GROWTH VARIABLES AND BRANCH TRAITS OF *DENDROCALAMUS MINOR* VAR. *AMOENUS* STAND AT DIFFERING DISTANCES FROM THE COASTLINE

ZHENG, J. M.[1*] – ZHANG, L. T.[2] – DENG, C. Y.[3*]

[1]*College of Civil Engineering, Putian University, Putian 351100, P. R. China*

[2]*Fujian Key Laboratory of Island Monitoring and Ecological Development (Island Research Center, MNR), Pingtan 350400, P. R. China*

[3]*College of Landscape Architecture, Fujian Agriculture and Forestry University, Fuzhou 350002, P. R. China*

[*]*Corresponding author*
e-mail: zjm1991@foxmail.com

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Abstract. Growth variables and branch traits play a key role in assessing plant growth and to harsh environmental conditions. This study aimed to reveal the response of *Dendrocalamus minor* var. *amoenus* (*D. minor* var. *amoenus*) stands at differing distances from the coastline. Four sites with various distances were selected, and the growth variables and branch traits of *D. minor* var. *amoenus* were determined in Dongshan Island, China. The results showed that the coastal distances would affect the height, density, Leaf area index (LAI), and branch length of *D. minor* var. *amoenus.* The *D. minor* var. *amoenus* have strong phenotypic plasticity to adapt the harsh coastal environment by reducing its height and increasing its leaf area index.
Keywords: *stand structure, gradient to the coastal line, sand, phenotypic plasticity, bamboo, branch traits*

Introduction

Plants of sandy coast survived in harsh environmental conditions (salt spray, wind stress, sand burial) (Griffiths and Orians, 2004). The wind stress and salt spray on the coast have a great influence on the growth and phenotypic characteristics of plants (Watt et al., 2005; McArthur et al., 2010), such as causing plant dwarf, partial crown, etc. (Zhang et al., 2011; Telewski, 2012). Adaptation to coastal habitats is difficult for most species, except for *Casuarina equisetifolia* and *Pinus thunbergii*, which are pioneer species. There are several studies suggesting that bamboo species exhibits high adaptation to sandy coast (Zheng et al., 2021, 2022; Zheng and Zheng, 2022). Bamboo plants can improve the soil quality of sandy soil (Tu et al., 2014; Zheng et al., 2020). Besides, bamboo species have attractive features and highly ornamental values for people's preferences (Zheng et al., 2021, 2022). Therefore, bamboo species were widely introduced to the sandy coast as the dominant species in Fujian Province, China.

The growth variables and branch traits play a key role in assessing plant growth and adaptation to harsh environments. The heterogeneous habitat will have a significant impact on the functional traits and population regeneration of bamboo plants (Wang et al., 2006). Previous studies suggested that plants near the coastline are shorter (Todo et al., 2019). There is strong phenotypic plasticity in bamboo species (Shi et al., 2014). Bamboo species adapt to the understory environment by adjusting their phenotype and light use efficiency (Montti et al., 2014). *Fargesia qinlingensis* adjusts its branch angles

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in mixed forests to improve its ability to capture light resource (Wang et al., 2006). Previous literature reported the leaf traits and diversity of bamboo species would be influenced by the distance to the coastline (Zheng et al., 2022; Zheng and Zheng, 2022). The growth variables of bamboo species were highly related to litter production (Bahru and Ding, 2020). However, the growth variables of bamboo species on the sandy coast have not been reported. To address all these concerns, the present study aimed to reveal the growth variables and branch traits of *Dendrocalamus minor* var. *amoenus* (*D. minor* var. *amoenus*) adapted to the coastal sand environment.

Materials and methods

Study area and study design

The study area is located at 23°41.2′N, 117°25.2′E in Dongshan Island, Fujian Province, China (*Fig. 1*). It has a subtropical maritime monsoon climate with obvious dry and wet seasons. The average annual wind speed was 7.1 m/s, and the average annual temperature was 20.8 ℃ (Kong, 1999). Typhoons usually occurred from July to August on Dongshan Island. The windbreak has some patches dominated by *D. minor* var. *amoenus* mixed with *Casuarina equisetifolia* as species on the sandy coast. The sampling and investigation were conducted from August to October 2022.

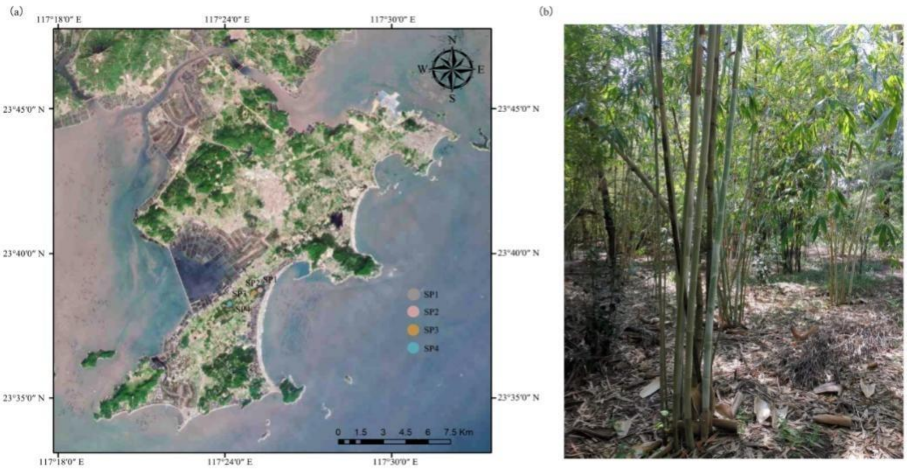

Figure 1. *The location of the study area and distribution of sample plots(a), and the situation of sample plots(b)*

We employed the quadrat method to sample four sample sites at differing distances from the coastline (see *Fig. 1*). Three subplots of 20 m × 20 m were randomly selected at each sample plot. The elevation, slope, and distance to the seashore of sample plots were measured by GPS and Google Earth software (see *Table 1*).

Table 1. *The situation of sample plots*

No	Elevation/m	Slope/°	Distance to seashore/m	Sampling position
SP1	0~10	3~10	100	117°25′13.00″E, 23°38′53.2″N
SP2	3~11	4~8	200	117°25′8.75″E, 23°38′53.16″N
SP3	2~12	5~7	400	117°25′00.13″E, 23°38′52.77″N
SP4	1~11	3~12	800	117°25′00.13″E, 23°38′52.77″N

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Growth variables and branch traits measurements

Three subplots of 20 m × 20 m were randomly selected at each sample plot. Among them, we selected 3-5 branches in each cluster and 5-10 clusters for each subplot. The branch traits of 15 branches at least in each subplot were measured. The growth variables of 15 individual plants at least in each subplot were determined.

The growth variables including diameter at breast height (DBH, cm), height (m), density (ramet·cluster^{-1}), crown area (m^2), and clear bole height (CDH, m) were measured. The DBH and CDH were measured by a girth ruler. The height and crown area were determined by a Leica Laser Rangefinder D81 (LeicaDISTO D5, Switzerland). The leaf area index (LAI) was recorded by LAI-2200c (LI-COR Ltd., America). The calculation formula of CWR (ratio of north-south crown width to west-east crown width) was determined as described by Lin et al. (2017). The branch traits including the branch length (cm), branch angle (°), and branch diameter (mm) were determined as described by Zheng et al. (2021).

Data analysis

The difference in growth variables and branch traits among the sample plots were analyzed for One-way ANOVA and Tukey HSD, which was performed on R 3.6.1. All values presented in the research are means ± SD (standard deviation).

Results

The distribution density of growth variables

The distribution density of DBH, LAI, density, and height was shown in *Fig. 2*. The DBH of SP3 is mainly distributed in 3~3.2 cm (distribution density>1.0, see *Fig. 2*). The LAI of SP2 fluctuates greatly, showing multiple peaks. The density of SP2 and SP3 is relatively small, while the density of SP1 and SP4 is relatively large. The height of SP1 is mainly concentrated between 7.0~8.0 m.

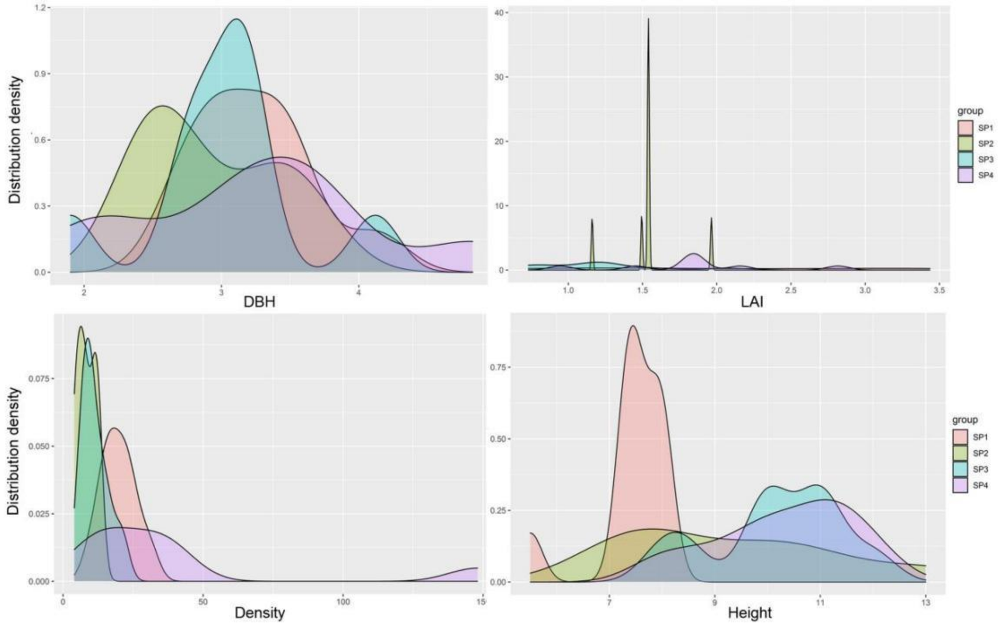

Figure 2. *The distribution density of different characteristics*

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Growth variables

The height of plants near the coast in SP1 are significantly shorter than the height of plants in SP2, SP3, and SP4 (*P*<0.05, see *Fig. 3*). There are no significant differences in height among the SP2, SP3, and SP4 (*P*>0.05). There were no significant differences in DBH, CDH, and CWR among the sample plots.

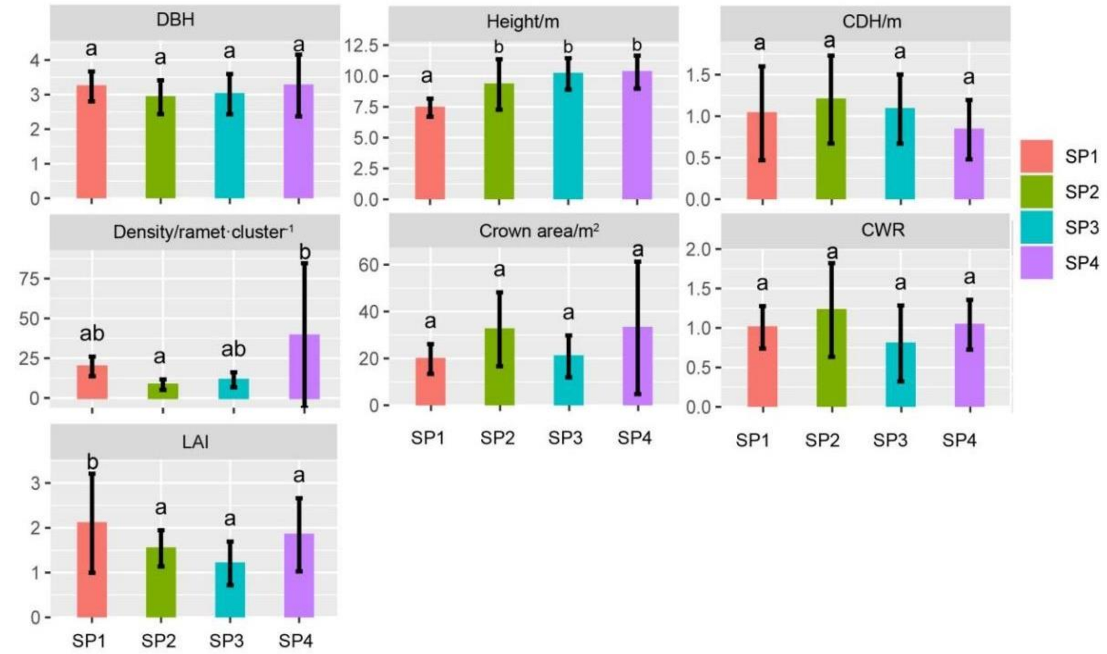

Figure 3. *Growth variables of different sample plots. *DBH: diameter at breast height; CDH: clear bole height; LAI: leaf area index; CWR: ratio of north-south crown width to west-east crown width; Different letters indicate significant differences (P<0.05)*

Branch traits

There was no significant difference in branch angle and branch diameter among the sample plots (*Fig. 4*). The branch lengths of SP3 and SP4 are significantly different (*P*<0.05).

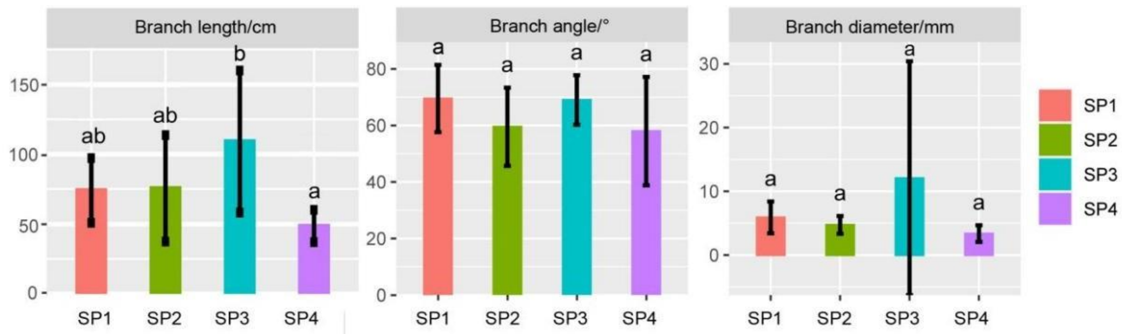

Figure 4. *Branch traits of different sample plots. *Different letters indicate significant differences (P<0.05)*

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Correlation of growth variables and branch traits

There is a significant positive correlation between density and crown area (*r*=0.65, *P*<0.05, *Fig. 5*). Density and DBH are significantly positively correlated (*r*=0.48, *P*<0.05), crown area and DBH are significantly positively correlated (*r*=0.44, *P*<0.05). The branch angle is negatively correlated with the height (*r*=-0.38, *P*<0.05), and the branch diameter is positively correlated with the branch length (*r*=0.38, *P*<0.05).

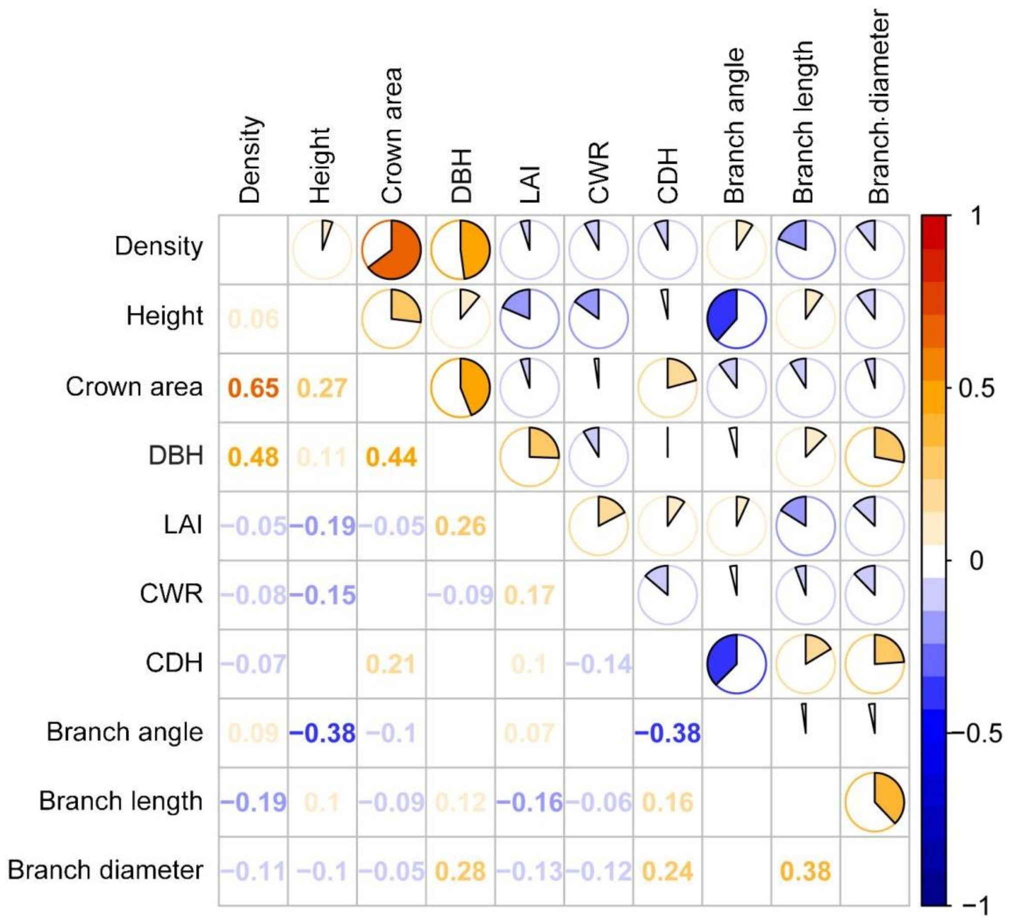

Figure 5. *The Pearson correlation coefficients between growth variables and branch traits. *The font color depth indicates the degree of correlation coefficients, where red indicates a positive correlation, and blue indicates a negative correlation. DBH: diameter at breast height; CDH: clear bole height; LAI: leaf area index; CWR: ratio of north-south crown width to west-east crown width*

The DBH has a positive linear correlation with the crown area and height (*Fig. 6*). There is a well-explained relationship between density with the crown area and DBH (see *Fig. 6a,b*). The slope in the regression equation of DBH and crown area (k=12.3, *Fig. 6c*) is greater than that of DBH and height (k=0.331, *Fig. 6d*), which suggested that the crown area increased more than height as the DBH increased.

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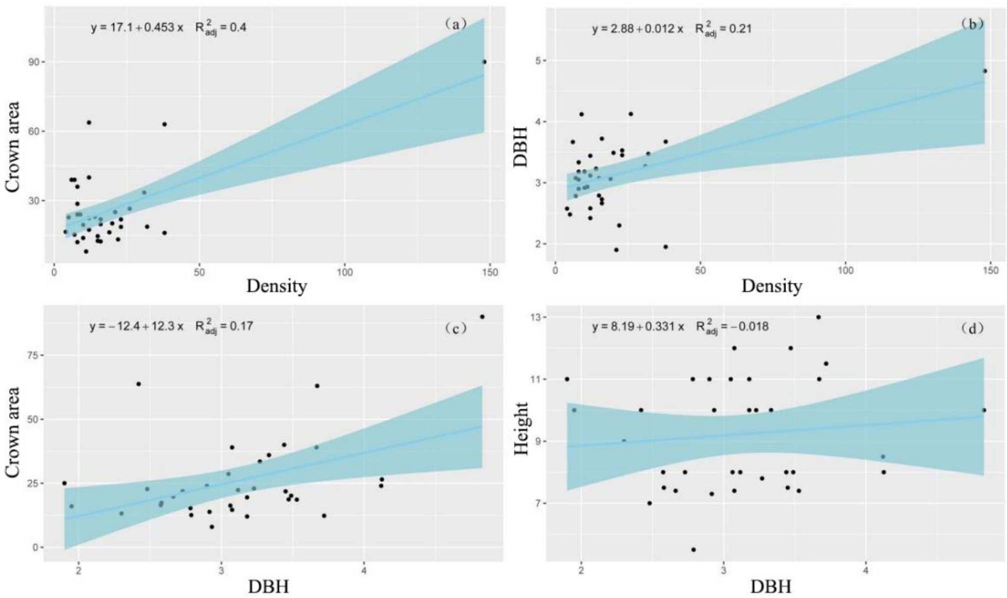

Figure 6. *Fitting equation of growth variables. *The blue area represents the 95% confidence interval. DBH: diameter at breast height*

Discussion

Density is the result of plants responding to the selection pressure of the natural environment (Japhet et al., 2009). The density of forest stands was regulated by environmental resources, which is highly related to individual resource allocation (Maherali and Delucia, 2001). The ability of individual plants to intercept light resources is strengthened as the density increases, thereby increasing the efficiency of resource utilization. High density would affect the individual plant's acquisition of light resources, and it would cause the branches to self-evacuate, and the crown area tends to be sparse (Lin, 2018). The crown area among four sample plots was not significantly different (P=0.23>0.05), indicating that the intraspecific competition and niche overlap of *D. minor* var. *amoenus* was weak, which suggested the growth stage of *D. minor* var. *amoenus* is growing. The population density of *Pinus thunbergii* increases with the distance from the shore (Han et al., 2008). As the distance from the shore increased, the density of SP4 increased significantly more than that of SP2 (P<0.05). But the density of SP2 did not differ significantly from the density of SP1 and SP3. Therefore, the driving factor in the formation of the difference is not the distance. The electrical conductivity and soil organic matter may be driving factors of distances from seashore (Zheng and Zheng, 2022). Previous studies indicated stand density may be related to the content of phosphorus in the soil (Larpkern et al., 2009). Higher densities have a stronger advantage in resisting coastal stress (Wu et al., 2018). Therefore, bamboo species in SP4 have a higher survival advantage relative to that in SP2.

Height is considered an important indicator of plant adaptation to the environment (Yang et al., 2015). The height of bamboo species in SP1 is significantly shorter than that of SP2, SP3, and SP4 (P<0.05). The result in this research is consistent with previous research results that the height of *Casuarina equisetifolia*, *Pinus thunbergii*, and *Salix matsudana* gradually decreases with the distance from the shore (Lin et al., 2017; Pajunen, 2018; Todo et al., 2019). The splash of waves and salt spray would affect the

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physiological activities of the plants, and the height of plants became shorter (Griffiths and Orians, 2004). Salt spray is compounded by high wind speed near the coast (Lin et al., 2017), and persistent wind blowing causes damage to plant physiological, biochemical, and functional traits, resulting in a tendency for plants to dwarf (Martin and Ogden, 2006; McArthur et al., 2010).

The effect of wind speed on plants depends on the wind speed and plant species (Niklas, 1998). Blowing wind would cause variations in the branch angles of plants and result in a partial crown (Lin et al., 2017). The present study is not consistent with the previous study, there is no significant difference in the partial crown, branch angle, and branch diameter of *Dendrocalamus minor* var. *amoenus* among different offshore distances. On the one hand, the majority of the wind is shredded by *Casuarina equisetifolia* in higher layers, and *Dendrocalamus minor* var. *amoenus* grows in the understory and suffered lower wind stress. Lower wind speed has less effect on mechanizing woody plants with a high degree of lignification (Vogel, 2009). In contrast to *Pinus thunbergii*and *Casuarina equisetifolia*, *Dendrocalamus minor* var. *amoenus* is a flexible plant, and is highly wind adaptable with long fibers, and a higher maximum bending moment. *D. minor* var. *amoenus* has high phenotypic plasticity and adapts to the growing stress of different environments by adjusting its growth variables and branch traits.

Conclusion

The coastal distances would affect the height, density, LAI, and branch length of *D. minor* var. *amoenus.* The results showed that there were no significant differences in the diameter at breast height (DBH), crown area, clear bole height (CDH), partial crown, branch angle, and branch diameter at differing distances from the coastline. The *D. minor* var. *amoenus* have strong phenotypic plasticity by to adapt the harsh coastal environment by reducing its height and increasing its leaf area index. The limitation of this research is that we have not determined the environmental factors. Future works would focus on the allometric allocation of functional traits of bamboo species on the sandy coast. This study would provide recommendations for *D. minor* var. *amoenus* stand on sandy coast.

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