Vegetable Science (2018) 45(2) : 185-190

Selection parameters for yield and quality traits in Bhut Jolokia (*Capsicum chinense* Jacq.) under poly-house condition from North East India

Ephilo Mena[1], SD Warade[1], RK Dubey[2], Mohd Talha Ansari[1]*and Md. Ramjan[1]

Received: October 2018 / Accepted: January 2019

Abstract

Sixteen genotypes of Bhut Jolokia were evaluated in polyhouse with three replications at vegetable research farm, CHF, CAU, Pasighat, Arunachal Pradesh. Correlation and path analysis were carried out to study the character association and contribution, respectively. Correlation There was a great deal of significant variation for all the characters among the genotypes. In the present investigation, Correlation studies revealed that characters like weight of ripe fruit (0.966, 0.874), fruit length (0.622, 0.503), weight of dry fruit (0.905, 0.805), dry fruit yield per plant (0.903, 0.875) and capsaicin content (0.458, 0.393) was observed significant positive correlation with fruit yield per plant both at genotypic and phenotypic level. However, at genotypic level, weight of ripe fruit had maximum positive direct effect on fruit yield per plant (1.025) followed by dry fruit yield per plant (0.865), fruit length (0.236), ascorbic acid content (0.203). The findings of present study confirmed that, weight of ripe fruit, fruit length, weight of dry fruit, dry fruit yield per plant and capsaicin content were the important characters for selection and chilli breeding programme.

Key words: Bhut Jolokia, King chilli, correlation, path analysis, genotypic, polyhouse

Introduction

Bhut Jolokia or King chilli or Habanero chile (*Capsicum chinense* Jacq.) is a species of chilli that is native to Amazon basin. The Dutch botanist, Nikolaus Joseph von Jacquin, erroneously named the species as *chinense* in 1776 as he believed that the species originated in China. The species varies greatly in appearance and characteristics of plant growth, flowering, fruit morphology, taste and pungency, which makes very difficult to identify (Singh et al. 2012). Yield is a complex character controlled by large number of contributing characters and their interaction. It is not only influenced by a number of related characters which are governed by few numbers of genes, but is also influenced to a greater extent by environment. The study of correlation coefficients will helps in simultaneous selection for more than one character (Vidya et al. 2018). Chilli is an often cross pollinated crop with high natural cross pollination and this also contributes to its variability, the aim of any breeding program depends on genetic diversity, characters association and direct and indirect effects on yield and its component character (Pandiyaraj et al. 2017). A phenotypic correlation is usually estimated by the product moment correlation (simple correlation). The genotypic correlation in its true sense may be interpreted as the correlation of breeding values (additive genetic). Therefore, selection made for one trait influenced the other linkage or pleotropically affected traits. Correlation between yield and its components and their relative contribution to the yield have a great importance in planning effective breeding programmes and selection of hybrids and parents. Correlation provides information on relationship and does not give any idea about their direct and indirect contribution. Consequently, this information is sometimes misleading with respect to identification of yield components. Path coefficient analysis is one such method which partitions correlation into direct and indirect effects (Wright, 1921 and Dewey and Lu, 1959). Path coefficient analysis helps for sorting out the total correlations into direct and indirect effects and useful in selecting high yielding genotypes available (Yatung et al. 2014a). Correlation simply measures the association between yield and other traits, whereas path coefficient analysis permits the separation of correlation into direct effects and indirect effects (Shweta et al. 2018). Therefore, sixteen King chilli genotypes were collected from different parts of the country and an attempt was made to study interrelationships among important characters and their

[1]College of Horticulture and Forestry, Central Agricultural University, Pasighat-791102 Arunachal Pradesh

[2] ICAR-Indian Institute of Vegetable Research, Varanasi-221305, Uttar Pradesh

*Corresponding author, Email: ansari.talha0@gmail.com

direct and indirect effects on fruit yield by path coefficient analysis.

Materials and Methods

The experiment was carried out in poly-house complex at College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh during 2015-2016. The experiment was laid out with sixteen genotypes (Table1) in randomized completely block design (RCBD) with three replications with spacing (60 x 50 cm). Correlation and path analysis was studied for characters *viz.*, plant height (cm), number of branch per plant, days to 50% flowering, days to first picking, weight of ripe fruit (g), fruit length (cm), number of fruit per plant, fruit yield per plant (Kk), weight of dry fruit (g), dry fruit yield per plant (Kg), ascorbic acid content (mg/100g), capsaicin content (%) and pigment analysis.

Genotypic (v_g) and phenotypic (v_p) correlation coefficients were estimated according to the formulae given by Al-Jibouri et al. (1958). The significance of phenotypic and genotypic correlation coefficient was compared with table r values, as given by Fisher and Yates (1963) at n-2 degree of freedom where 'n' denotes number of genotypes. The path coefficient analysis was done to calculate direct and indirect contribution of different characters towards yield. The direct and indirect effects were calculated by solving the following set of simultaneous equations proposed by Dewey and Lu (1959).

Table 1: List of Chilli genotypes with their sources of collection

Genotype	Source
CHFKC-1	Along , Arunachal Pradesh (A.P)
CHFKC-2	Palin (A.P.)
CHFKC-3	Yazali (A.P.)
CHFKC-4	Kurungkumey (A.P.)
CHFKC-5	Mebo (A.P.)
CHFKC-6	Pasighat (A.P.)
CHFKC-7	Kiyit (A.P)
CHFKC-8	Imphal (Manipur)
CHFKC-9	Tseipama (Nagaland)
CHFKC-10	Daporijo (A.P)
CHFKC-11	Mariyang (A.P)
CHFKC-12	Pasighat (A.P)
CHFKC-13	Dimapur (Nagaland)
CHFKC-14	Mariyang (A.P)
CHFKC-15	Pasighat (A.P)
CHFKC-16	Along (A.P)

Results

Genotypic and phenotypic correlation: The phenotypic and genotypic correlation coefficients among different characters were worked out in all possible combinations (Table 2). The genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the characters; indicated strong association between the two characters genetically. Correlation studies revealed that characters like weight of ripe fruit (0.966, 0.874), fruit length (0.622, 0.503), weight of dry fruit (0.905, 0.805), dry fruit yield per plant (0.903, 0.875) and capsaicin content (0.458, 0.393) had significant positive correlation with fruit yield/plant both at genotypic and phenotypic level. However, negative association of fruit yield/plant was illustrious with plant height (-0.079, -0.111), number of branch/plant (-0.161, -0.315), ascorbic acid content (-0.255, -0.207), â-Carotene (-0.284, -.0233) and á-carotene (-0.272, -.0261) both at genotypic and phenotypic level, respectively.

Path coefficient analysis: Upon the assessment of apparent relationship between yield and yield components, it was felt necessary to partition the direct and indirect effects of each character on yield to understand the association more realistically (Table 3). At phenotypic level, path coefficient analysis showed that weight of ripe fruit had maximum direct positive effect on fruit yield per plant (0.716) followed by dry fruit yield per plant (0.511), days to first picking (0.314), number of fruits/plant (0.158), shelf life at ambient temperature (0.117), capsaicin content (0.115), â-carotene content (0.046) and ascorbic acid content (0.023). While, maximum negative direct effects on fruit yield/plant were recorded for days to 50% flowering (-0.287) followed by weight of dry fruit (-0.157), fruit length (-0.147), á-carotene content (-0.117), plant height (-0.051) and number of branch/plant (-0.027) (Table 3). At genotypic level, weight of ripe fruit had maximum positive direct effect on fruit yield/plant (1.025) followed by dry fruit yield/plant (0.865), fruit length (0.236), ascorbic acid content (0.203), á-carotene content (0.104) shelf life at ambient temperature (0.061) and days to first picking (0.048). However, maximum negative direct effect on fruit yield per plant were observed by weight of dry fruit (-1.012) followed by days to 50% flowering (-0.253), plant height (-0.171), number of fruit/plant (-0.159), number of branch/plant (-0.106), â-carotene content (-0.069) and capsaicin content (-0.0124) (Table 3).

At phenotypic level, the weight of dry fruit imposed high positive indirect effect on fruit yield per plant was recorded through weight of ripe fruit (0.630), followed by dry fruit yield/plant through weight of ripe fruit (0.517), weight of dry fruit through dry fruit yield/plant (0.440), fruit length through weight of ripe fruit (0.380), weight of ripe fruit through dry fruit yield/plant (0.369),

Table 2: Phenotypic and genotypic correlation coefficients among the yield and its contributing characters

Character	Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Plant height	P	1.000	0.055	-0.231	-0.216	-0.000	-0.007	-0.172	0.041	-0.017	0.188	0.210	-0.353*	-0.027	0.008	-0.111
	G	1.000	0.367*	-0.149	-0.099	-0.024	0.024	-0.214	0.073	0.044	0.496**	0.371**	-0.443**	-0.032	0.053	-0.079
Number of branch/plant	P		1.000	0.018	0.064	0.025	-0.341*	-0.144	-0.047	-0.097	-0.088	0.324*	-0.062	0.285*	0.198	-.031
	G		1.000	-0.385**	-0.229	0.077	-0.501**	-0.584**	-0.037	-0.2456	-0.479**	0.326*	-0.142	0.401**	0.301*	-0.161
Days to 50% flowering	P			1.000	0.945**	-0.019	0.250	-0.027	0.036	0.033	0.127	0.143	-0.026	-0.336*	-0.314*	0.014
	G			1.000	0.942**	0.005	0.359*	-0.372**	0.054	-0.098	-0.037	0.087	-0.082	-0.429**	-0.351*	-0.122
Days to first picking	P				1.000	0.083	0.376**	-0.008	0.090	0.081	0.025	0.090	0.000	-0.349*	-0.366*	0.114
	G				1.000	0.157	0.531**	-0.320*	0.143	0.008	-0.182	0.024	-0.052	-0.442**	-0.426**	0.032*
Weight of ripe fruit	P					1.000	0.531**	-0.299*	0.880**	0.722**	-0.280	-0.233	0.398**	-0.259	-0.229	0.874**
	G					1.000	0.564**	-0.542**	0.900**	0.818**	-0.279	-0.240	0.416**	-0.295*	-0.250	0.966**
Fruit length	P						1.000	-0.050	0.502**	0.470**	-0.106	-0.369**	0.341*	-0.596**	-0.597**	0.503**
	G						1.000	-0.060	0.517**	0.547**	-0.148	-0.471**	0.374**	-0.631**	-0.674**	0.622**
Number of fruit/plant	P							1.000	-0.266	0.219	0.002	0.002	-0.031	0.096	-0.078	0.133
	G							1.000	-0.506**	-0.264	0.060	-0.025	0.065	0.222	-0.067	-0.293*
Weight of dry fruit	P								1.000	0.8609**	-0.1561	-0.1980	0.2596	-0.3941*	-0.0261	0.8059**
	G								1.000	0.9694**	-0.1459	-0.2171	0.2621	-0.4290**	-0.0496	0.9055**
Dry fruit yield/plant	P									1.000	-0.138	-0.158	0.209	-0.334	-0.074	0.875**
	G									1.000	-0.142	-0.207	0.279*	-0.396**	-0.076	0.903**
Shelf life at ambient temperature	P										1.000	-0.048	-0.453**	-0.204	0.077	-0.221
	G										1.000	-0.204	-0.613**	-0.243	0.081	-0.286*
Ascorbic acid content	P											1.000	-0.303*	0.460**	0.142	-0.207
	G											1.000	-0.338*	0.521	0.181	-0.255
Capsaicin content	P												1.000	-0.101	-0.172	0.393**
	G												1.0000	-0.1081	-0.1922	0.4587**
β-Carotene	P													1.000	0.362*	-0.233
	G													1.000	0.373**	-0.284
α- Carotene	P														1.000	-0.261
	G														1.000	-0.272
Fruit yield/plant	P															1.000
	G															1.000

*= Significant @ 0.05 probability, **= significant @ 0.01 probability *P= Phenotypic, G=Genotypic

days to 50% flowering through days to first picking (0.297), capsaicin content through weight of ripe fruit (0.285), fruit length through dry fruit yield/plant (0.241), fruit length through days to first picking (0.118), number of fruit per plant through dry fruit yield/plant (0.112) and capsaicin content through dry fruit yield per plant was observed (0.107) (Table 3). However, negative indirect effect on fruit yield/plant were showed by days to first picking through days to 50% flowering (-0.271) followed by number of fruit/plant through weight of ripe fruit (-0.2143), shelf life at ambient temperature through weight of ripe fruit (-0.201), â-carotene content through weight of ripe fruit (-0.186), â-carotene content through dry fruit yield/plant (-0.1710), ascorbic acid content through weight of ripe fruit (-0.167), á-carotene content through weight of ripe fruit (-0.164), weight of ripe fruit through weight of dry fruit (-0.136), dry fruit yield/plant through weight of dry fruit (-0.135) and á-carotene content through days to first picking (-0.115) (Table 3). At genotypic level, weight of dry fruit imposed high positive indirect effect through weight of ripe fruit (0.923) followed by dry fruit yield/plant through weight of ripe fruit (0.839), weight of dry fruit through dry fruit yield/plant (0.838), weight of ripe fruit through dry fruit yield/plant (0.708), fruit length through weight of ripe fruit (0.578), number of fruit/plant through weight of dry fruit (0.531), fruit length through dry fruit yield/plant (0.473), â-carotene content through weight of dry fruit (0.434), capsaicin content through weight of ripe fruit (0.427), capsaicin content through dry fruit yield/plant (0.241) and days to first picking through weight of ripe fruit (0.162) (Table 3). However, in the case of negative indirect effect, high negative indirect effect was exerted by dry fruit yield/plant through weight of dry fruit (-0.981), followed by weight of ripe fruit through weight of dry fruit (-0.912), number of fruit/plant through weight of ripe fruit (-0.556), fruit length through weight of dry fruit (-0.523), â-carotene content through dry fruit yield/plant (-0.343), shelf life at ambient temperature through weight of ripe fruit (-0.286), capsaicin content through weight of dry fruit (-0.265), á-carotene content through weight of ripe fruit (-0.257), ascorbic acid content through weight of ripe fruit (-0.247), days to first picking through days to 50% flowering (-0.238), number of branch/plant through dry fruit yield/plant (-0.212) (Table 3).

Discussion

In the present investigation, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the characters; indicated strong association between the two characters genetically. Correlation studies revealed that characters like weight of ripe fruit, fruit length, weight of dry fruit, dry fruit yield/plant and capsaicin content had significant positive correlation with fruit yield/plant both at genotypic and phenotypic level. Similar results were also reported by Datta and Jana (2010), Ullah et al. (2011), Kumar et al. (2012), Krishnamurthy et al. (2013), Amit et al. (2014) and Dubey et al. (2015) in their experiments. However, negative association of fruit yield per plant was illustrious with plant height and number of branch/plant both at genotypic and phenotypic level, indicated that fruit yield and plant height and number of branch/plant could not be improved simultaneously through selection and suggested that, this character should not be emphasized for direct selection of high yielding genotype. So, independent selection for this trait could be made to get improved population.

In the present investigation at genotypic level, fruit yield per plant was taken as dependent variable and other 14 traits were considered as causal variables. Weight of ripe fruit had maximum positive direct effect on green fruit yield/plant followed by dry fruit yield/plant and fruit length at genotypic level; indicated that these are the real independent characters and have maximum contribution towards increase in fruit yield per plant. These observations were conformity with Kumari et al. (2011), Vikram et al. (2014) and Yatung et al. (2014a). The high positive direct effect of weight of ripe fruit on fruit yield per plant was counter balanced by its positive indirect effect *via* plant height, days to first picking, fruit length, weight of dry fruit, dry fruit yield/plant and capsaicin content. However, high positive direct effect of dry fruit yield/plant on green fruit yield per plant was counter balanced by its positive indirect effect *via* number of branch per plant, days to 50% flowering, days to first picking, weight of ripe fruit, fruit length, number of fruit per plant and capsaicin content. Negative direct effect on fruit yield per plant was imposed by weight of dry fruit (both at phenotypic and genotypic level), days to 50% flowering (both at phenotypic and genotypic level), plant height (both at phenotypic and genotypic level), number of branch/plant (both at phenotypic and genotypic level), number of fruit/plant (genotypic level). High negative indirect contribution of dry fruit yield/plant via weight of dry fruit followed by weight of ripe fruit through weight of dry fruit, number of fruit/plant through weight of ripe fruit, fruit length through weight of dry fruit, â-carotene content through dry fruit yield/plant, shelf life at ambient temperature through weight of ripe fruit, capsaicin content through weight of dry fruit, á-carotene content through weight of ripe fruit, ascorbic acid content

Table 3: Direct (diagonal) and indirect effects of fruit yield components on fruit yield per plant at phenotypic (P) and genotypic (G) level in King chilli

Character		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Plant height (1)	P	-0.051	-0.002	0.011	0.011	0.000	0.000	0.008	-0.002	0.000	-0.009	-0.010	0.018	0.001	-0.000
	G	-0.170	-0.062	0.025	0.017	0.004	-0.004	0.036	-0.012	-0.007	-0.084	-0.063	0.075	0.005	-0.009
Number of branch/plant (2)	P	-0.001	-0.026	-0.000	-0.001	-0.000	0.009	0.003	0.001	0.002	0.002	-0.008	0.001	-0.007	-0.005
	G	-0.039	-0.106	0.041	0.024	-0.008	0.053	0.062	0.004	0.026	0.051	-0.034	0.015	-0.042	-0.032
Days to 50% flowering (3)	P	0.066	-0.005	-0.286	-0.271	0.005	-0.072	0.007	-0.010	-0.009	-0.036	-0.041	0.007	0.096	0.090
	G	0.037	0.097	-0.252	-0.238	-0.001	-0.090	0.094	-0.013	0.025	0.009	-0.022	0.020	0.108	0.088
Days to first picking (4)	P	-0.067	0.020	0.296	0.313	0.026	0.118	-0.002	0.028	0.025	0.008	0.028	0.000	-0.109	-0.115
	G	-0.004	-0.011	0.045	0.047	0.007	0.025	-0.015	0.006	0.000	-0.008	0.001	-0.002	-0.021	-0.020
Weight of ripe fruit (5)	P	-0.000	0.018	-0.014	0.060	0.715	0.380	-0.214	0.630	0.516	-0.200	-0.167	0.285	-0.186	-0.164
	G	-0.025	0.079	0.005	0.161	1.025	0.578	-0.556	0.923	0.838	-0.286	-0.246	0.426	-0.303	-0.256
Fruit length (6)	P	0.001	0.050	-0.036	-0.055	-0.078	-0.147	0.007	-0.074	-0.069	0.015	0.054	-0.050	0.087	0.088
	G	0.005	-0.118	0.084	0.125	0.133	0.236	-0.014	0.122	0.129	-0.035	-0.111	0.088	-0.149	-0.159
Number of fruit/plant (7)	P	-0.027	-0.022	-0.004	-0.001	-0.047	-0.008	0.158	-0.042	0.034	0.000	0.000	-0.005	0.015	-0.012
	G	0.034	0.093	0.059	0.051	0.086	0.009	-0.159	0.081	0.042	-0.009	0.004	-0.010	-0.035	0.010
Number of fruit/plant (8)	P	-0.006	0.007	-0.005	-0.014	-0.138	-0.079	0.041	-0.157	-0.135	0.024	0.031	-0.040	0.062	0.004
	G	-0.074	0.037	-0.055	-0.145	-0.911	-0.523	0.513	-1.012	-0.981	0.147	0.219	-0.265	0.434	0.050
Dry fruit yield/plant (9)	P	-0.008	-0.049	0.017	0.041	0.369	0.240	0.112	0.440	0.511	-0.070	-0.080	0.106	-0.171	-0.038
	G	0.038	-0.212	-0.085	0.006	0.707	0.473	-0.229	0.838	0.864	-0.123	-0.179	0.241	-0.342	-0.066
Shelf life at ambient temp. (10)	P	0.022	-0.010	0.015	0.003	-0.032	-0.012	0.000	-0.018	-0.016	0.117	-0.005	-0.053	-0.023	0.009
	G	0.030	-0.029	-0.002	-0.011	-0.017	-0.009	0.003	-0.008	-0.008	0.061	-0.012	-0.037	-0.014	0.005
Ascorbic acid content (11)	P	0.004	0.007	0.003	0.002	-0.005	-0.008	0.000	-0.004	-0.003	-0.001	0.022	-0.006	0.010	0.003
	G	0.075	0.066	0.017	0.004	-0.048	-0.095	-0.005	-0.044	-0.042	-0.041	0.203	-0.068	0.105	0.036
Capsaicin content (12)	P	-0.040	-0.007	-0.003	0.000	0.045	0.039	-0.003	0.029	0.024	-0.052	-0.035	0.115	-0.011	-0.019
	G	0.005	0.001	0.001	0.000	-0.005	-0.004	-0.000	-0.003	-0.003	0.007	0.004	-0.012	0.001	0.002
β-Carotene (13)	P	-0.001	0.013	-0.015	-0.015	-0.011	-0.027	0.004	-0.017	-0.015	-0.009	0.020	-0.004	0.045	0.016
	G	0.002	-0.028	0.030	0.030	0.020	0.044	-0.015	0.030	0.027	0.017	-0.036	0.007	-0.069	-0.026
α- Carotene (14)	P	-0.001	-0.023	0.036	0.042	0.026	0.069	0.009	0.003	0.008	-0.009	-0.016	0.020	-0.042	-0.116
	G	0.005	0.031	-0.036	-0.044	-0.025	-0.069	-0.007	-0.005	-0.008	0.008	0.018	-0.019	0.038	0.103
Fruit yield/ plant (15)	P	-0.111	-0.031	0.014	0.114	0.874	0.503	0.133	0.805	0.875	-0.221	-0.207	0.393	-0.2331	-0.2610
	G	-0.079	-0.161	-0.122	0.032	0.966	0.622	-0.293	0.905	0.903	-0.286	-0.255	0.458	-0.284	-0.272

through weight of ripe fruit, days to first picking through days to 50% flowering, number of branches/plant through dry fruit yield per plant. These results were in concurrence with the results of Vikram et al. (2014) and Yatung et al. (2014a & 2014b)

Conclusion

On the basis of correlation association analysis, it could be concluded that the selection criteria based on weight of ripe fruit, weight of dry fruit, fruit length, and dry fruit yield/plant can provide better results for the improvement of fruit yield in Bhut Jolokiai. With an eye to the future, King chilli may soon gain more repute for their health benefits as antioxidant becomes an everyday word to consumers than they have in the past. The genetic basis of the different traits needs to be assessed in order to ascertain their constancy in population with the application of DNA markers linked to the respective traits for molecular characterization of these genotypes of *Capsicum chinense.*

Ikjka'k

भूत जोलोकिया/किंग मिर्च के सोलह प्रभेदों का मूल्यांकन पॉलीहाउस में तीन प्रतिकृतियों के साथ सब्जी अनुसंधान फार्म, सीएचएफ, सीएयू, पासीघाट (अरूणाचल प्रदेश) में किया गया जिसमें क्रमशः गुण सम्बन्ध योगदान को ज्ञात करने के लिए सहसंबंध और पथ विश्लेषण किया गया। आपसी सहसंबंध प्रभेदों के बीच सभी गुणों के लिए महत्वपूर्ण भिन्नता पायी। सहसंबंध अध्ययनों से यह पता चला कि परिपक्व फल का भार (0.966, 0.874), फल की लंबाई (0.622, 0.503), सूखे फल का भार (0.905, 0.805) का वजन, प्रति पौध सूखे फलों की उपज (0.903, 0.875) और कैप्सेकिन सामग्री (0.458, 0.393) के मध्य सार्थक धनात्मक सह–सम्बन्ध उपज के लिए अनुवांशिक एवं बाह्यदृश्य रूप के स्तर पर पाया गया। हालांकि, अनुवांशिक स्तर पर, पके हुए फल के वजन पर प्रति पौधे (1.025), सूखे फलों की पैदावार (0.865), फलों की लंबाई (0.236), एस्कॉर्बिक एसिड की मात्रा (0.203) के बाद फल के उपज पर अधिकतम सकारात्मक प्रत्यक्ष प्रभाव देखा गया। वर्तमान अध्ययन के निष्कर्षों से पुष्टि होती है कि परिपक्वव फल, फल की लंबाई, सूखे फल का वजन, पौधें और कैप्सैकिन की मात्रा के सूखे फल के उपज का चयन और मिर्च प्रजनन कार्यक्रम के लिए महत्वपूर्ण घटक हैं।

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