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Flowering, Physiological and Biochemical Responses of Heliconia Genotypes Under Shade House Conditions

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Abstract

The present research work was carried out at the College of Horticulture, Anantharajupeta during 2018-19. The experiment was laid out in Randomized Block Design, with three replications and with 8 genotypes. The treated rhizomes were planted under 50 per cent shadehouse condition. All the flowering, physiological attributes and anthocyanin content varied significantly among multiple heliconia genotypes grown under shadehouse conditions. Among multiple genotypes, inflorescence length (26.18 cm), number of spikes clump^{-1} (4.50), number of bracts spike^{-1} (9.56) stomatal conductance (0.38 mol m^{-2} s^{-1}), rate of photosynthesis (9.23 µmol m^{-2} s^{-1}), transpiration rate (4.17 mmol m^{-2} s^{-1}) and anthocyanin content in flowers (3.64 mg 100 g^{-1} tissue) recorded highest in genotype G_6. However significantly longest stalk (61.25 cm), maximum bract size (25.38 cm^2) were recorded in G_2 and G_1, respectively. While more leaf intercellular CO_2 (317.38 µmol m^{-2} s^{-1}) was recorded in genotype G3.

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Introduction

Heliconia, is a rhizomatous, herbaceous perennial plant and commonly known as 'Lobster-claws', 'Wild plantains' or 'False bird of paradise'. *Heliconia* (*Heliconia* spp.) belongs to family *Heliconia*ceae and is amongst the most attractive of all the exotic tropical flowering plants, comprises of single genus, with about 250-300 species.[2] *Heliconia*s are native

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to Central and South America, the Caribbean Islands and some of the islands of South Pacific, possessing chromosome number 2n(4x)=24.[2] It is distributed primarily from the North of Mexico to the South of Brazil.[3] Some species of *Heliconia* are utilized as ornamental plants, usually being grown both as landscaping plant and as cut flowers owing to its colour and longer durability of its floral bracts. Wide variation in vegetative growth, size, shape and arrangement of bracts have been reported by different authors.[1] Due to its unusual inflorescence, *Heliconia* is categorized as 'Specialty Flower'.[2] Colourful bracts protect the small flowers and form the inflorescence, which is used as cut flowers and landscaping featured plants. *Heliconia* is mostly grown for beautifying the garden, presently growing as cut flower because of its brilliant color, exotic form, long, straight peduncles and excellent postharvest characteristics, tolerance to biotic and abiotic stresses and reasonable prices. These all features made it an outstanding flower for the florist. It likes warm and humid conditions and can grow well even under partial shade.[3]

Now a days, research in the field of crop improvement leads to the introduction of different varieties having different forms and colors by both government and private institutions. According to flowering habit, they are grouped in different groups *viz.,* erect growing ones and pendant or hanging type. So, there is a need to evaluate hybrids and varieties in any particular agro-climatic region. Several reports of good performance of modern cut flowers are available from the location.[4] To meet the growing demand for cut flowers in the fast-growing areas of Rayalaseema region of Andhra Pradesh, introduction and popularization of modern flowers are necessary. At present, the farmers are not aware of the improved varieties and are still growing only local varieties which are not only less attractive in their shape, size and colour, but also exhibit very low productivity. In *Heliconia*, sufficient number of varieties or genotypes are under cultivation but their performance varies from place to place.[10] The quality of cut flower is primarily a varietal trait and is generally influenced by climatic conditions prevailed during the growing period at a particular place. It is very essential to study the performance of varieties in a particular place before recommending to the farmers. Though the crop has great significance in the market, there are some bottlenecks associated in its cultivation. Non availability of planting material, lack of improved varieties, high market fluctuations are some of the other problems which are often faced by the farmers. The results obtained from this study would be a base to develop a strong breeding program for *Heliconia*s and to identify the best genotypes suitable for the region. Keeping the above in view, an investigation was planned and carried out.

Material and Methods

The present investigation was carried out during the year 2018-2019 at College of Horticulture, Dr. Yeduguri Sandhinti Rajasekhara Reddy Y.S.R Horticultural University, Anantharajupeta, Y.S.R Kadapa District of Andhra Pradesh, India. The trial was planned with seven genotypes collected from Horticultural Research Station, Pandirimamidi, East Godavari District (Dr. Y.S.R Horticultural University, Andhra Pradesh) and one genotype was collected from a local farmer at Dumpalagattu (village), Khazipet (mandal), Y.S.R Kadapa Dist. Andhra Pradesh. The experiment was laid out in Randomized Block Design, with three replications and with 8 genotypes *viz.,* G_1- *Heliconia* cv. Golden Torch, G2- *Heliconia psittacorum rubra,* G_3- *Heliconia densiflora*, G_4- *Heliconia* cv. Orange By Gyro, G_5 - *Heliconia* cv. Alan Carle, G_6 - *Heliconia rostrata*, G_7 - *Heliconia* cv. Eden Pink and G_8 - Local check.

Ploughing and digging of the land were done and brought to fine tilth. The plots were prepared under shade house condition with 50 per cent shade. All the stubbles of previous crop and weeds were removed from the field and burnt. The required numbers of plots (24) were prepared of size (4.00 m x 3.20 m). The soil of experimental block was red loamy with pH 7.40 and E.C. 0.27 dSm^1. Rhizomes were treated with ridomil MZ 1.5 g + dimethoate 2 ml + dhanuvit 0.5 ml $litre^{-1}$ water before sowing. The healthy rhizomes were planted into the pits at a depth of 10-15 cm, at a spacing of 1.00 m x 0.80 m during first week of June, 2018. Rhizome planting was done in the morning hours and light irrigation was given immediately after planting. Organic manure in the form of well rotten farm yard manure was applied @ 1.5-2.0 kg per planting pit prior to rhizome sowing and mixed well. Nitrogen 20g $plant^{-1}$, phosphorus 20g $plant^{-1}$ and potassium 20g $plant^{-1}$ were applied monthly prior to blooming. After the commencement of flowering, each clump is applied with nitrogen 10g plant^{-1}, phosphorus 10g plant^{-1} and potassium 20g plant^{-1} at monthly intervals. *Heliconia* genotypes were foliar fed with potassium nitrate (13:0:45) @ 7 g l^{-1} at 6, 8 and 10 months after rhizome sowing. Depending upon the weather, soil and crop growth condition, watering was given to *Heliconia* genotypes through drip irrigation at weekly thrice. Necessary plant protection measures were followed to prevent insect pest incidence. Five plants were selected in each plot at random, tagged and labeled properly for recording observations. The experiment was carried out for the period from June, 2018 to May, 2019. The data recorded on various parameters were statistically analysed by the procedure outlined by.[5]

Results and Discussion

Inflorescence Length (cm)

Data presented in Table 2 revealed that the performance of *Heliconia* genotypes for inflorescence length varied significantly among the genotypes studied. Among the genotypes tried for the inflorescence length, the genotype G_6 exhibited longest inflorescence (26.18 cm) which was followed by G_5 (19.69 cm) and this was on par with G_7 (17.92 cm), G_1 (17.07 cm). While the genotypes G_3, G_4 and G_8 did not produce spikes. The inflorescence length is an important character of display value. Plant height is an important character as it contributes towards better spike length with more number of florets and thereby enhances spike quality. The variation with respect to the above trait among genotypes may be due to genetic traits and the effect of prevailing environmental conditions under shadehouse (Table 1). The varied length was obtained in the present study as the nature of inflorescence is different from species to species and a variation of erect or pendent, composed of bracts in one plane or spirally arranged was noticed. The findings obtained in the study are similar to the findings by[6] and 7 in *Heliconia*. The tall *Heliconia* genotype *Heliconia rostrata* (Table 2) are capable of producing blooms with longer inflorescence. *Heliconia* spikes with more number of bracts also have longer inflorescence.[8] The pendent genotypes of *Heliconia* tend to produce longer inflorescence as reported earlier in *Heliconia*.[9] In earlier results (data is not presented), plant height at multiple growth stages recorded was maximum in genotype G_6 which might have also resulted in having longer inflorescence.

Number of Spikes Clump^{-1}

The data presented in Table 2 exhibits significant variation pertaining to the number of spikes clump^{-1} among the genotypes evaluated. The genotype G_6 had higher number of spikes clump^{-1} (4.50) which was found significantly superior compared to remaining genotypes which was followed by G_7 (2.64) which was statistically on par with the genotype G_5 (2.50), G_1 (2.42) and G_2 (2.00). While the genotypes G_3, G_4 and G_8 did not produce spikes. The above findings are in agreement with the reports in *Heliconia*.[8] A vigorous plant with increased number of green leaf containing high amount of chlorophyll is likely to increase the assimilation of carbohydrates. This improves the source-sink relationship with greater portioning coefficient which might increase the number of flowers plant^{-1} year^{-1}. Carbohydrate is also a constituent part of nucleoprotein and sugar-phosphate (ATP and ADP). Thus, it appears that increased plant metabolites might have produced more inflorescences in *Heliconia*.[10] The increased flower yield might be attributed to the greater leaf area, the number of sucker's plant^{-1}, more number of leaves plant^{-1} as well as leaf chlorophyll content and these would have resulted in production and accumulation of maximum photosynthates which ultimately results in production of more number of spikes with bigger sized flowers. . A number of suckers results in more production of leaves, the size of the leaf and number of leaves plant^{-1} decides the efficiency of photosynthesis activity which contributed towards better growth and yield.[11] The variation in yield characters might also be due to genetic nature of the cultivar and also the effect of agro-climatic conditions. The varietal differences for yield potential may also be attributed to additive gene effect.

Length of the Stalk (cm)

A perusal of data embodied in Table 2 revealed that the genotypes differed significantly with respect to stalk length. The longest stalk of 61. 25 cm was registered in G_2 which was found significantly superior to rest of the genotypes, it was followed by the genotype G_1 (45.30 cm) and this was on par with G_5 (43.65 cm), G_7 (38.99 cm) and G_6 (38.03 cm). The variation in stalk length in different cultivars might be due to variation in their intrinsic factor. Varied length was obtained in the present study as the nature of inflorescence is different from species to species and a variation of erect or pendent, composed of bracts in one plane or spirally arranged was noticed. Flower stalk length is very important quality trait which decides the quality of *Heliconia* cut flowers and also plays an important role in the vase life by extending their postharvest life.[12] The length of the flower spike is an important attribute for selection since it is used for floral decoration.[13] The stalk length is a genetic factor therefore; it is expected to vary among the cultivars as earlier observed by.[14] These results are related to the findings for some *Heliconia* species, since the stems had greater lengths at high shading levels, probably due to etiolation, which is a plant elongation due to the limited light.[15] Hence in the same corollary, the genotype G_2 had longer stalk due to the congenial environmental conditions prevail and by receiving 40 - 50 per cent shade under shade house conditions during the period of investigation (Table 1).

Table 1: Monthly mean temperature (^{0}C), relative humidity (%) and light intensity (lux) during the investigation period

Month	Temperature (°C) (9 am)		Relative Humidity (%) (9 am)		Light Intensity (Lux) (12 Noon)	Temperature (°C) (4 pm)		Relative Humidity (%) (4 pm)		Rainfall (mm)
	Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.	
June, 2018	35.24	26.42	72.32	40.25	34951	36.23	28.42	56.42	34.84	54.20
July, 2018	34.38	25.87	70.70	41.41	32953	36.47	28.05	57.00	36.67	46.00
August, 2018	33.85	24.01	72.06	42.29	28685	35.75	26.18	49.06	29.29	211.10
September, 2018	34.36	20.47	71.76	42.10	29586	34.73	22.47	49.76	28.10	728.60
October, 2018	32.71	20.58	73.70	43.22	28632	34.71	22.58	47.70	31.22	164.10
November, 2018	30.61	18.85	73.40	46.83	27921	32.61	20.85	53.40	34.83	1869.30
December, 2018	28.29	17.99	78.64	47.12	26235	30.29	22.99	52.64	35.12	584.20
January, 2019	39.35	18.00	82.25	45.19	27258	31.35	23.45	50.25	37.19	638.00
February, 2019	33.03	18.42	73.88	34.35	30458	35.61	22.40	59.17	38.36	00.00
March, 2019	36.10	23.33	70.62	33.67	34487	38.22	23.70	48.62	27.54	00.00
April, 2019	37.87	24.50	69.65	32.84	37012	38.92	26.50	52.65	34.65	690.20
May, 2019	39.50	25.68	69.10	30.45	39032	39.50	27.41	49.10	32.87	00.00

Number of Bracts Spike^{-1}

The number of bracts spike^{-1} was significantly influenced by various genotypes investigated and the data was depicted in Table 2. Among the genotypes studied under the attribute number of bracts spike^{-1}, the genotype G_6 had more number of bracts spike^{-1} (9.56) which was followed by G_1 (4.13) and was found on par with G_5 (4.00), G_2 (4.00). The production of flowers plant^{-1} might be affected by the genetic variation of different cultivars. The variation in the number of bracts produced plant^{-1} might be due to its intrinsic factor and the results are in consonance with the findings in tuberose.[16] The variations in flowering parameters might be due to flowering cycle, probably related to the seasonality and genetic makeup of individual genotypes of *Heliconia*. Inflorescence with lesser number of open bracts at harvesting stage is preferred for their longer durability and ease in handling and packing in *Heliconia*.[9] In acute flower like *Heliconia*, the economic value depends on the attractive nature of inflorescence. The display value of *Heliconia* increases with increase in number of bracts spike^{-1}. The genotype with longer inflorescence in *Heliconia* has more number of bracts spike^{-1}.[8] The genotype *Heliconia rostrata* (G_6) had longer inflorescence (26.18 cm) (Table 2) and hence the result for having more bract count spike^{-1}.

Size of the Bract (cm^2)

The data in Table 2 indicated that the size of bract differed significantly due to the influence of multiple genotypes investigated. Significantly G_1 recorded the highest bract size (25.38 cm^2) which was on par with G_6 (22.72 cm^2) and this was on par with G_5 (20.24 cm^2) and G_7 (19.66 cm^2). Higher bract size contributes to greater attractiveness in *Heliconia* varieties. Robust *Heliconia* genotypes recorded highest bract size.[17] The varieties with more number of florets, bigger floret size and more number of florets open at a time are well suited for exhibition purpose. The variation might be attributed to differences in genetic constitution of genotypes. The present findings are in conformity with the earlier findings of[18] in gladiolus, in gerbera[19] and in snapdragon.[6]

Table 2: Flowering attributes of different Heliconia genotypes under shade house conditions

	Genotypes	Inflorescence length (cm)	Number of spikes $clump^{-1}$	Length of the stalk (cm)	Number of bracts $spike^{-1}$	Size of the bract (cm^2)
G_1	*Heliconia* cv. Golden Torch	17.07	45.30	2.42	4.13	25.38
G_2	*Heliconia psittacorum rubra*	11.95	61.25	2.00	4.00	15.07
G_3	*Heliconia densiflora*	0.00	0.00	0.00	0.00	0.00
G_4	*Heliconia cv.* Orange By Gyro	0.00	0.00	0.00	0.00	0.00
G_5	*Heliconia cv.* Alan Carle	19.69	43.65	2.50	4.00	20.24
G_6	*Heliconia rostrata*	26.18	38.03	4.50	9.56	22.72
G_7	*Heliconia cv.* Eden Pink	17.92	38.99	2.64	3.80	19.66
G_8	Local Check	0.00	0.00	0.00	0.00	0.00
	SEm ±	1.06	0.44	2.49	0.46	1.11
	CD (P= 0.05)	3.26	1.35	7.62	1.24	3.42

Leaf Intercellular CO_2 (µmol m^{-2} s^{-1})

The data corresponding to this trait is presented in Table 3 and a significant response was observed among the genotypes. The genotype G_3 recorded highest leaf intercellular CO_2 (317.38 µmol m^{-2} s^{-1}) which was on par with G_4 (315.55 µmol m^{-2} s^{-1}), G_6 (315.20 µmol m^{-2} s^{-1}), G_1 (312.20 µmol m^{-2} s^{-1}), G_7 (307.87 µmol m^{-2} s^{-1}) and G_8 (300.00 µmol m^{-2} s^{-1}). The above findings obtained might be due to congenial micro climatic conditions prevail under 50 per cent shade level for the *Heliconia* genotype. This statement finds support from 20 they reported that increase in shading increased the leaf intercellular CO_2. Among 2 ornamental passion flower hybrids studied,[21] recorded higher values for leaf intercellular CO_2 in Passiflora 'Aninha' (0.52 ± 0.29 mmol (H_2O) m^{-2} s^{-1}), Passiflora 'Priscilla' (0.74 ± 0.81 mmol (H_2O) m-2 s^{-1}) and in *Passiflora palmeri* var. sublanceolata (0.74 ± 0.01 mmol (H_2O) m^{-2} s^{-1}) among 13 ornamental passion flowers.[22]

Stomatal conductance (mol m^{-2} s^{-1})

Analysis of data with respect to stomatal conductance is furnished in Table 3. The above parameter shows significant response among 8 genotypes tried under shadehouse conditions. The genotype G_6 showed the maximum stomatal conductance (0.38 mol m^{-2} s_{-1}) which was on par with G_7 (0.21 mol m^{-2} s^{-1}). Higher stomatal conductance in G_6 genotype found during current study indicates that this may tend to diffuse more CO_2 to chloroplast and thus have greater photosynthetic activity and produce more biomass. Stomatal conductance is a numerical measure of the rate of passage of either water vapour or carbon dioxide through the stomata. Stomatal conductance plays an important role in the plant-atmosphere water exchange and, hence, it is a key parameter in many ecological models.[23] Increased stomatal conductance is an indicator of higher gas exchange capacity of the leaf.[24] These results are consistent with recent studies that suggest that a greater distribution of diffuse radiation photons improve leaf gas exchange in several protected crops.[20] Our results find support from [21] that they recorded maximum stomatal conductance in *Passiflora* 'Aninha' (0.32 ± 0.05 mol (H_2O) m^{-2} s^{-1}) and in *Passiflora* 'Priscilla' (0.35 ± 0.18 mol (H_2O) m^{-2} s^{-1}). Among 3 ornamental flowers, under 50 per cent shade net conditions,[22] found maximum stomatal conductance (0.30 ± 0.02 mol (H_2O) m^{-2} s^{-1}) in *Passiflora palmeri* var. sublanceolata. A Similar opinion was put forwarded by[25] in rhododendron cultivars.

Table 2: Flowering attributes of different Heliconia genotypes under shade house conditions

	Genotypes	Leaf intercellular CO_2 (μmol m^{-2} s^{-1})	Stomatal conductance (mol m^{-2} s^{-1})	Photosynthetic rate (μmol m^{-2} s^{-1})	Transpiration rate (mmol m^{-2} s^{-1})	Anthocyanin content (mg $100g^{-1}$ tissue)
G_1	*Heliconia* cv. Golden Torch	312.20	0.20	8.49	2.88	2.56
G_2	*Heliconia psitta-corum rubra*	266.50	0.12	2.00	0.55	2.64
G_3	*Heliconia densiflora*	317.38	0.04	0.81	0.45	0.00
G_4	*Heliconia cv.* Orange By Gyro	315.55	0.14	3.72	1.79	0.00
G_5	*Heliconia cv.* Alan Carle	275.32	0.19	7.15	2.43	1.77
G_6	*Heliconia rostrata*	315.2	0.38	9.23	4.17	3.64
G_7	*Heliconia cv.* Eden Pink	307.87	0.21	5.39	3.10	2.69
G_8	Local Check	300.00	0.18	4.26	2.69	0.00
	SEm ±	8.20	0.05	1.38	0.34	0.21
	CD (P= 0.05)	25.11	0.17	4.24	1.05	0.65

Rate of Photosynthesis (μmol m^{-2} s^{-1})

The data in Table 3 confirmed that the photosynthetic rate was significantly influenced by various genotypes evaluated. Significantly maximum photosynthetic rate of 9.23 μmol m^{-2} s^{-1} was recorded in G_6 which was on par with G_1 (8.49μmol m^{-2} s^{-1}), G_5 (7.15μmol m^{-2} s^{-1}) and G_7 (5.39μmol m^{-2} s^{-1}). A more number of suckers results in more production of leaves, the size of the leaf and number of leaves $plant^{-1}$ decides the efficiency of photosynthesis activity which contributed towards better growth and yield. In the present study, *Heliconia* plants under low light intensity (Table 1) were taller, indicating that plants under low light intensity may allocate more biomass to the shoot for the growth of leaves and for the full absorption of limited energy to meet the demand for plant photosynthesis.[26] The increased leaf area of *Heliconia* species under shade house condition indicates that plants increase their photosynthetic surface to contribute to a more efficient absorption of light radiation. Fifty per cent shade levels recorded higher plant height, number of leaves and petiole length. This phenomenon is consistent with our earlier results corresponding to biometric observations including leaf area. The superior performance level was because of higher leaf chlorophyll content and photosynthetic rate.[27] Under 50 per cent shade net conditions, among 3 ornamental flowers, higher photosynthetic rate (21.09 ± 0.60 m mol (CO_2) m^{-2} s^{-1}) was recorded in *Passiflora morifolia*.[22] The maintenance of photosynthesis in shaded plants compared with exposed trees indicated that use of screen structures in semiarid environments could help reduce plant water stress and increase water use efficiency.[28] The increase in diffuse light in greenhouses or tunnels has been noted in other studies, indicating that the polyethylene used promotes a greater transformation of direct light into diffuse light, which results beneficial for photosynthesis and productivity in horticultural crops.[20]

Transpiration Rate (mmol m^{-2} s^{-1})

A close sight of the data revealed that the genotypes demonstrated highly significant differences for transpiration rate and data are represented in Table 3. Transpiration rate recorded was highest in G_6 (4.17 mmol m^{-2} s^{-1}) which was followed by G_7 (3.10 mmol m^{-2} s^{-1}). In chrysanthemum[29] reported similar type of finding for rate of transpiration (4.95 mmol m^{-2} s^{-1}).[22] also recorded maximum transpiration rate in *Passiflora palmeri* var. *sublanceolata* (5.09 ± 0.20 mmol (H_2O) m^{-2} s^{-1}) among 3 types of ornamental passion flowers. Our results coincide and get support from the above author's findings. The rate of transpiration was found to be inversely proportional to shade level. Transpiration rate is directly dependent on temperature, light intensity, relative humidity and transmittance. Moderate shading levels resulted in reduced leaf temperature and leaf transpiration without reducing net photosynthesis. This reduced leaf transpiration was likely attributed to reduced evaporative demand and probably explains the increased soil water content and reduced plant water uptake under shaded conditions. The linear relationship between net photosynthesis and stomatal conductance suggests that stomatal control of photosynthesis was substantial under shade. The increased internal CO_2 concentration with increased shade level also suggests, however, that there were also non-stomatal factors such as mesophyll or biochemical factors, limiting net photosynthesis.[30]

Anthocyanin Content in Flowers (mg 10 g^{-1} tissue)

The data depicted for this attribute is made available in Table 3 and *Heliconia* genotypes differed significantly for the attribute tested. Among the genotypes studied, the genotype G_6 produced the highest anthocyanin content (3.64 mg 100 g^{-1}) which was followed by G_7 (2.69 mg 100 g^{-1}). The remaining genotypes *viz.,* G_3, G_4, and G_8 did not show anthocyanin content as they do not come for blooming during the period of study. The presence of anthocyanin and carotenoid pigments coloration have been demonstrated in the inflorescence bracts of other ornamental rhizomatic plants like *Heliconia*[31] and bird-of-paradise.[32] In addition,[33] reported that both anthocyanins and carotenoids significantly influenced the flower color in different cultivars of orchids that resulted in orange-red and red flowers. Our result showed that the increase in anthocyanin contents was affected the photosynthetic pigment accumulation in the bracts during early pigmentation. These observations indicate that photosynthetic pigments were synthesized in the first stage of inflorescence development before replaced by the different phenolic compounds. The observation is in agreement with the finding of[34] in poinsettia inflorescence bracts. Shading treatments were significantly affected the pigmentation patterns and inflorescence development of *Heliconia*. The results are corroborated with the findings in bougainvillea[35] and petunia.[36]

Conclusion

Finally, it may be concluded that *Heliconia rostrata* (G_6) was proved to be the best among the other *Heliconia* genotypes for enhanced flowering, physiological and biochemical parameters. Hence it may be suitable for commercial cultivation under shade house conditions in Rayalaseema region of Andhra Pradesh.

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