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Research Article

PRINCIPAL COMPONENT ANALYSIS OF ENVIRONMENTAL FACTORS INFLUENCING THE DISTRIBUTION OF *TRIBULUS TERRESTRIS* L. IN THE SOUTHERN KHANH HOA REGION

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ABSTRACT

This study investigates the ecological distribution of the Tribulus terrestris L., a species listed in the Vietnamese Red Book (EN), which commonly grows wild in coastal areas of Khanh Hoa Province. The study focuses on analyzing the climatic characteristics and principal physicochemical composition of soil samples taken from Thai An hamlet, My Tan hamlet, and Do Vinh ward, and their impact on the natural distribution of Tribulus terrestris. The results show that the study area is characterized by a hot and very dry climate, with high seasonal temperatures and humidity. The soil's physicochemical index is predominantly sandy, but also exhibits neutral to moderately alkaline pH (7.45 - 8.77) and low nutrient concentrations. Principal component analysis also reveals differences in environmental factors among these study sites. Specifically, at Thai An, clay content shows a positive correlation with K_2O and a negative correlation with organic matter. At My Tan, the positive relationship between clay and K_2O is stronger, and the positive correlation between pH, EC, and sand is even stronger in areas with high clay content. At Do Vinh, strong positive correlations are observed among pH, EC, and readily available nitrogen, whereas P_2O_5 and K_2O exhibit weak correlations in soil layers with higher concentrations. EC and readily available N are strongly correlated, while pH shows only moderate positive correlations with nutrient content.

Keywords: *Tribulus terrestris*; ecological characteristics; soil chemistry and physicochemical properties; principal component analysis (PCA)

1. Introduction

The *Tribulus terrestris* is a rare medicinal plant listed in the Vietnamese Red Book at the endangered (EN) level. It commonly grows wild in coastal and riverside areas of the South Central coastal provinces (Tran, 2023). Gai ma vuong is a herbaceous plant with compound leaves and small leaflets, yellow flowers, spiny fruit, and adapts well to sandy,

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dry environments. The plant has medicinal properties, including a bitter taste, kidney tonic, treatment of back pain, support for male physiology, and regulation of female physiology (Elkamali et al., 2016; Huang & Hsieh, 1994; Raju & Raju, 2023; Semerdjieva & Evstatieva, 2010). Khanh Hoa Province, a coastal region in South Central Vietnam, is a significant distribution area for *T. terrestris* (Do et al, 2006).

Beyond its ecological significance, *T. terrestris* holds considerable medicinal value in traditional medicine (Do, 2004). In Vietnam, *Tribulus terrestris* is mainly distributed in the coastal provinces of Central and South Central Vietnam, from Quang Binh, Thua Thien Hue to Khanh Hoa, Ninh Thuan, and Binh Thuan (Do et al., 2006). Field surveys show that the plant often grows on vacant lots, coastal sandy soil, gravel soil, along roadsides, and in areas with human disturbance (Bui et al., 2024). Due to the risk of extinction, research on in vitro propagation (tissue culture) is being promoted in Vietnam. The goal is to develop effective propagation processes to conserve genetic resources and provide raw materials for research and production of medicinal herbs, reducing exploitation pressure on natural populations (Quach & Hoang, 2025).

The Southern Khanh Hoa region (Ninh Thuan province before the province merger) is characterized by a harsh tropical monsoon climate, experiencing severe droughts during the dry season and significant floods during the rainy season (Tu et al., 2018; People's Committee of Ninh Thuan Province, March, 2025).

The natural vegetation in this region is well-adapted to sandy, nutrient-poor soils, necessitating specific adaptive features for survival and growth (Ho & Truong, 2015). Plants, in general, develop diverse adaptive characteristics to thrive in varying environmental conditions (Pham, 2024). For instance, in arid climates with intense sunlight, many plant species exhibit morphological and anatomical adaptations such as thick cuticles, multicellular hairs on leaves, and well-developed palisade parenchyma to reduce water loss (Pham, 2021). These adaptations to adverse environmental conditions demonstrate the species' ability to survive by adapting to and responding to environmental impacts.

Despite its rarity and medicinal importance, comprehensive research on the ecological adaptations of *T. terrestris* to specific environmental conditions in Vietnam remains limited. Particularly, studies focusing on its morphological and anatomical structures in relation to its habitat are scarce. To address this knowledge gap and contribute to the conservation and rational utilization of this endangered species, this study was conducted. This research focused on the ecological characteristics of *T. terrestris* in three specific locations within Khanh Hoa province. The scope encompassed a detailed survey of climatic and soil ecological characteristics (physicochemical properties, soil nutrient composition).

Although this plant has medicinal value and is endangered in Viet Nam, its ecological characteristics and physicochemical properties of the soil in its distribution areas have not been fully studied. Therefore, this study was conducted to provide scientific data on soil

ecological characteristics and contribute to the conservation and efficient exploitation of this endangered plant in its natural habitat. This study focuses on the climatic ecological characteristics and soil properties in three areas in Khanh Hoa Province where the *T. terrestris* is distributed.

2. Materials and methods

2.1. Study Period and Location

This study was conducted from October 2024 to April 2025. Plant and soil samples were collected during three distinct phases: September 15, 2024; September 26, 2024; and December 1, 2024. Sample collection occurred at three locations in Khanh Hoa Province, Vietnam (Figure 1), including Thai An Hamlet, My Tan Hamlet (Vinh Hai Commune), and Do Vinh Ward. Laboratory analyses were performed at the Plant Ecology Laboratory (M203), Faculty of Biology, Ho Chi Minh City University of Education.

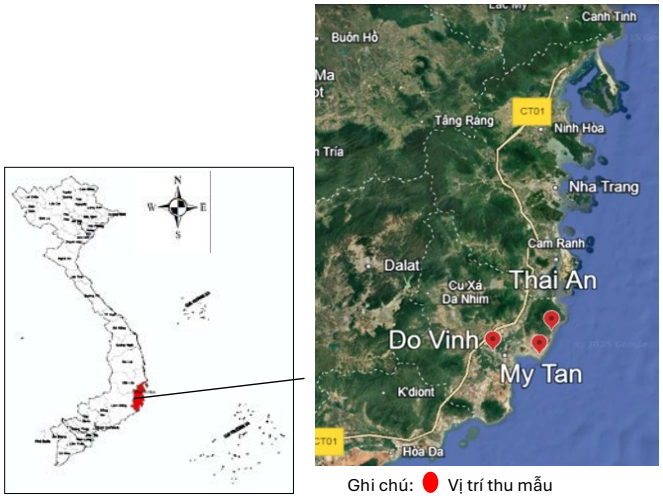

Figure 1. *Research locations in three regions of southern Khanh Hoa Province*

2.2. Methods

2.2.1. Field Study Methods

Soil Sample Collection and Preservation: Soil samples for physicochemical analysis were collected from a depth of 0-30 cm. At each survey site, soil was collected from five evenly distributed points using a diagonal or zigzag pattern, depending on the terrain. These initial soil samples were combined into a homogeneous mixture, from which a representative sample (at least 2 kg) was taken. The collected soil samples were placed in labeled plastic bags with information such as sample code, depth, sampling location, and date. In the laboratory, the soil samples were spread thinly on individual clean plastic trays (fully labeled to avoid confusion between samples) and air-dried in a well-ventilated area, away from direct sunlight. Larger soil clumps were broken up, and any plant debris was removed. The cleaned soil is then finely ground and stored in labeled plastic bags clearly indicating the code of each sample for analysis of its properties.

2.2.2. Laboratory Research Methods

Bioclimatic Diagram Construction Method: Relevant scientific literature and meteorological data on the climate conditions of Southern Khanh Hoa were collected. Climatic and bioclimatic analyses were based on meteorological data from Phan Rang station from 1993 to 2020. Bioclimatic diagrams were constructed following Nguyen Khanh Van's method (Nguyen et al., 2000), based on the relationship between monthly rainfall (R mm) and mean monthly temperature (T°C).

Soil analyses were conducted using established Vietnamese national standards. Mechanical composition was determined by the specific gravity method, pH_{H2O} and pH_{KCl} by a chemical method, and Electrical Conductivity (EC mS/cm) through conductivity measurements of saturated soil solutions. The Desiccation Coefficient was measured by the mass, while Organic Matter (OM %) was assessed using the Walkley-Black method. Total Nitrogen (%) and available-N (mg/Kg) were analyzed via the Kjeldahl method. Available P_2O_5 was determined using the Olsen method, and available K_2O by the emission spectroscopy method (Ministry of Science and Technology: TCVN 5255:2009; TCVN 8661:2011; TCVN 8662:2011; TCVN 8941:2011; Ministry of Science, Technology and Environment: TCVN 6498:1999).

2.3. Data analysis

Data were processed using Excel 2013 to calculate mean values, standard deviations, and compare means of two samples using the U-test (95% confidence) (Triola, 2006; Walpole et al., 2012). Multivariate regression analysis and ANOVA were performed using Statgraphics Plus (Statgraphics Technologies, 2001; Quinn & Keough, 2002). PASS was also utilized, and Principal Component Analysis (PCA) was also used to analyze the relationships among ecological factors (NCSS, 2007).

3. Results and discussion

3.1. Climate characteristics of the distribution area of Tribulus terrestris in Khanh Hoa

Climate is an important factor influencing the distribution of vegetation, the growth and development of plant species (Tu et al., 2018). The main climatic factors of the southern region (Phan Rang station) of Khanh Hoa province are recorded in Appendix 1, showing that this area has a tropical monsoon climate with a high average temperature (27.3°C), with the highest temperature in May. The average monthly temperature range is quite large (5.8 - 8.4°C), and the average annual sunshine hours are high, reaching 3.029 hours. However, the sunshine hours are unevenly distributed between the dry and rainy seasons. The rainy season is relatively short, from September to November. November has the highest rainfall at nearly 171.0 mm, and February has the lowest (<2.8 mm).

Table 1. *Climatic factors measured at Do Vinh station, Khanh Hoa Province (1993-2020)*

Parameter	Month												Annual Mean/ Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Sunshine hours (hours)	241.7	255.2	278.5	278.3	258.2	239.2	234.0	242.2	195.6	194.0	189.7	189.4	3.029
Air temperature (°C)	25.1	25.4	26.6	28.1	29.3	29.1	28.5	28.6	27.9	27.2	26.7	25.6	27.3
Temperature range (°C)	7.1	7.3	7.9	7.7	8.4	8.3	8.3	8.5	7.8	7.0	6.1	5.8	7.5
Rainfall (mm)	8.8	2.8	12.0	20.4	65.6	61.7	54.7	51.2	138.6	168.1	171.0	83.6	838.5

The bioclimatic analysis at Phan Rang station (Figure 2) shows that the southern area of Khanh Hoa experiences a dry season lasting nine months (Nguyen et al., 2000). This prolonged dry season has many impacts on the growth and development of the wild *Tribulus terrestris* plant in the study areas. The rainy season is relatively short, only about three months (September – November, months with rainfall exceeding 100 mm), providing more suitable humidity for the growth and development of *T terrestris*. Therefore, *T terrestris* living in these areas will have the adaptive characteristics of drought-tolerant plants and a short growth and development period, usually flowering from May to August, fruiting from June to September, after which the fruit ripens, the seeds germinate, and develop well during the rainy season (Mirsa, 1962; Pathak, 1970).

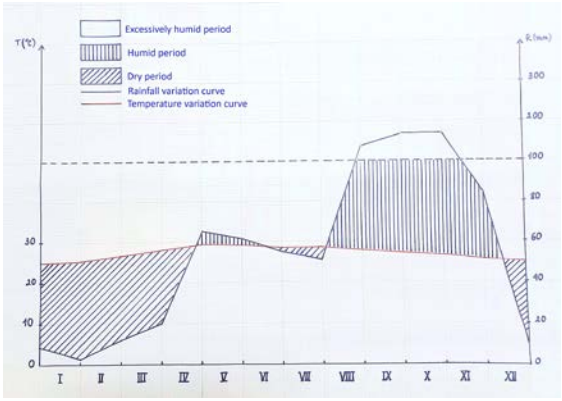

Figure 2. *Bioclimatic chart of Phan Rang station (Southern Khanh Hoa)*

3.2. Physicochemical Characteristics of Soil in the Study Areas

The results of the physicochemical analysis of soil samples collected from the three study areas are presented in Table 2. Table 2 shows that the physicochemical indices of the soil in these areas differed significantly. Specifically:

The soil pH values ranged from 7.45-8.77 for pHH_2O and 7.32-7.93 for pHKCl (neutral to strongly alkaline). These results are consistent with the findings of Tripathi et al. (2019), suggesting that this pH scale is suitable for the growth of *T. terrestris*. In addition, soil pH affects soil colloid solutions and ion exchange capacity. Electrical conductivity (EC)

also varied among the three sampling areas, with EC values inversely proportional to pH values. The soil drying coefficient in all three areas was low, indicating rapid moisture loss due to poor water retention. In particular, the soil in the Thai An Hamlet exhibited the lowest drought coefficient, averaging 1.0035.

Regarding soil mechanical composition, this is an important indicator determining soil properties and assessing its suitability for crop growth. All three areas have a relatively high sand content, and analysis shows statistically significant differences between the three locations. The sand content, from highest to lowest, is in Do Vinh (89%), Thai An (83%), and My Tan (73.93%).

Organic matter (OM) is a very important component of soil and is essential for plant growth; however, the content of organic matter in the soil in all three areas was very low, such as only 0.52% in Thai An, about 3.73% in My Tan, and only about 4.21% in Do Vinh. Total nitrogen (N) in the soil was also relatively low, ranging from very low (<0.05%) to moderate (0.12 - 0.20%) in the study areas. Similarly, the readily available nitrogen content was low (<4 mg/100g soil) in Thai An and My Tan. Do Vinh had a moderate readily available nitrogen content (4.39 mg/100g soil, corresponding to 4-8 mg/100g soil). In addition, phosphorus (P) is also an important macronutrient. Do Vinh and My Tan had higher readily available P_2O_5 content (3.42 mg/g and 3.36 mg/g, respectively) compared to Thai An (2.44 mg/g). Potassium (K) is very important for the physiological functions of plant cells. According to the assessment scale of the Agricultural Handbook (1989), the readily absorbable K_2O content in Thai An was at an average level (18.78 mg/100g), while My Tan and Do Vinh had much higher content (50.97 mg/100g and 45.05 mg/100g, respectively).

Table 2. *Physicochemical indices of soil in the survey areas (n=3, Mean ± SD)*

Analysis Parameter		Area		
		Thai An	My Tan	Do Vinh
pH_{H2O}		8.77 ± 0.01^c	8.21 ± 0.01^b	7.45 ± 0.01^a
pH_{KCl}		7.92 ± 0.00^b	7.93 ± 0.01^b	7.32 ± 0.01^a
Electrical Conductivity (EC) (µS/cm)		140.50 ± 0.12^a	181.80 ± 0.06^b	341.70 ± 0.58^c
Desiccation Coefficient		1.0035 ± 0.0005^a	1.0075 ± 0.0008^b	1.0064 ± 0.0013^b
Mechanical Composition (%)	Clay	7.13 ± 0.12^b	5.07 ± 0.12^a	8.07 ± 0.12^c
	Silt	9.87 ± 0.12^b	21.00 ± 0.00^c	2.93 ± 0.12^a
	Sand	83.00 ± 0.00^b	73.93 ± 0.12^a	89.00 ± 0.00^c
Organic Matter (OM%)		0.52 ± 0.07^a	3.73 ± 0.06^b	4.21 ± 0.10^c
Total N (%)		0.03 ± 0.00^a	0.19 ± 0.00^c	0.16 ± 0.00^b
Available N (mg/100g)		1.07 ± 0.04^a	1.73 ± 0.04^b	4.39 ± 0.04^c
Available P_2O_5 (mg/100g)		2.44 ± 0.03^a	3.36 ± 0.03^b	3.42 ± 0.05^b
Available K_2O (mg/100g)		18.78 ± 0.03^a	50.95 ± 0.07^c	45.05 ± 0.07^b

Note: Different letters (a, b, c) within a row indicate statistically significant differences (P<0.05) based on the LSD test

3.3. Correlation Analysis of Ecological Factors in Khanh Hoa Province via PCA

3.3.1. In Thai An

Principal component analysis in the Thai An area is shown by the following PC1: PC1 = 0.25611 pHH_2O + 0 pHKCl + 0.70909 EC -0.9652 Clay + 0.9652 Silt + 0 Sand -0.9652 Organic matter + 0 Ntt -0.25611 P_2O_5 + 0.70909 K_2O - 0.70909 available N (Total explained variance ≈ 95%).

The PC1 loading coefficient of Thai An is closely related to the physicochemical indices of the soil (NCSS, 2007). The silt layer (0.9652) as well as K_2O (0.70909) have many positive effects on PC1. This shows that areas with high silt content as well as high potassium content are significant contributing factors to the variance in PC1. *Tribulus terrestris*, distributed in areas disturbed by agriculture or sandy soils, thrives in conditions where higher levels of alluvial deposits allow for better water retention of nutrients, and K_2O is an essential component for plant growth. Clay (-0.9652), organic matter (OM) (-0.9652), and readily available nitrogen (-0.70909) all have negative effects on PC1. Conversely, *T. terrestris* is more suited to soils with less organic matter; therefore, soils rich in clay and with higher organic matter content may hinder its growth and distribution in this area. The nitrogen content in the soil plays a crucial role in plant growth and development. PCA analysis results show that readily available nitrogen is a positive factor in the soil environment (correlation coefficient> 99%), positively influencing plant growth and development. Electrical conductivity showed a relatively high positive correlation (0.70909), indicating tolerance to mild salinity, such as in coastal areas, while P_2O_5 showed a very low negative correlation.

3.3.2. In My Tan

PC1 = -0.99148 pH_{H2O} + 0.60852 pH_{KCl} + 0.60852 EC + 0.99148 Clay + 0 Silt - 0.99148 Sand + 0.60852 OM + 0 Ntt - 0.38296P_2O_5 + 0.99148 K_2O + 0.60852 available N (Cumulative Explained Variance ≈ 83%)

PC1 values in the My Tan area show that clay (0.99148) and K2O (0.99148) have very large positive loading coefficients. This result contrasts with the Thai An area, where Tribulus terrestris in My Tan is very suitable for soils with high clay and potassium content. This indicates that the adaptability of Tribulus terrestris varies depending on the soil conditions in different distribution areas. The pHH2O (-0.99148) and Sand (-0.99148) values have very high negative loading coefficients and are closely related to PC1. The remaining indices, such as pHKCl (0.60852), EC (0.60852), OM (0.60852), and available N (0.60852). All have average positive loading coefficients.

3.3.3. In Do Vinh

PC1 = 0.99912 pH_{H2O} + 0.99912 pH_{KCl} + 0.99912 EC + 0.53584 Clay - 0.53584 Silt + 0 Sand - 0.24885 OM + 0 Ntt - 0.99912 P_2O_5 - 0.99912 K_2O + 0.99912 available N (Cumulative Explained Variance ≈ 91%)

The PC1 loading coefficients in the Do Vinh area show that the pHH_2O (0.99912), pHKCl (0.99912), EC (0.99912), and available N (0.99912) values all have very high positive loading coefficients. This analysis indicates that pH, EC, and available nitrogen are important ecological factors affecting the distribution of *Tribulus terrestris* in Do Vinh. Soil with high alkalinity, high salinity, and high readily available nitrogen is a favorable condition for *Tribulus terrestris* growth in this area. Conversely, the P_2O_5 (-0.99912) and K_2O (-0.99912) indices have very high negative loading coefficients, possibly suggesting that these nutrients are not limiting factors or that *Tribulus terrestris* has adapted to the environment with lower concentrations in this area. In terms of mechanical composition, Clay (0.53584) has a positive correlation, while Silt (-0.53584) has a negative but moderate correlation.

3.3.4. In all 3 areas

PC1 = -0.97233 pH_{H2O} - 0.97784pH_{KCl} + 0.99998 EC + 0.58887 Clay - 0.65405 Silt + 0.6664 Sand + 0.74584 OM + 0.52022 Ntt + 0.70322 P_2O_5 + 0.52378 K_2O + 0.99967 available N (Cumulative Explained Variance ≈ 94%)

A general analysis of the three areas regarding the main factors showed that EC (0.99998) and readily available N (0.99967) had very high positive loading coefficients, which are factors with a positive impact on the first main component. In Khanh Hoa province, *Tribulus terrestris* is usually concentrated in areas with high salinity or coastal areas and low readily available nitrogen. However, the pHH_2O (-0.97233) and pHKCl (-0.97784) values had strong negative loading coefficients. For example, low soil pH (slightly acidic) is strongly associated across the areas. The remaining indices, such as Sand (0.6664), Organic matter (0.74584), P_2O_5 (0.70322), Clay (0.58887), K_2O (0.52378), and Silt (-0.65405), show average positive/negative loading coefficients.

3.4. Discussion

The hot, dry season in southern Khanh Hoa, with its monsoon climate, is a crucial ecological condition for drought-tolerant plants such as *T. terrestris*. This plant adapts to this season, flowering and fruiting after the dry season transitions to the rainy season, and regenerating during the humid season (September to November), then regenerating again when the dry season arrives with increased rainfall, creating a characteristic seasonal growth cycle for this species.

The physicochemical properties of the soil are determined by its main component being sand and severe nutrient deficiency. Sandy soils have poor water retention and drain quickly, making them susceptible to drought. The morphological characteristics of *T. terrestris*, such as its creeping growth habit and thick hairy stem, allow for efficient water utilization (Gibson, 1996), which is part of the plant's adaptation to minimize water loss. A pH range from neutral to strongly alkaline is ideal for the growth of *T. terrestris* and may indicate tolerance and therefore preference for alkaline soil conditions. The salt content of the soil is a common factor mentioned in soil studies in coastal areas. However, the organic

matter, total N and P_2O_5, and readily available K_2O content in My Tan and Do Vinh were higher than in Thai An. This suggests that the high readily available K_2O content in My Tan and Do Vinh may be beneficial in water-intensive environments, as potassium is active and helps regulate water absorption and acidity (Marschner, 2012).

Principal component analysis (PCA) provides information on the various environmental influences on the *T. terrestris* species. Each study area showed differences in principal components when PCA analysis was performed according to Jolliffe (2002) and Hair et al. (2010). In Thai An Hamlet, a positive correlation with silt and K_2O was shown, although the correlation was less positive than with clay, organic matter, and readily available nitrogen. Therefore, soil mineral content and water retention capacity are very important. In addition, EC showed a moderately positive correlation, indicating the salt tolerance characteristics of the *T. terrestris* species. On the other hand, principal component analysis (PCA) in My Tan Hamlet showed a strong positive relationship with clay and K_2O content, and a negative correlation with pHH_2O and sand, suggesting that higher but not significantly higher clay content, but more potassium, is suitable for creating a more balanced soil texture in this analysis (Brady & Weil, 2016). Do Vinh showed a very prominent pattern and high positive loading coefficients for pHH_2O, pHKCl, EC, and available nitrogen, along with excellent negative loading coefficients of P_2O_5/K_2O. Clearly, if the *T. terrestris* population had better tolerance to alkaline and saline conditions, with little or no nitrogen, they could thrive. The inverse relationship between phosphorus and potassium may suggest that either they are not limiting factors, or they are absorbed in a way that gives the plant a chance to grow and retain them at lower temperatures rather than very high temperatures (Mathur, 2014). Principal component analysis common to all three regions provided a more comprehensive view of the environmental factors influencing the distribution of the *T. terrestris* species. Particularly high positive values for EC and available N were observed in this region, which are key environmental factors representing salinity tolerance and available N supply. Negative values for Sand, Organic Matter (OM), P_2O_5, Clay, K_2O, and pHH_2O were also relatively low. The dominant positive value of PC1 with 62.311% variance suggests that these factors represent the highest ecological gradients influencing the differential distribution of *T. terrestris*. The positive correlation of available nitrogent (over 99%) as a growth factor and the negative correlation of pH and silt as limiting factors among the PCA measurements also provide significant statistical support for the information we obtained about the physicochemical properties of the soil.

4. Conclussion

The species *T. terrestris* in Khanh Hoa Province has the ability to grow and adapt well to humid tropical monsoon climate conditions, with prolonged dry weather and high temperatures. It thrives in sandy to slightly clayey soils with pH values ranging from neutral to alkaline. The PCA analysis of the primary environmental components reveals interactions

among different soil factors across locations. While the plant exhibits good salt tolerance and nitrogen balance, factors such as soil pH, clay content, silt, and phosphorus vary significantly across locations. These findings provide crucial support for conservation efforts focusing on habitat protection and the potential for ecological restoration of the wild *T. terrestris* population in the coastal areas of South Central Vietnam.

- ***Conflict of Interest:*** *Authors have no conflict of interest to declare.*
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PHÂN TÍCH THÀNH PHẦN CHÍNH CÁC YẾU TỐ MÔI TRƯỜNG ẢNH HƯỞNG ĐẾN SỰ PHÂN BỐ CỦA GAI MA VƯƠNG (*Tribulus terrestris* L.) Ở KHU VỰC PHÍA NAM TỈNH KHÁNH HÒA

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TÓM TẮT

Nghiên cứu này khảo sát hiện trạng phân bố sinh thái của loài cây Gai ma vương (Tribulus terrestris L.) được ghi trong Sách Đỏ Việt Nam (EN), thường mọc hoang ở các vùng ven biển tỉnh Khánh Hòa. Nghiên cứu này tập trung phân tích đặc điểm khí hậu và thành phần chính của yếu tố lí hóa của đất lấy mẫu từ xã Thái An, xã Mỹ Tân và phường Đô Vinh ảnh hưởng đến sự phân bố của loài Gai ma vương trong tự nhiên. Kết quả phân tích cho thấy khu vực nghiên cứu có môi trường nóng và khí hậu rất khô, cùng với nhiệt độ và độ ẩm theo mùa rất cao. Chỉ số lí hóa của đất chủ yếu là đất cát với tỉ lệ cao, nhưng cũng có độ pH thấp (7.45 – 8.77) và nồng độ chất dinh dưỡng thấp. Phân tích thành phần chính (PCA) cũng cho thấy có sự khác biệt về các yếu tố môi trường tại các địa điểm nghiên cứu này. Cụ thể, có tương quan thuận giữa hàm lượng sét ở Thái An và K_2O, và tương quan nghịch giữa hàm lượng sét và các chất hữu cơ. Tại Mỹ Tân, mối quan hệ tích cực giữa đất sét và K_2O còn mạnh hơn, và mối tương quan tích cực giữa pH, EC và cát còn mạnh hơn nữa ở những vùng đất có nhiều đất sét. Tại Đỗ Vinh, chúng ta có mối tương quan tích cực rất tốt giữa pH, EC và N dễ hấp thụ, nhưng lại có mối tương quan kém giữa P_2O_5 và K_2O ở tầng đất có nồng độ cao hơn. EC và N dễ hấp thụ có mối tương quan rất tốt, nhưng pH và hàm lượng chất dinh dưỡng chỉ có tương quan dương.

Từ khóa: Gai ma vương; đặc điểm sinh thái; hóa - lí đất; phân tích thành phần chính