0.03			
Total	1.26	33				

ns p>0.05; * p≤0.05; ** p≤0.01; *** p≤0.001

CONCLUSIONS

It is scientifically proven that this species has an excellent capacity to control the expansion and optimize light interception by increasing the proportion of leaf surface, if the availability of nutrients in the soil is improved (Lakić & Vojin, 2015; Deru, et al., 2014).

The results obtained regarding the biological growth of the 34 local perennial ryegrass provenances revealed a better adaptation of the biological material from the Blahniței Plain area compared to that collected from the Plateau or Mountain area.

The ANOVA analysis of variance revealed that the relationship between the biological development of perennial ryegrass and major abiotic factors has the best significance when comparing the data groups between leaf blade length and the accumulation of 10^0C in the plant. The significance value of P was 0.040, this value rejects the null hypothesis and statistically assures us of the existence of a significant interdependence between the dynamics of leaf dimensions and the accumulation of temperature.

The results of this research show that the determining factor in the dynamics of biological growth is the amount of precipitation. The growth of perennial ryegrass in the presence of precipitation is almost double compared to the accumulation of an identical amount of temperature. Moreover, studies published in related research reveal that the major limiting factors are drought and high temperatures, factors accentuated by current climate change (Förster et al., 2018).

It is expected that in the future, global climate change will cause decreases in agricultural production due to lack of water during the growing season. To overcome this problem, a genetic improvement of drought tolerance is needed by creating and expanding new varieties in cultivation. Consequently, improving the adaptability of perennial forage plants to high and/or low temperature can increase forage yield and turf quality in regions where their biological development is strongly affected (Zhao et al., 2016; Förster et al., 2018).

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