International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 5S, 2025
https://www.theaspd.com/ijes.php

# Influence of seasonal weather on the growth and productivity of *Brachiaria humidicola*

**Bui Van Loi**[a,c], **Nguyen Ty**[b]
[a]Hue University, 03 Le Loi, Hue, Vietnam. https://orcid.org/0000-0002-4493-2702. Corresponding author: Email: bvloi@hueuni.edu.vn
[b]Faculty of Biology, University of Education, Hue University, 32 Le Loi, Hue, Vietnam. https://orcid.org/0000-0002-1397-4985. Email: nguyenty@hueuni.edu.vn
[c] Faculty of Animal Sciences and Veterinary Medicine, Hue University of Agriculture and Forestry, Hue University

**Abstract**
This study examines the impact of seasonal climate variations on the growth and productivity of Brachiaria humidicola in Thua Thien Hue Province (renamed Hue City as of January 1, 2025), Vietnam. Field experiments assessed key growth parameters: plant height, canopy height, shoot density, and biomass yield, across two distinct seasons: the spring-summer dry season and the autumn-winter rainy season. The plant's adaptation to waterlogging was also analyzed through morphological and physiological assessments. Results show that *B. humidicola* maintains high productivity across both seasons, with significantly greater biomass yields during the spring-summer period ($P < 0.05$). The species exhibited strong waterlogging tolerance, supported by aerenchyma formation in its roots and leaf sheaths, as well as effective oxygen release mechanisms. These traits highlight *B. humidicola*'s potential as a climate-resilient forage crop, capable of adapting to extreme weather patterns associated with climate change, such as prolonged flooding and seasonal droughts. These findings establish *B. humidicola* as a reliable forage crop for sustainable livestock production in flood-prone and drought regions, ensuring a consistent feed supply for ruminants year-round while supporting agricultural resilience in the face of changing climatic conditions.

**Keywords:** *Brachiaria humidicola*, biomass yield, productivity, waterlogging tolerance.

## 1. INTRODUCTION

Vietnam's central coastal region serves as a primary center for ruminant livestock, hosting over 60% of the country's total population of these animals. As agriculture transitions from traditional extensive grazing to semi-intensive and intensive farming systems, the need for dependable, high-quality forage has grown increasingly urgent. Livestock productivity in this region relies heavily on the availability of green fodder, which is derived from cultivated grasses, natural pastures, and agricultural by-products. However, the region's variable and harsh climate poses a persistent challenge to meeting the year-round nutritional demands of livestock [15].

Thua Thien Hue, situated at the core of this region (and designated as Hue City from January 1st, 2025), experiences two sharply contrasting seasons: a hot, dry spring-summer period and a rainy, flood-prone autumn-winter period. These climatic extremes significantly disrupt agricultural and livestock productivity. The dry season brings high temperatures, extended droughts, and parched soils, causing natural vegetation to wither and forage supplies to dwindle. Conversely, the rainy season delivers heavy rainfall, frequent flooding, and cooler temperatures, further limiting suitable feed options. Seasonal fluctuations in temperature, humidity, sunlight, and rainfall directly affect the growth, yield, and nutritional quality of forage crops [17].

To address these challenges, forage species such as Napier grass (*Pennisetum purpureum*), lemongrass (*Cymbopogon* spp.), and Ruzi grass (*Brachiaria ruziziensis*) have been introduced to the region. Although these grasses offer high biomass yields and ease of cultivation, their adaptation to Hue's extreme weather remains limited. This underscores the need for resilient forage crops capable of thriving under drought and flooding conditions. *B. humidicola is a promising option, recognised* for its adaptability to diverse environments, including waterlogged and arid soils [6,8]. Native to tropical and subtropical zones, *B. humidicola* is globally valued for its ability to endure adverse conditions. Its deep root system enhances drought resistance, while its capacity to form aerenchyma, air-conducting tissues that transport oxygen to submerged roots, supports survival in waterlogged soils. These traits make it well-suited for flood-prone areas like Hue [7]. The grass offers multiple advantages for sustainable livestock production: it provides a steady year-round supply of green fodder, mitigating seasonal shortages; its high leaf-to-stem ratio boosts palatability and nutritional content, with studies showing ruminants favor leaf-rich grasses for their elevated protein and nutrient levels; and its resilience reduces the need for intensive management, lowering costs for farmers [18].

Despite its potential, the successful integration of *B. humidicola* into the forage systems of Hue requires a thorough understanding of how seasonal climatic factors influence its growth and productivity. Previous research has demonstrated that tropical grasses exhibit significant variations in growth performance across different seasons. For example, higher temperatures and longer sunshine hours during the dry season often promote faster growth and higher biomass yields. Conversely, the reduced light intensity and lower rainy season temperatures can limit photosynthesis, leading to slower growth rates and lower yields. Additionally, excessive rainfall and waterlogging during the rainy season may increase plant mortality and reduce harvested forage quality [20,22].

This study investigates the seasonal growth dynamics and productivity of *B. humidicola* in Hue, analyzing key indicators such as plant height, canopy height, leaf-to-stem ratio, and shoot density under spring-summer and autumn-winter conditions. It also explores the grass's waterlogging adaptations, including aerenchyma formation and root oxygen release, to elucidate its resilience in flooded settings. By offering evidence-based insights into *B. humidicola*'s growth patterns and adaptive mechanisms, this research seeks to advance sustainable forage systems in Vietnam's central coastal region. The results aim to inform farmers and policymakers in selecting resilient forage species and optimizing management practices to enhance livestock productivity, stabilize feed supplies, and bolster the economic sustainability of livestock farming in Hue and comparable agroecological zones.

## 2. MATERIALS AND METHODS

*2.1. B. humidicola cultivation*

*B. humidicola* was cultivated in experimental fields in Huong Tho commune, Hue, Vietnam, from January 2021 to December 2022.

Experimental design: A completely randomised design (CRD) was designed, featuring two seasonal treatments: spring-summer (the dry season) and autumn-winter (the rainy season). B. humidicola was planted across four replicated plots, each spanning 1 hectare (250 $m^2$ per plot). The planting process included: (1) Soil preparation, weeding and tilling to a depth of 20–30 cm for aeration before planting; (2) Fertilization was applied around 30 tons of organic manure per hectare before planting; (3) Healthy grass stems with evenly spaced leaf nodes were selected and planted in rows, with three-stem clusters buried 7–10 cm deep at 30 cm spacing and (4) Watering and maintenance: Irrigation was applied daily (on non-rainy days) for the first 15–20 days, and dead plants were replaced. Weeding was conducted 2–3 times weekly until full ground cover was achieved.

*2.2. Growth parameters and measurement methods*

Maximum Plant Height: Measured from the soil surface to the highest leaf tip.

Canopy Height: Measured at five random points within each plot.

Shoot Density: Counted at various growth stages.

Leaf-to-Stem Ratio: Determined from a 10 kg sample per plot, with a 1 kg subsample analyzed.

Assessment of B. humidicola's adaptation to waterlogging conditions

Dissolved Oxygen Content: Measured using an oxygen probe 5 cm above the soil surface.

Leaf Sheath and Root Morphology: Post-harvest, leaf sheath and root samples were collected. Thin cross-sections were prepared with a razor blade, stained with 1–2 drops of acetocarmine, and examined microscopically to compare waterlogged and non-waterlogged structures.

Oxygen Release from Roots: Three samples per plot were tested for oxygen release from waterlogged and non-waterlogged roots. Grass sections with intact roots were submerged in a solution of 0.1% agar, 12 mg/L methylene blue, and 130 mg/L sodium thiosulfate. [10, 11], oxygen release triggers a redox reaction: methylene blue turns blue in the agar solution, becomes colorless with sodium dithionite ($Na_2S_2O_4$), and reverts to blue with oxygen presence, indicating root oxygen release.

*2.3. Evaluation of growth performance*

Green Matter Yield: Biomass, including wilted and dried branches (excluding weeds), was harvested on dry, dew-free days, cut 5–10 cm above ground, and weighed fresh in the field.

Dry Matter Yield: Calculated as Dry Matter Yield = Green Matter Yield × % Dry Matter Content, with dry matter content determined by drying samples at 105°C to constant weight.
Protein Yield: calculated as Protein Yield = Dry Matter Yield × % Protein Content in Dry Matter.

*2.4. Data processing*

Collected data were managed using Microsoft Excel and analyzed with Minitab software (version 16.0) following the ANOVA method.

## 3. RESULTS AND DISCUSSION

*3.1. Climatic conditions in Hue during the experiment period*

Seasonal variations in temperature, humidity, sunshine hours, and average monthly rainfall were recorded across the spring-summer (dry) and autumn-winter (rainy) seasons in Hue. Data in [Fig. 1, 6] indicate that temperature, humidity, and sunshine hours remained relatively high and comparable between seasons, but rainfall differed significantly. Autumn-winter rainfall peaked at 339.1 mm, far exceeding spring-summer levels. Temperature in Hue fluctuated widely throughout the year. The average temperature was 24.4°C in spring-summer and 25.7°C in autumn-winter. Peak temperatures occurred in June, July, and August, averaging 28–29°C and occasionally reaching 40–41°C due to hot southwesterly winds. In contrast, the lowest temperatures in autumn-winter averaged 19°C in January, dipping below 10°C during cold northeastern winds. Monthly temperature shifts were more pronounced in winter, with rapid declines in November and December and sharp increases in March and April. Daily lows typically occurred between 5–6 a.m., and highs between 12–2 p.m. (Thua Thien Hue Statistics Office, 2022). These climatic variations significantly influence grass growth and productivity, challenging livestock farming. Effective heat management in summer and cold protection in winter are thus critical.

*3.2. Humidity Patterns*

Relative humidity in Hue remains high year-round, with significant seasonal, monthly, and daily variations. Average relative humidity was 80.2% in spring-summer and 84.7% in autumn-winter [Fig. 1,6], contributing to an annual average of 87.3%, one of the highest in Vietnam. Humidity inversely correlates with temperature and displays distinct seasonal patterns. Low humidity periods, from April to August, range from 74% to 87.6%, peaking in July with hot southwesterly winds. High humidity spans September to March, peaking at 93.4% in December. Daily fluctuations are most pronounced between 4–6 a.m. (highest) and 1–2 p.m. (lowest).
Sunshine Hours: Hue records fewer sunshine hours than other Vietnamese regions, with 167.4 hours in spring-summer and 181.0 hours in autumn-winter. This pattern distinguishes its climate from the Northern, Central Highlands, and Southern regions.
Rainfall Characteristics: Hue receives Vietnam's highest annual rainfall, averaging 3,877 mm. Spring-summer rainfall averaged 118.4 mm, while autumn-winter reached 339.1 mm [Fig. 1, 6]. Rainfall is driven by the northeast monsoon's early phases, peaking in October at 1,234 mm. The driest months, February to April, see a minimum of 78 mm in February. Rainy days range from 150 to 220 annually, with 21–24 days per month in October and November. Maximum rainfall events (500–1,000 mm) often last 4–6 days, triggering widespread flooding. High rainfall intensity and variability challenge agricultural and livestock production. Frequent drizzle from December to April, especially in February and March, reduces evaporation, sustaining elevated humidity during the dry season.

*3.3. Impact of seasons on the growth*

Key growth parameters, leaf-to-stem ratio, maximum plant height, canopy height, number of shoots per clump, and clump circumference—are essential for evaluating the forage potential of *B. humidicola*. These metrics were monitored across the spring-summer and autumn-winter seasons [Tab. 1]. Results reveal significant seasonal differences in these parameters (P<0.05), with higher values consistently recorded in spring-summer compared to autumn-winter. This is likely due to favorable spring-summer conditions, including moderate temperatures, balanced humidity, longer sunshine hours, and lower rainfall [Fig. 1,6], which optimize *B. humidicola*'s growth and development.
The leaf-to-stem ratio, a quality parameter reflecting grass palatability for livestock, was significantly higher in spring-summer (53.79%) than in autumn-winter (41.99%) (P<0.05). Livestock prefer higher ratios (Phan et al., 2020). Le et al. (2012) reported a leaf-to-green matter ratio of 57.1–64.5% for *Brachiaria* species, while [18] found ratios of 23.9–39.3% for Guinea grass and 42.1–55.3% for Ruzi grass. Maximum plant height of *B.*

*humidicola* also varied seasonally (P<0.05), reaching 77.96 cm in spring-summer versus 71.59 cm in autumn-winter. [4,5] recorded heights of 82.61 cm for Guinea grass and 90.87 cm for Mulato II grass. Canopy height showed significant seasonal differences (P<0.05), averaging 62.07 cm in spring-summer and 58.67 cm in autumn-winter. [10] noted Brachiaria canopy heights of 45–65 cm, while [20] reported 54.9 cm (rainy season) and 51.5 cm (dry season) for *S. guianensis* CIAT 184. [17] found Guinea grass canopy heights of 48.55 cm at 40 days and 65.22 cm at 50 days.

The number of shoots per clump differed significantly (P<0.05), with 59.7 shoots in spring-summer and 47.13 in autumn-winter, influenced by soil, water, fertilizers, and climate. [16] reported 22 shoots per clump for *Brachiaria* after 60 days, while [12, 13, 14] found 7.98–14.90 for *Paspalum* grass. Clump circumference was larger in spring-summer (73.91 cm) than in autumn-winter (66.81 cm), with significant differences (P<0.05).

*3.4. Impact of seasonal variations on the productivity*

As shown in **[Tab. 2]** *B. humidicola* exhibited significantly higher productivity in spring-summer than in autumn-winter (P<0.05). Green matter yield averaged 14.97 tons/ha/cut in spring-summer, compared to 12.89 tons/ha/cut in autumn-winter. Dry matter and protein yields followed the same trend, reflecting the negative effects of lower temperatures, reduced sunshine, and excessive rainfall in autumn-winter.

These results are consistent with prior studies showing that tropical grasses thrive under high light intensity and moderate temperatures [20,14] found that grass productivity in Thanh Hoa dropped in winter, with herbaceous species yielding only 22.93–37.23% of annual totals. [12] reported that spring-summer conditions, higher temperatures, longer sunshine hours, and lower rainfall, boosted grass productivity to 72–75% of annual yield (over five cuts), while autumn-winter, spanning 40% of the year, contributed just 25–28% (over three cuts). They attributed this to waterlogging-induced plant mortality, slower growth from lower temperatures and reduced sunshine, and inadequate care due to unfavorable weather. [14], observed that dry matter yields peaked during moderate rainfall and high temperatures, followed by low rainfall and high temperatures, and were lowest with high rainfall and low temperatures. Grass regeneration and growth rely heavily on light and water availability. In low-rainfall months (April–September), adequate irrigation and extended sunshine enhanced productivity, whereas low temperatures and insufficient light reduced yields in the rainy season (October–December). Reduced sunshine hours, critical for C4 plants like *B. humidicola*, lower chlorophyll α concentration and overall chlorophyll density, limiting photosynthesis and biomass accumulation [6]. Contrasting findings emerged from [12], who reported higher grass productivity in Gia Lai's rainy season, linked to red basalt soil and a prolonged dry season (November–April) causing water shortages that constrained growth. Similarly, [16] noted comparable trends in Ha Giang, highlighting the role of regional soil and climate differences.

*3.5. Assessment of adaptation to waterlogging conditions*

*Dissolved oxygen content*

Dissolved oxygen is essential for metabolic processes, supporting the growth, reproduction, and productivity of plants and aquatic organisms. Dissolved oxygen levels increased with wider planting distances, indicating that lower plant density reduced root oxygen consumption. For example, plots with 50 × 50 cm spacing retained significantly higher oxygen levels (2.41 mg/L) than those with 20 × 50 cm spacing (1.45 mg/L), [4, 15]. Experimental results suggest that denser planting leads to greater root oxygen consumption, lowering dissolved oxygen content in water. In potted experiments, dissolved oxygen levels were generally lower due to limited water movement, reduced air contact, and minimal light exposure. However, dissolved oxygen levels remained higher in pots than in field conditions. By the 30th day after waterlogging, dissolved oxygen in pots with a 25 cm water depth had dropped to 0.30 mg/L, likely due to the small pot diameter (40 cm) and a planting density of three cuttings per pot. Additionally, stagnant water with minimal air exchange and low light penetration further reduced oxygen levels. Unlike in the pot experiment, water samples from field trials did not turn dark **[Tab.3]**.

Dissolved oxygen levels also varied significantly across harvest cycles (P < 0.05) [2,3]. In each season, oxygen levels were highest in the first cycle, gradually declined in the second, and reached their lowest in the third. During the first cycle, root systems were still developing, resulting in minimal oxygen consumption. By the third cycle, well-established roots consumed more oxygen, further depleting dissolved oxygen levels. Our findings align with previous research, [13] reported that dissolved oxygen levels in Paspalum grass were influenced by planting density and harvest cycles.

Formation of internal air-conducting structures

Microscopic observations revealed that in non-waterlogged leaf sheaths [Fig. 2], air-conducting tissues (aerenchyma) were either absent or not well-developed. In contrast, waterlogged samples [Fig. 3] exhibited well-developed aerenchyma with larger diameters, facilitating oxygen transport between roots and shoots.

Root observations showed a similar trend: non-waterlogged roots had fewer air pores, whereas waterlogged roots developed more numerous and prominent air pores, forming interconnected networks for oxygen exchange [Fig. 4, 5]. This adaptation helps plants maintain oxygen supply under prolonged waterlogging conditions. According to [9] and [2], some plant species respond to waterlogging by developing aerenchyma, which transports oxygen to submerged roots and mitigates oxygen deficiency caused by flooding.

*Observation of oxygen release from roots*

To assess oxygen release, three samples per plot were tested under waterlogged and non-waterlogged conditions. In non-waterlogged roots, oxygen release was negligible, as no visible color change occurred in the surrounding solution after 30 minutes, consistent with the absence of air-conducting tissues.

## Conclusion

This study highlights the ability of *B. humidicola* to maintain high productivity year-round in Hue, with significantly higher yields in the spring-summer season ($P < 0.05$). Its strong adaptability to waterlogging, evidenced by aerenchyma formation and oxygen release mechanisms, makes it a reliable forage option for flood-prone areas. Integrating *B. humidicola* into local forage systems can help farmers mitigate seasonal feed shortages and enhance livestock production. Further research should explore optimal cultivation methods and their long-term effects on soil health and animal performance to maximize their benefits.

## Acknowledgements

This manuscript was supported by our colleagues, laboratories, and students working in the field. Although we do not receive any financial support from the Institution, we tried to improve our power and conditions in teaching and doing research for these ideas. Finally, we also want to thank farmers who helped with the harvest and drying, and gave to ruminant animals.

## Conflict of Interest

The authors declare that they have no conflicts of interest.

## Ethical Certificate

No ethical certificate, just one confirmation of University Scientific Committee, where the research have been done and used the laboratoty system. During the COVID-19 pandemic, we did not receive any funds.

## Funding

This research did not receive any financial support.

Data available: 10.6084/m9.figshare.28694606

## References

[1] AOAC, 1990. Official Methods of Analysis, Helrich K. editted ed. 15th edn., Association of Official Analytical Chemists, Washington, DC, USA. https://archive.org/details/gov.law.aoac.methods.1.1990/page/n33/mode/2up

[2] Armstrong, W., 1971. Oxygen diffusion from the roots of some British bog plants. New Phytologist. 70(4), 715-723. https://www.nature.com/articles/204801b0

[3] Armstrong, W., 1971. Radial oxygen loss from intact rice roots as affected by distance from the apex, respiration, and waterlogging. Physiologia Plantarum. 25(2), 192-197. doi:10.1111/j.1399-3054.1971.tb01427.x

[4] Elstner, E.F., Osswald, W., 2011. Mechanisms of oxygen activation during plant stress. Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences. 102, 131-154. doi:10.1017/S0269727000014068

[5] Ho, V.T., Doan, D.L., Vang, A.M., Le, X.T., 2021. Evaluating the growth and green matter yield of chine grass and mulato II grass planted in PU Nhung commune, Tuan Giao district, Dien Bien province. Journey Science – Tay Bac University. 24, 50-55. http://tapchi.utb.edu.vn/index.php/journalofscience/article/viewFile/347/401

[6] Hoang, V.T., Tran, D.V., 2012. Production potentials and quality of some grass varieties and fodder crops for dairy cows in Nghia Dan, Nghe An. Journal of Science and Development. 10(1), 84-94. http://thuvien.ued.udn.vn/handle/TVDHSPDN_123456789/ 43600

[7] Jackson, M.B., & Drew, M.C., 1984. CHAPTER 3 - Effects of Flooding on Growth and Metabolism of Herbaceous Plants, in: T. T. Kozlowski (Ed.), Flooding and Plant Growth, pp. 47-128. San Diego: Academic Press. https://sci-hub.se/10.1016/B978-0-12-424120-6.50008-0
[8] Kozlowski, T.T., 1986. Oxygen stress in plants: mechanisms and adaptation. https://link.springer.com/book/10.1007/978-1-4614-8591-9
[9] Krame, P.J., 1988. Water relations of plants and soils, Academic Press. Authors: Paul J. Kramer, John S. Boyer, Hardback ISBN: 978-0-12-425060-4; eBook ISBN: 9780080924113: https://shop.elsevier.com/books/water-relations-of-plants-and-soils/kramer/978-0-12-425060-4
[10] Le, X.D., Nguyen, T.M., Phan, T.K., 2012. The effect of organic fertilization on the production capacity of some Brachiaria group grass varieties. http://www.trungtamqlkdg.com.vn/TTG_Res/Uploads/Acrobat/nghiencuukhoahoc/_2012/B28_thucan.pdf
[11] Nguyen, T.H.N., Nguyen, V.H., Nguyen, T.N., Do, T.T.D., 2011. The effect of planting distance on growth, development and yield of *Paspalum atratum* grass in flooded field conditions. Journal of Livestock Science and Technology. 31, 81-90. https://sti.vista.gov.vn/file_DuLieu/dataTLKHCN//CVv25/2011/CVv25S3120110-81. pdf
[12] Nguyen, T.M., Dang, D.H., Nguyen, V.L., 2006. Experiment with building a model of seed production and green feed based on expanding the area of intensive cultivation of suitable grass varieties for cow breeding in the Northern Midlands and the mountainous regions. Scientific Reports of the Institute of Animal Husbandry. 1-9.
[13] Nguyen, T.M., Nguyen, H.V., Pham, H.P., Dinh, V.D., Tran, T.H., Tran, N.L., Nguyen, X.B., 2017. Yield and nutritional value of some species of grass planted in irrigated sandy soil in Binh Dinh province. Hue University Journal of Science. 126(3A), 129-137.
[14] Nguyen, V.T, Pham V.Q., Phi, N.L, Hoang, T.N., Nguyen, T.T., Bui, N.H., Giang, V.S. and Le, T.C., 2021. Yield and quality grass varieties Ruzi, Mombasa, Hamil and K280 in Chu Se district, Gia Lai province. Journal of Livestock Science and Technology. 125, 56-66.
[15] Nguyen, X.B., Nguyen, T.V., Nguyen, H.V., Ta, N.A., 2010. Ability to produce green matter of some grass varieties in regions of Quang Tri province. Journal of Livestock Science and Technology. 22, 52-59.
[16] Nguyen, X.C., Dao, B.Y., 2017. Selection of High-yielding Tree and Grass Species for Cattle Feed Suitable for Ecological Conditions in Ha Giang. Journal Science Journal Science VNU: Earth and Environmental Sciences. 33(1S-2017), 1-6.
[17] Pham, T.H., 2017. Growth and development of VA06 grass and Ghine TD58 in Eakar, Dak Lak province. Journal of Science of Can Tho University. 51, 1-7. **DOI:** 10.22144/ctu.jvn.2017.072
[18] Phan, T.H.N., Duong T.T.H., Tran, T.M.N., Nguyen, V.L., Tang, T.H., Nguyen, V.L., 2020. Evaluation of the Growth, Yield and Quality of Some Forage Species at the Different Cutting Times in Gia Lam, Hanoi. Vietnam Journal of Agricultural Science. 18(8), 580-587. http://tapchi.vnua.edu.vn/wp-content/uploads/2020/08/tap-chi-so-8.1.5.pdf
[19] Phung, T.H., Nguyen, K.N., Ho, T.T., 2021. A survey on growth characteristics and anatomical structure of *Brachiaria mutica* growing under greenhouse conditions. Journal of Science of Can Tho University. 57, 205-215. **DOI:** 10.22144/ctu.jvn.2021.158
[20] Ta, Q.T., Nguyen, V.Q., Nguyen, D.T., 2019. Evaluation of growth and efficiency of grass varieties for cows raising in Thach Thanh – Thanh Hoa province. Vietnam Journal of Agricultural Science and Technology. 5(102), 35-38.
[21] Tsukarahara, K., Kozlowski, T.T., 1986. Oxygen deficiency in waterlogged plants. Journal of Plant Physiology. 120(2), 165-176. 10.3389/fpls.2020.627331
[22] Tu Q.H., Tran, T.H. and Tu Q.T., 2017. A study on the green matter and grass meal production performance of *Stylosanthes guianensis* CIAT 184 cultivated in Thai Nguyen Province. Vietnam Journal Science and Technology. 19(8) 8.2017. https://vjst.vn/Images/Tapchi/2017/8B/8B-23-27.pdf
[23] Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci. 74 (10), 3583-97. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

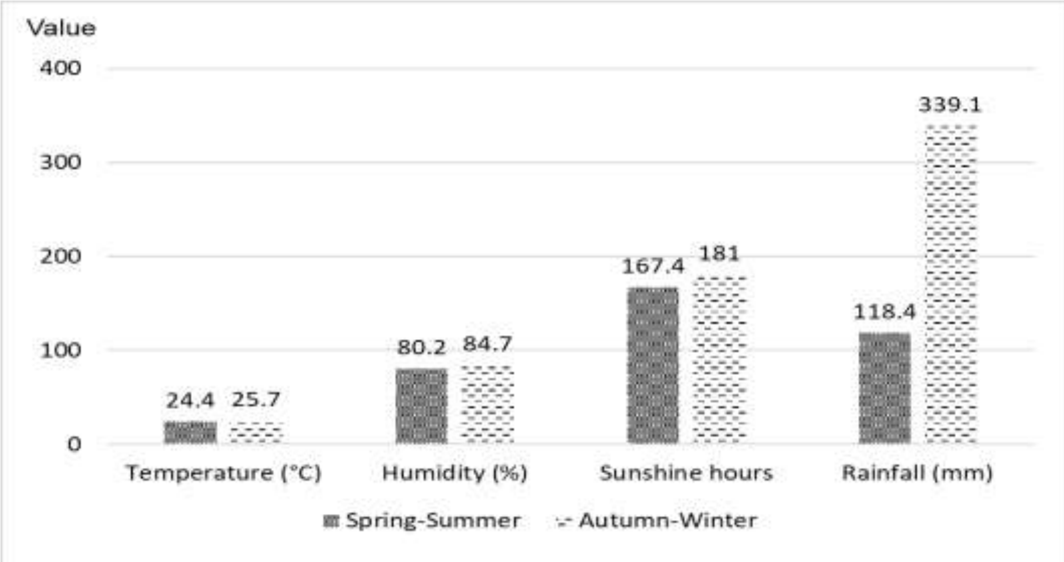


**Figure 1.** Seasonal climate conditions in Thua Thien Hue (designated as Hue City from January 1, 2025).

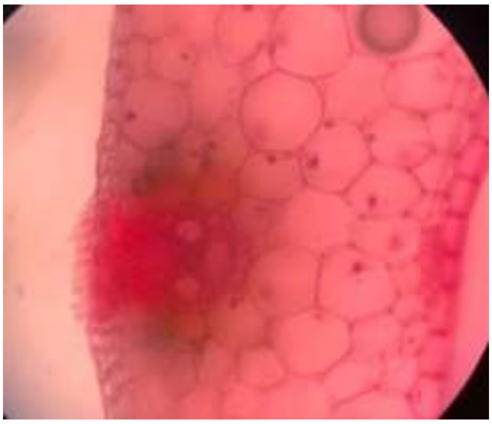

**Figure 2.** Cross-section of a non-waterlogged leaf sheath.

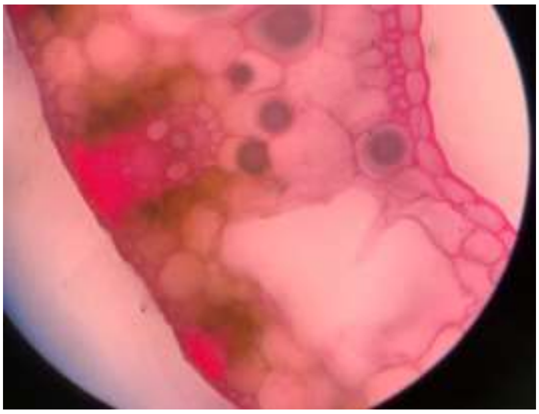

**Figure 3.** Cross-section of a waterlogged leaf sheath.

**Figure 4.** Cross-section of a mature root (non-waterlogged).

**Figure 5.** Cross-section of a mature root (waterlogged).

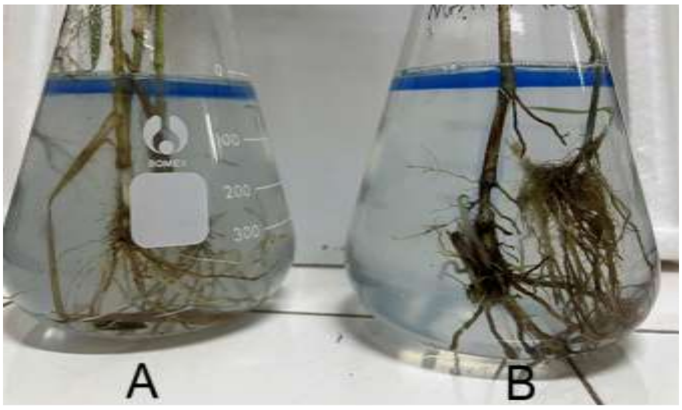


**Figure 6.** Experiment observing oxygen release in *B. humidicola* roots under non-waterlogged (A) and waterlogged (B) conditions.

**Some pictures during the experiment**

6.1. Staining and imaging of *B. humidicola* tissue


6.2. The non-waterlogged (A) and waterlogged (B) *B. humidicola*


6.3. The non-waterlogged (A) and waterlogged (B) *B. humidicola* before the observing oxygen release experiment

**Tables**

**Table 1-=**

**.** Seasonal impact on growth parameters of *B. humidicola.*

| Growth Parameter | Spring-Summer | Autumn-Winter | SEM | P-value |
|---|---|---|---|---|
| Leaf-to-Stem Ratio (%) | 53.79[a] | 41.99[b] | 0.768 | 0.000 |
| Maximum Plant Height (cm) | 77.96[a] | 71.59[b] | 0.909 | 0.000 |
| Canopy Height (cm) | 62.07[a] | 58.67[b] | 0.939 | 0.011 |
| Number of Shoots per Clump | 59.70[a] | 47.13[b] | 1.200 | 0.000 |
| Clump Circumference (cm) | 73.91[a] | 66.81[b] | 1.438 | 0.001 |

*Values with different letters indicate statistically significant differences between the two seasons at P<0.05*

**Table 2.** Seasonal impact on productivity parameters of *B. humidicola*

| Parameter | Spring-Summer | Autumn-Winter | SEM | P-value |
|---|---|---|---|---|
| Green Matter Yield (tons/ha/cut) | 14.97[a] | 12.89[b] | 0.254 | 0.000 |
| Dry Matter Yield (tons/ha/cut) | 3.66[a] | 3.18[b] | 0.062 | 0.000 |
| Protein Matter Yield (tons/ha/cut) | 1.12[a] | 0.97[b] | 0.019 | 0.000 |

*Values with different letters indicate statistically significant differences between the two seasons at P<0.05*

**Table 3.** The dissolved oxygen content in experimental plots

| Planting Distance | Cut 1 (mg/L) | Cut 2 (mg/L) | Cut 3 (mg/L) | Planting Distance |
|---|---|---|---|---|
| 20 x 50 cm | 1.45b | 1.37b | 1.05b | 20 x 50 cm |
| 30 x 50 cm | 1.78ab | 1.61ab | 1.12ab | 30 x 50 cm |
| 40 x 50 cm | 2.08a | 1.95a | 1.08a | 40 x 50 cm |
| 50 x 50 cm | 2.41a | 2.25a | 1.09a | 50 x 50 cm |
| **P-value** | * | * | | **P-value** |

* *indicates significant differences at P<0.05*

**Mghjjo[**
**]]**
**';lk;puoyhppoyhoyo0uoujju./-**