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CORRELATION AND PATH COEFFICIENT ANALYSIS OF YIELD AND YIELD COMPONENT IN SOME OF BROAD BEAN (*Vicia faba* L.) GENOTYPES

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Faba bean is a grain legume and grown for its high protein content in the seed. It is also serves as a rotational crop which play great role in controlling disease epidemics in areas were cereal mono-cropping is abundant. Yield in faba bean, similar to the other crops, is a complex trait and constitute by many of morphological and physiological traits. This study was carried out during 2011-12 and 2012-13 in two region of Iran including Guilan and Lorestan provinces. Field experiments were conducted in a randomized complete block design with three replications and ten genotypes. The results of combined analysis of variance indicated that the studied genotypes differed significantly for all of the studied traits. The results indicated also environment effect and environment × genotype interaction effects were significant or highly significant for all of the traits. The highest seed yield were determined for genotype 1 (3159.9 and 4016.9 kg ha^{-1} at 2012 and 2013, respectively) in Guilan and genotype 5 (495.44 kg ha^{-1}) in Lorestan. The results of correlation analysis indicated that there were positive significant correlation coefficients between seed yield and seed length (LS), seed width (WS), pod length (PL) and hundred seed weight (HSW) in Guilan province at two cropping season. Path coefficient analysis indicated that traits containing number of pod per plant, number of steam per plant, pod length, seed length/width ratio and hundred seed weight had the highest positive direct effects on dry seed yield in studied faba bean genotypes. Attention should be paid to some of characters such as pod length, hundred seed weight, number of pods per plant and number of stems per plant for augmentation of seed yield and these traits could be used as selection criteria in faba bean breeding programs. These findings indicate that selection for each or full of the above traits would be accompanied by high yielding ability under such conditions. It could be concluded that the high yielding genotypes,

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such as 1 and 2 could be used to improve faba beans and making possibilities of extending production of this legume crop.

Key words: breeding, correlation, *Vicia faba,L.* locally landraces

INTRODUCTION

Faba bean, *Vicia faba* L., is the only species known in cultivation of section *Faba*. Faba bean was divided two subspecies; *V. faba* subsp. *paucijuga* Murat and *V. faba* subsp. *faba* L.. The taxon *V. faba* subsp. *faba* L. was classified in three variety groups, var. minor, var. equina and var. *faba* (major). Variety groups were also referred to as tick bean, horse bean or field bean and broad bean (DUC *et al.,* 2010). Faba bean is a self-pollinating plant with significant levels of outcross and inter-cross, ranging from 20 to 80% depending on genotype and environmental effects (SUSO and MORENO, 1999).

Faba bean is a grain legume and grown for its high protein content (25.4%) in the seed (KARADAVUT *et al.,* 2010). The green immature beans are boiled and eaten as vegetable. The mature seeds can be used for feeding livestock, swine, and equine and poultry animals. The stock or haulms is used as animal feeding staffs. Faba bean also serves as a rotational crop which play great role in controlling disease epidemics in areas were cereal mono-cropping is abundant (YOHANNES, 2000).

Locally landraces and breeding varieties were used in faba bean culture. The locally landraces could represent as an economically valuable opportunity for farmers in marginal areas and become the basis for plant breeders to develop new varieties (TERZOPOULOS *et al.,* 2008). Autochthonous Landraces, in fact, evolved from ancient types through conscious and unconscious phenotypic selection by farmers, contain adaptive genes to different agroecological conditions (CHAHAL and GOSAL, 2002).

Yield improvement is a major breeding objective of most crop improvement programs (GHOBARY and ABD-ALLAH, 2010). Yield in faba bean, similar to the other crops, is a complex trait and constitute by many of morphological and physiological traits. Seed yield is affected by genotype and environmental factors because it is a quantitative trait. Using as selection criteria of characters, direct relationship with seed yield increase the success of selection in plant breeding (KARASU and OZ, 2010). Therefore, progress of breeding in such traits are primarily conditioned by the magnitude and nature of variation and interrelationships among them (RAFFI and NATH, 2004)

Correlation analysis describes the mutual relationship between different pairs of characters without providing the nature of cause and effect relationship of each character. Significant positive correlations were detected between faba bean seed yield and each of number of pods per plant, number of seeds per plant, seed weight per plant and biological yield (ALGHAMD, 2007). TADESSE *et al*. (2011) indicated number of pods per plants, number of seeds per pod, thousand seed weight and plant height had significant association with seed yield per plot. The seed yield per plant exhibited positive and significant correlation with clusters per plant, pod length, plant height, branches per plant, pods per plant and hundred seed weight (BADOLAY *et al.,* 2009). ULUKAN *et al.* (2003) also found positive and significant relationships between biological yield and plant height and grain number per pod. KENENI and JARSO (2002) indicated positive and significant correlation between Seed yield and number of pods per plant.

Simple correlation analysis is not able to provide detailed and actual knowledge in the relation between dependent variable and predictor variables. Hence, the path analysis was also performed to determine the direct and indirect contribution of each character to seed yield (CHITRA and RAJAMANI, 2010). This method, developed by WRIGHT (1921) as a statistical tool, enables to study complex relationships between traits. Many researchers have studied cause and effect relationships among seed yield and yield-related traits in faba bean. TADESSE *et al.* (2011) indicates days to flowering, days to maturity, number of pod per plants, seed per pod, thousand seed weight and plant height had high positive direct effect on seed yield per plot. ULUKAN *et al.* (2003) indicated the direct and indirect effects of plant height, pod length, first pod height, pod number per plant and grain number per pod upon biological yield. In the other study, path analyses showed that number of seeds per plant and 100-seed weight were the major direct contributors to seed yield per plant (BERHE *et al.,* 1998). GOLPARVAR (2012) revealed that bean traits containing percent of total nitrogen of shoot, number of nodule per plant and biological yield accounted for 92.3 percent of variation exist in percent of nitrogen fixation. RADIĆ *et al.* (2013) suggested that 1000 seed weight has maximum positive and seed germination maximum negative direct effect on yield of sunflower by path analysis. According to results of path analysis plant height, ear diameter and grain moisture had highly significant genetic and phenotypic direct effects on maize grain yield (FILIPOVIĆ *et al.*, 2014).

The objective of the present study was to estimate the correlations and partition of the coefficient of correlation between seed yield with its primary components, into direct and indirect effects to determine the relative importance of each one in faba bean seed yield in three environments.

MATERIALS AND METHODS

This study was carried out during 2011-12 and 2012-13 in Shanderman, Guilan province, Iran (longitude, 49° 55´ E; latitude, 37° 27´ N; altitude, 71 m above sea level; climate, wet) and during 2011-12 in Broujerd agriculture and natural resources station, Lorestan province, Iran (longitude, 48° 45´ E; Latitude, 35° 55´ N; Altitude, 1629 m above sea level; Precipitation, 455.2 mm; climate, semidry and dry). Experimental material comprised 6 genotypes of faba bean (*Vicia faba* L.,). Some features genotypes are presented in Table 1.

Tab. 1. Information of faba bean studied genotypes

Genotype	Genotype name	Origin	Breedng status	Seed structure
1	-	North of Iran (Guilan)	Autochthonous Landrace	Large
2	Barrakat	Iran/ Gurgaon	Breeding variety	Large
3	France	France	Breeding variety	Intermediate
4	-	Lorestan (Borujerd1)	autochthonous Landrace	Small
5	FILIP3	Syria	Breeding variety	Small
6	FILIP5	Syria	Breeding variety	Small

Experimental field area

The sowing of seeds was conducted in 8 December 2011 and 2012 in Guilan and in 8 March 2011 in Lorestan province by hand. Field experiments were conducted in a randomized complete block design with three replications. Each plot consisted of four rows with 6 m long and distance between rows was 50 cm. The seeding rate was 15 plants per m^2. Forty five kilogram nitrogen, phosphorus and potassium per hectare were applied as compose fertilizer (15-15-15) prior to sowing. All recommended agronomic practices were followed to raise good crop.

The following statistical model was adopted for experimental design:

$$Y_{ijkl} = \mu + E_i + R(E)_{j(i)} + G_k + GE_{ik} + e_{ijkl}$$

Where,

μ: general mean; E_i: effect of i^{th} environment (i = 1,2); $R(E)_{j(i)}$: effect of j^{th} block within the i^{th} environment (j = 1,2,3); G_k: effect of k^{th} genotype (I = 1, 2………..10); GE_{ik} : effect of the interaction of the k^{th} genotype with the i^{th} environment; e_{ijk}: experimental error.

Estimated characters

Fifteen plants of each plot were harvested by hand and the characters *viz* pod length (PL), number of seeds per pod (NSP), number of stems per plant (NStPl), number of pods per plant (NPoPl), dry seed length (LS), dry seed width (SW) and hundred seed weight (HSW) were measured before and after of harvesting. Seed yield per plot was measured after removal of the marginal effect and reported as dry seed yield per m^2 (SY).

The statistical techniques

The data of seed yield and its components were analyzed by the following statistical procedures. Significance of correlation coefficients were tested in the probably levels of 0.05 and 0.01. These correlations were further analyzed using path coefficients as illustrated by LI (1968). The path analysis was done as given by WRIGHT, (1921) and elaborated by DEWEY and LU (1959) to calculate the direct and indirect contribution of various traits to yield. Also, the relative importance of direct and indirect effects on seed yield was determined by path analysis. In path analysis, seed yield was the dependent variable and the other traits were considered as independent variables. All of the statistical analysis carried out using SAS 9.2.

RESULTS

Analysis of variance and genotype's mean performance

The results of combined analysis of variance indicated that the studied genotypes differed significantly for all of the studied traits. The results indicated also environment effect were significant or highly significant for all of the traits exception of seed width. The other results of combined analysis of variance were the significance of environment × genotype interaction effects for all of the studied traits (Table 2).

Table 3 presents the mean values of some of the traits across genotypes in three environments. The obtained differences for all investigated traits point out the diversity of investigated genetic material. The highest seed yield were determined for genotype 1 (3159.9 and 4016.9 kg ha^{-1} at 2012 and 2013, respectively) in Guilan and genotype 5 (495.44 kg ha^{-1}) in Lorestan. These two genotypes are autochthonous landraces in Guilan and Lorestan provinces, respectively. The ratio of length of seed to weight (L/W) was differed in six genotypes in three environments. The highest value of this parameter was obtained in genotype 1 at three environments. The highest value of hundred seed weight was also indicated in genotype 1 (161.33, 175 and 118.44 g in three environments).

Tab. 2. Combined analysis of variance for some of morphological traits in bean

SOV	df	SY	LS	WS	NPoPl	NSP	NStPl	PL	L/W	HSW
E		66325.52**	0.497**	0.0023^{ns}	86.34*	7.96**	7.16*	22.37**	0.227**	10564.90**
R(E)	2	609.48	0.024	0.0125	10.71	0.21	1.31	1.42	0.0057	304.29
G	9	7963.60*	1.779**	0.5497**	93.38**	2.69**	1.06*	69.03**	0.1145**	24525.93**
G*E	18	26014.14**	0.615**	0.3732**	19.75*	1.65**	0.32**	30.96**	0.0801**	5342.45**
error		3266.04	0.0139	0.0088	9.11	0.17	0.42	2.14	0.0078	262.16
CF		27.31	6.72	7.17	27.34	12.77	20.52	15.53	6.61	14.59

SY: Dry seed yield per m^2; PL: pod length; NSP: number of seeds per pod; NStPl: number of stems per plant; NPoPl: number of pods per plant; LS: dry seed length; SW: dry seed width; LW seed length/width ratio and HSW: hundred seed weight.
ns, not significant; * and **, significant at the 0.05 and 0.01 probability level respectively.

Tab. 3. Averaged performance for some of morphological traits in faba bean genotypes

Genotype	SY (kg ha^{-1})			L/W(ratio)			HSW(gr)		
	Guilan-2012	Guilan-2013	Lorestan-2012	Guilan-2012.	Guilan-2013	Lorestan-2012.	Guilan-2012.	Guilan-2013	Lorestan-2012
1	3159.9^{a}	4016.9^{a}	1223.5^{dc}	1.51^{a}	1.49^{a}	1.33^{b}	161.33^{ab}	175.0^{a}	118.44^{a}
2	2622.3^{ab}	3368.6^{ab}	1530.3^{b}	1.40^{abc}	1.46^{a}	1.26^{b}	139.00^{a}b	137.5^{b}	102.19^{b}
3	2302.9^{ab}	2716.8^{bc}	1049.5^{d}	1.42^{ab}	1.41^{a}	1.29^{b}	106.00^{b}	108.33^{c}	105.43^{ab}
4	2040.7^{abc}	1834.8^{d}	1291.0^{c}	1.32^{bc}	1.38^{a}	1.28^{a}	48.00^{c}	55.0^{e}	44.14^{d}
5	1121.3^{c}	1925.4^{d}	1849.3^{a}	1.30^{c}	1.43^{a}	1.24^{b}	89.67^{b}	90.00^{d}	83.82^{c}
6	1110.9^{c}	1592.4^{d}	1732.5^{b}	1.37^{bc}	1.34^{a}	1.04^{c}	52.87^{c}	53.33^{e}	56.76^{d}
LSD(1%)	1623.2	742.6	238.3	0.12	0.21	0.14	45.93	16.64	14.71

The symbol of traits is the same as in Table 2.

Correlation Analysis

The correlation coefficients between traits in three environments had presented in Table 4. Values close to 1 indicate that two variables are behaving almost identically. Conversely, a value close to -1 indicates that two traits are behaving in opposite manner, i.e. when one element is increased the other decreased. A value near 0 indicates that the two elements are independent of each other. The results indicated there were positive significant correlations between seed yield and seed length (LS), seed width (WS), number of stems per plant (NStPl), pod length (PL) and hundred seed weight (HSW) in first environment (Guilan-2012). The results also indicated that there were positive correlations between seed yield and LS, WS, number of pods per plant (NPoPl), number of seeds per pod (NSP), PL and HSW in second environment (Guilan-2013). But there were only significant positive correlation between seed yield and NPoPl in third environment (Lorestan-2012). In this environment the correlation coefficients between seed yield and the traits containing LS, WS, NPoPl, Pl and HSW were negatively significant.

Tab. 4. Correlation coefficients between faba bean studied characters (first row, above diagonal: 1th env. second row, above diagonal: 2th env.and belove diagonal: 3th env).

Traits	SY	LS	WS	NPoPl	NSP	NStPl	PL	L/W	HSW
SY	1	0.80**	0.81**	0.19	0.36	0.53**	0.70**	0.35	0.71**
		0.33	0.38*	0.13	0.34	-0.15	0.41*	-0.13	0.31
LS	-0.85**	1	0.98**	0.11	0.36	0.47*	0.83**	0.54**	0.87**
			0.99**	-0.02	0.29	0.35	0.75**	0.44	0.99**
WS	-0.62**	0.52**	1	0.05	0.39	0.48*	0.86**	0.38	0.88**
				-0.02	0.31	0.35	0.75**	0.28	0.98**
NPoPl	0.42*	-0.46*	-.11	1	-0.13	0.63**	-0.05	0.34	0.01
					-0.19	0.22	-0.23	-0.01	-0.04
NSP	-0.33	0.25	.23	-0.37	1	0.08	0.76**	0.03	0.34
						-0.34	0.81**	0.02	0.29
NStPl	-0.33	0.27	.31	0.39	-0.06	1	0.36	0.15	0.39
							-0.03	0.07	0.33
PL	-0.65**	0.74**	.38	-0.38	0.27	0.28	1	0.28	0.75**
								0.27	0.75**
L/W	-0.28	0.55**	-.42*	-0.34	0.01	-0.01	0.39	1	0.36
									0.37
HSW	-0.66**	0.64**	.30	-0.64**	0.01	0.17	0.56**	0.38	1

The symbol of traits is the same as in Table 2.

Path coefficient analysis

The results of path analysis on data set of first environment (Guilan-2012) indicated that four traits containing PL, NStPl, HSW and L/W had the positive direct effect on seed yield and explained 64% of the total variation for SY (Table 5). This means that the most of the variation in seed yield of studied faba been genotypes in this environment was explained by the traits included in the model. The other two traits containing NPoPl and NSP had negative direct effect on seed yield. When the results of correlation and path coefficient analysis are examined, it is observed that NPoPl and NSP had a positive correlation by seed yield, but they had a negative direct effect on this response variable. The reason of positive correlation between seed yield and these two traits is positive indirect effects of NPoPl and NSP on seed yield *via* the other traits containing L/W and HSW.

The results of path analysis for data set of second environment (Guilan-2013) were presented in Table 6. Based on tolerance and inflation factor values and besides the magnitude of direct effect, NPoPl, PL and HSW were considered as the first-order variables and had positive direct effect on seed yield traits under this environment. These three traits via NSP and L/W that had negative direct effect on seed yield, explained 34% of the total variation for seed yield. This means that the most of variation in response variable was explained by the traits included in the model. It indicated that these traits with positive direct effect on seed yield are main contributors towards yield. The direct effects of these three predictor variables on seed yield were 0.269, 0.323 and 0.286, respectively. When the results of correlation and path coefficient analysis are examined, it is observed that NPoPl and HSW recorded a direct positive effect on seed yield, but they had a negative indirect effect *via* the other predictor variables. Estimated coefficient of correlation between NPoPl and seed yield was low and insignificant (0.13), but partial analysis of correlation coefficients showed higher direct effect of NPoPl on seed yield (0.27). The reason of this is the negative indirect effect of NPoPl on seed yield *via* the other variables.

Tab. 5. Path coefficients for seed yield components in faba bean in Guilan at 2012. The diagonal under line numbers is direct effects of any trait on seed yield.

Traits	NPoPo	NSP	NStPl	PL	L/W	HSW	Overall effects
NPoPl	-0.028	0.0038	-0.017	0.0012	0.0098	-0.0004	0.186
NSP	0.0115	-0.086	-0.007	-0.065	-0.0016	-0.028	0.362
NStPl	0.179	0.0226	0.286	0.103	0.042	0.112	0.535
PL	-0.021	0.337	0.161	0.446	0.117	0.334	0.701
L/W	0.039	0.002	0.0167	0.030	0.115	0.041	0.354
HSW	0.0034	0.0824	0.096	0.184	0.089	0.245	0.705
	R^2=0.64				$\sqrt{1-R^2}$ =0.59		

The symbol of traits is the same as in Table 2.

Tab. 6. Path coefficients for seed yield components in faba bean in Guilan at 2013. The diagonal under line numbers is direct effects of any trait on seed yield.

Traits	NPoPl	NSP	PL	L/W	HSW	Overall effects
NPoPl	0.269	0.059	-0.061	0.0024	-0.011	0.127
NSP	-0.071	-0.324	0.009	-0.023	-0.106	-0.150
PL	-0.073	-0.009	0.323	0.086	0.242	0.407
L/W	-0.0027	-0.0218	-0.0809	-0.303	-0.1145	-0.1230
HSW	-0.0123	0.094	0.215	0.108	0.286	0.307
	R^2=0.34			$\sqrt{1-R^2}$ =0.81		

The symbol of traits is the same as in Table 2.

The results of path analysis for data set of third environment (Lorestan-2012) were showed in Table 7. Seed yield was determined by the positive direct effect of NPoPl and negative direct effects of the other traits containing NSP, NStPl, PL, L/W and HSW. The adjusted R square was 53% in this data set. Number of pod per plant, in addition to the direct effect on seed yield had positive indirect effect through the traits containing NSP, PL, L/W and HSW. The negative direct effect of the traits included in the model on this data set indicated that should be used more variables that had positive direct or indirect effect on seed yield.

Tab. 7. Path coefficients for seed yield components in faba bean in Lurestan at 2012. The diagonal under line numbers is direct effects of any trait on seed yield.

Traits	NPoPl	NSP	NStPl	PL	L/W	HSW	Overall effects
NPoPl	0.0011	-0.0004	0.0004	-0.0004	-0.0003	-0.0006	0.415
NSP	0.106	-0.292	0.018	-0.079	-0.0017	-0.002	-0.324
NStPl	-0.029	0.0046	-0.0746	-0.0213	0.0007	-0.012	-0.331
PL	0.1001	-0.071	-0.074	-0.261	-0.102	-0.147	-0.655
L/W	0.002	-0.00003	0.00006	-0.0024	-0.0062	-0.0023	-0.276
HSW	0.422	-0.004	-0.114	-0.370	-0.249	-0.657	-0.665
		R^2=0.53			$\sqrt{1-R^2}$ =0.57		

The symbol of traits is the same as in Table 2.

DISCUSSION

The results of path analysis were presented in Table 5-7. According to the results, the predictive variables for seed yield were different in any of each environment. Based on tolerance and inflation factor values and besides the magnitude of direct effect the traits containing number of pod per plant, number of steam per plant, pod length, seed length/width ratio and hundred seed weight had the highest positive direct effects on dry seed yield in studied faba bean genotypes. When the results of correlation and path coefficient analysis are examined, it is observed that these predictor variables recorded a direct positive effect on seed yield and they had a positive indirect effect *via* the other traits.

The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components. One component is the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable. The other component is the indirect effect(s) of a predictor variable on the response variable through the predictor variables (DEWEY and LU, 1959).

Our results obtained from six faba bean genotypes in three environment and showed that the coefficient of determination were 64, 34 and 54%, respectively. It represents the influence of the traits involved in the study on total variability of dry seed yield. Path coefficient analysis indicated that the traits containing pod Length, hundred seed weight and number of stems per plant play major role in seed yield determination of faba bean. This result concur with ALGHAMD (2007) detected significant positive correlations between seed yield and each of number of pods per plant, number of seeds per plant, seed weight per plant and biological yield. In confirming with our results, BERHE *et al.* (1998) indicated the number of seeds per plant and 100-seed weight were the major direct contributors to seed yield per plant. These results also agree with those of TADESSE *et al.* (2011) and ULUKAN *et al.* (2003) that found out number of pods per plant, seed per pod, thousand seed weight, pod length, and grain number per pod had high positive direct effect on seed yield per plot.

CONCLUSIONS

Conclusively, attention should be paid to some of characters such as pod length, hundred seed weight and number of stems per plant, for increase of seed yield and these traits could be used as selection criteria in faba bean breeding programs. These findings indicate that selection for each or full of the above traits would be accompanied by high yielding ability under such conditions. These results suggest that the mentioned traits are the most important seed yield components in the development of high yielding varieties. Results showed that the genotype 1 and 2 possessed the high values of traits. These results reflect that the selection prospects within this genotype to improve the performance through breeding program. It could be concluded that the high yielding genotypes, such as 1 and 2 could be used to improve faba beans and making possibilities of extending production of faba bean. Moreover, the traits that exhibited strong and positive association with yield could be used as selection criteria for improving faba bean.

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KORELACIJA I PAT KOEFICIJENT ANALIZA PRINOSA I KOMPONENTI PRINOSA KOD RAZLIČITIH GENOTIPOVA BOBA (*Vicia faba* L.)

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Izvod

Bob se gaji zbog visokog sadržaja proteina u semenu . Takođe služi kao rotacioni usev koji ima veliku ulogu u kontroli epidemije bolesti u područjima gde se gaje žitarice u monokulturi. Ispitivanja su vršena u toku 2011-2012 i 2012-2013 u dva regiona , uključujući Iran i Guilan Lorestan provincije. Vršena su ispitivanja deset genotipova u poljskim uslovima u slučajnom blok sistemu u tri ponavljanja. Rezultati kombinovane analize varijanse ukazuju das u se ispitivani genotipovi značajno razlikovali u svim ispitivanim osobinama. . Rezultati su pokazali uticaj spoljne sredine a interakciju genotip x spoljna sredina je značajna ili visoko značajna za sve osobine . Utvrđene su značajne pozitivne korelacije koeficijenti između prinosa semena i dužine semena (LS) , širine semena (VS) , dužine mahune (PL) i mase 100 zrna (HSV) u provinciji Guilan u dve sezone . Analiza Pat koeficijenta je pokazala da broj mahuna po biljci , broj izdanaka po biljci , dužina mahune, dužine semena / širine i težine 100 zrna imaju najviše direktne pozitivne efekte na prinos suvog semena kod svih ispitivanih genotipova i mogu se koristiti kao kriterijumi u oplemenjivanje boba.

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