BIHAREAN BIOLOGIST 5 (1): pp.63-68
Article No.: 111109

http://biologie-oradea.xhost.ro/BihBiol/index.html

Relationships among yield and yield components and essence in cumin (*Cuminum cyminum* L.) under different climate conditions

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Received: 10. January 2011 / Accepted: 06. May 2011 / Available online: 08. May 2011

Abstract. An experiment was conducted to study effects of nitrogen fertilizer and plant density on quantitative relationships between yield and yield components and essential oil in cumin (*Cuminum cyminum* L.) under three different climate testing sites (cold, tropical and moderate climate locations) in western of Iran. Plant density (80, 120, 160 plant m^{-2}) and Nitrogen fertilizer (0, 25, 50, 100 kg ha^{-1}) were main and subsidiary factors respectively. Maximum yield (1275 kg ha^{-1}) and essence (2.78%) were obtained at 100 kg nitrogen ha^{-1} and 160 plant m^{-2} in moderate location. Analysis of variance for testing contrasts of plant density and nitrogen fertilizer showed significant linear relationship between nitrogen fertilizer and yield components. A quadratic relation was found to be significant between nitrogen fertilizer and yield, yield components as well as between nitrogen fertilizer and essence percent. Significantly positive correlations were also observed between yield and number of seed per plant, number of umbel per plant, number of seed per umbel, thousand seed weight and biologic yield at tropical location. To gain maximum seed and essence of cumin, moderate location is recommended.

Key words: Cumin *(Cuminum cyminum L.)*, path analysis, yield, yield components, Climate condition.

Introduction

Cumin (*Cuminum cyminum* L.) is one of the most important medicinal plant (Iacobellis et al. 2005, Shirke et al. 2008) and one of the important seed spice belonging to Umbellifreae, has 3–4% volatile oil and about 15% fixed oil (Sowbhagya et al. 2008). Common spices of cumin have a long history of use in eastern cultures as food flavors, perfumes and medicinal values (Tunçtürk 2006). Cumin powder is generally used as a food additive for imparting flavor to foods (Singh, 2000). Essential oils and properties of extract in cumin are affected by conditions of growth. Plant density and nitrogen fertilizer are two important factors for growth and management of cumin (Ashraf et al. 2006, Hashemi et al. 2007, Mehriya et al. 2007, Azizi & Kahrizi 2008). Seed is the main component in cumin because essential oil was extracted from seeds (Li & Jiang 2004, Beis et al. 2005, Li et al. 2009). Other yield components (number of umbel per plant, number of seed per umbel, number of seed per plant and thousand seed weight) affected seed yield (Azizi & Kahrizi 2008). Therefore complicated relationships between yield and yield components and essential oil are made. However, there are no sufficient research works concerning the evaluation for environmental factors-traits interactions and relationships between yield and its components in cumin. Current work is designed to investigate relationship among studied traits at different climate conditions of western Iran and to study the effects of different plant density and nitrogen fertilizer levels on quantitative relationship between yield and yield components and essential oil in cumin (*Cuminum cyminum* L.).

Material and methods

Experimental design

An experiment was conducted as split plot based on randomized complete block design with four replications in three different climate locations of Lorestan Province in the west of Iran. The plant seeds of this experiment were received from the National Botanical Garden of Iran. Nitrogen fertilizer (N) as main factor with four levels (0, 25, 50, 100 Kg N/ha) and plant density as subsidiary factor with three levels (80, 120, 160 Plants/m^2) were applied in 5×7 m^2 plots with 5 rows. Cultivation activities, sampling, harvest and Oil extraction was done according to Azizi & Kahrizi (2008).

Before seed sowing, the soil in three climates was analyzed for its physico-chemical characters including elements absorbability and percent, pH, EC (Electrical Conductivity), total organic carbon, total nitrogen and texture soil. Then soil bed was organized via cultivation activities.

As locations had different climates, the seeds were sown in different dates (20 Oct, 6 Feb and 1 Mar for moderate, cold and tropical regions, respectively). For lay out density treatments thousand seed weight of seed was measured and then calculated weight of seeds for sowing in plots. Nitrogen fertilizer was applied in two stages of growth (half in post emergence and another half in flowering initiation stage). At end of growth, 0.25 m^2 of crop was harvested in 3 rows of plots. The harvested plots were dried at room temperature.

Location selection based on climates

Lorestan province in the west of Iran has variable climate. This province was the best candidate for our experiment to evaluate in all climatic conditions. Therefore three locations were selected as follow:

Cold location (Azna) Longitude: 48° 36' E, Latitude: 33° 23' N, Altitude: 1620 m

Moderate location (Khoramabad): Longitude: 48° 22' E; Latitude: 33° 29' N; Altitude: 713 m

Tropical location (Poldokhtar): Longitude: 47° 43' E; Latitude: 33° 9' N; Altitude: 16 m

The traits have been measured according to Azizi & Kahrizi (2008), including seed yield (SY), harvest index (HI), essential oil percent (%EOP), biological yield (BY), thousand seed weight (TSW), number of seed per umbel (SPU), number of umbel per plant (UPP) and number of seed per plant (SPP).

Data analysis

Data were subjected to SAS program (1999) for combined ANOVA analysis, ss (sum of squares) segregation (testing contrast), correlation and path analysis. The Duncan's multiple range test was used for comparing means of seed yield and essence percent. Significance was declared at $p < 0.05$.

Results and discussions

Combined ANOVA

Combined ANOVA for yield and its components are presented in Table 1. The results showed that location had a significant effect on yield, yield components and percent of essence. The effects of plant density and fertilizer were significant for yield, yield components and percent of essence.

Location × Density effect was found to be significant for percent of essence, yield, thousand seed weight, harvest index, biological yield and number of seed per plant. Fertilizer × location effect was significant for percent of essence and biological yield. The location × fertilizer × density effect was significant for yield, harvest index and biological yield. The effect of fertilizer × Density was not significant for yield and harvest index and was significant for other traits. These results indicated that the location is an important factor which affects on quality and yield of cumin.

Abdollah (2009) reported significant difference for seed yield of cumin among different locations of southern Khorasan Province (Iran) but there wasn't significant difference in row spacing. Because southern Khorasan Province has one climatic condition (tropical condition) but Lorestan Province has three different climatic conditions. This comparison showed that plant density effects in cumin were depended on climatic condition.

Mean comparison for seed yield and essence percent

Results of Duncan multiple ranges test at 5% probability level were showed in Figures 1 and 2. They indicate maximum seed yield (1275 kg ha^{-1}) and essence percent (2.78%) were gained using 100 kg nitrogen ha^{-1} and 120 plants m^{-2} at moderate location. Choudhary et al. (2006) reported that a significant yield increase of cumin obtained using increase nitrogen fertilizer. Okut & Yidirim (2005) found the effects of fertilizer and density upon significant seed yield of the other *apiaceae* (*coriander*). Ashraf et al. (2006) found significant increase in oil content of black cumin (*Nigella sativa* L.) using 30 kg N ha^{-1}. Density and nitrogen fertilizer interaction is a key option to obtain high results in seed yield and essence percent. Macro elements such as nitrogen must apply by increasing plant density, because in high plant density large number of plants were growing and yield components per area were increased. Under high plant density, competition for nitrogen was higher than competition for light. Because thin leaves of cumin didn't make light competition therefore by applying more nitrogen fertilizer in high plant density, seed yield and essence percent were increased.

Testing contrasts for density and nitrogen fertilizer

ANOVA for testing contrasts (ss segregation) of density and nitrogen fertilizer showed significant linear relationship between nitrogen fertilizer and yield components (Table 2). A quadratic relation was found to be significant between nitrogen fertilizer and yield and between nitrogen fertilizer and yield components. Quadratic association of nitrogen fertilizer was significant for essence percent. Significant linear relationships were found between plant density and harvest index, essence percent, biologic yield, number of seed per umbel and number of seed per plant. Between yield, yield components, essence percent and density quadratic associations were significant. Non-significant linear relationship and significant quadratic relationship between yield and density and between yield and nitrogen fertilizer showed that there was one optimum point for plant density and nitrogen fertilizer to gain maximum yield (100 kg nitrogen ha^{-1} at 120 plant m^{-2} in moderate location at this research).

Correlation and path analysis for tropical location

Significantly positive correlations were found between yield and number of seed per plant (r= 0.79**), number of umbel per plant (r= 0.77**), number of seed per umbel (r= 0.80**), thousand seed weight (r=0.80**) and biologic yield (r=0.84**) at tropical location (Table 3). Number of seed per plant correlated positively and significantly with number of umbel per plant (r=0.94**), number of seed per umbel (r= 0.93**), thousand seed weight (r=0.88**) and biological yield (r= 0.70*). Correlation of number of umbel per plant with number of seed per umbel (r=0.80**), thousand seed weight (r=0.91**) and biologic yield (r=0.60*) was positive and significant. Number of seed per umbel correlated positively and significantly with thousand seed weight (r=0.78**) and biologic yield (r=0.75**). A positive and significant correlation was found between thousand seed weight and biologic yield (r=0.66*).

Path analysis revealed that biological yield (0.88), harvest index (0.51), number of seed per umbel (0.37) and number of umbel per plant (0.22) had maximum, positive direct effects on seed yield at tropical location, respectively (Table 5). However, number of seed per plant had negative direct effect (-0.57) on seed yield at tropical location. Number of seed per umbel (0.66), number of seed per plant (0.62), thousand seed weight (0.58), number of umbel per plant (0.53) and essence percent (0.48) through biologic yield had maximum, positive indirect effects on yield at tropical location (Table 4). Number of seed per plant through number of umbel per plant (-0.54), number of seed per umbel (-0.53) and thousand seed weight (-0.50) had maximum, negative indirect effect on seed yield. These results showed that in cumin biological yield had maximum positive correlation with seed yield and positive indirect effect of biological yield on seed yield was maximum amount at tropical location. Yield components had negative indirect effects on seed yield through number of seed per plant. Singh & Mittal (2003) conducted path coefficient study for fennel (*Foenkulum vulgare* Mill.). Their experiment revealed that 100-seed weight had maximum direct contribution towards yield followed by number of umbels per plant and number of seeds per umbel. At tropical location of current research some yield components like number of seed per plant, number of umbel per plant, number of seed per umbel and thousand seed weight, had significant correlation with seed yield. But these yield components had non-significant correlation at moderate location. Correlation of essence percent and seed yield was significant at moderate location which wasn't found at tropical location. These differences for two locations showed that essence production was higher at the moderate location. Also at the moderate location few components affected seed yield in comparison with the tropical location, therefore the moderate location was the best location to grow cumin and stable yield.

Correlation and path analysis for moderate location

Correlation coefficient between yield and biologic yield (r=0.88**) and between yield and essence percent (r=0.80**) were high, positive and significant in the moderate location (Table 5). Correlation of essence percent with number of seed per plant (r=0.60*), number of seed per umbel (r=0.65*) and biological yield (r=0.90**) were positive and significant in moderate location (Table 6). Biological yield correlated with number of seed per umbel positively and significantly (r=0.60**). Thousand seed weight correlated with number of

Table 1. Combined ANOVA for yield and it's components at three different locations in cumin. [SY: Seed yield, HI: Harvest index, Eop%: Essential oil percent, BY: Biological yield, TSW: Thousand seed weight, SPU: number of seed per umbel, UPP: number of umbel per plant, SPP: number of seed per plant].

SOV	Df	Means of squares							
		SY (×10^3)	HI	EOP%	BY	TSW	SPU	UPP	SPP
Location (L)	2	457.8**	191.1*	11.74**	959589.7**	20.17**	20.02**	261.3**	60102.9**
environment (E)	9	11.03	44.8	0.47	61426.9	0.31	0.20	11.6	347.1
Density (D)	2	580.82**	741.2**	0.82*	1184353.4**	4.06**	21.81**	545.9**	99801.2**
L × D	4	148.48**	340.8**	0.67*	142538.8*	0.95**	0.89	9.5	1960.8*
E × D	18	6.09	40.5	0.24	47715.3	0.12	0.42	3.3	769.6
Fertilizer (F)	3	109.42**	278.8**	1.87**	612877.4**	0.47*	26.48**	81.4**	48380.5**
F × D	6	227.67	115.6	1.61**	702427.2**	4.19**	14.71**	503.6**	88089.9**
L × F	6	17.42	63.6	0.55*	147528.6**	0.15	0.36	7.4	632.1
L × F× D	12	42.83**	107.6*	0.42	115694.7**	0.12	0.38	10.7	440.2
Error	81	8.82	53.5	0.19	45535.3	0.17	0.59	7.6	734.8
(CV %)		0.013	16.0	26.34	13.8	10.5	10.3	7.8	10.1

*, ** Significant P> 0.05 and P>0.01 level of probability, respectively; CV: Coefficient of Variation; Df: Degree of freedom; SOV: Source of variations

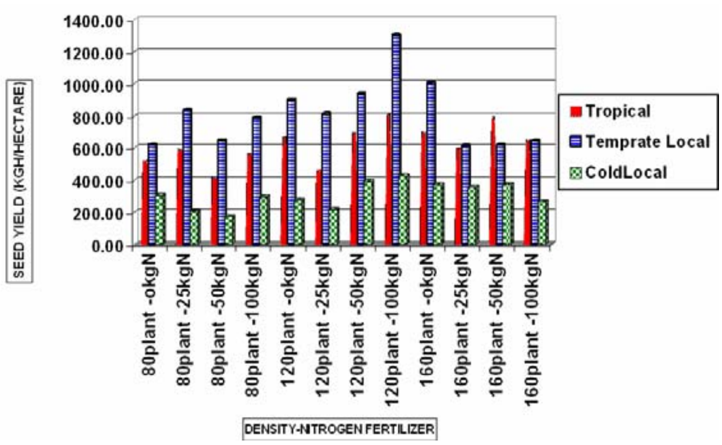

Figure 1. Mean comparison fertilizer, plant density and location effect for seed yield in cumin (To decrease crowd, letters of DMRT haven't been shown).

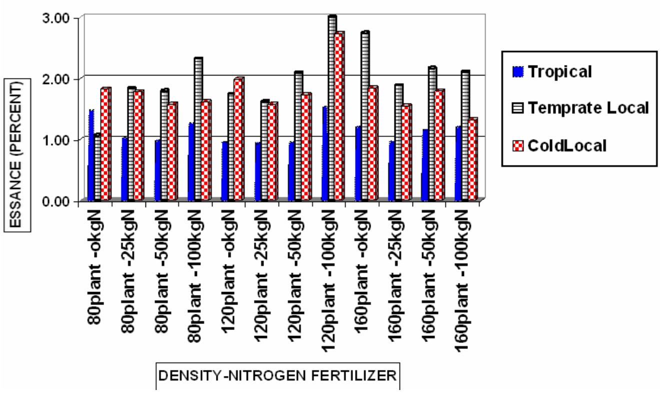

Figure 2. Mean comparison fertilizer, plant density and location effect for essence% in cumin. (To decrease crowd, letters of DMRT weren't shown).

Table 2. ANOVA for testing contrasts (ss segregation) of density and nitrogen fertilizer in cumin.

Source of variation	Df	Means of squares							
		SY (×10^3)	HI	EOP%	BY (×10^3)	TSW	SPU	UPP	SPP (×10^3)
Lin. F	1	5.81	326.34*	0.31	895.52**	4.41**	37.50**	688.01**	141.60**
Qud. F	1	1155.83**	1156.00**	1.33*	1473.19**	3.71**	6.12**	403.75**	57.99**
Lin. D	1	15.53	535.61**	2.41**	1254.09**	0.06	23.83**	0.56	27.26**
Qud. D	1	310.43**	286.17*	3.20**	564.63**	1.22**	14.06**	240.25**	53.28**
Lin. F vs. Lin. D	1	336.92**	188.75	0.81*	51.57**	0.01	1.01	247.96**	24.44**
Lin. F vs. Qud. D	1	10.19	33.84	0.01	23.06	10.15**	15.04**	1496.26**	163.10**
Qud. D vs. Lin. F	1	17.23	102.38	0.05	31.24	9.66**	20.19**	983.51**	131.30**
Qud. F vs. Qud. D	1	90.56**	27.50	2.18**	579.78**	2.66**	2.00	1.53	4.32*

*, ** Significant P> 0.05 P>0.01 level of probability, respectively; F: Fertilizer; D: Density; Lin: Linear; Qud: Quadratic; vs: versus

Table 3. Correlation coefficients for different traits at tropical location in cumin.

	SPP	UPP	SPU	TSW	BY	EOP%	HI	SY
SPP	1							
UPP	0.94**	1						
SPU	0.93**	0.80**	1					
TSW	0.88**	0.91**	0.78**	1				
BY	0.70*	0.60*	0.75**	0.66*	1			
EOP%	0.48	0.41	0.41	0.30	0.54	1		
HI	0.27	0.41	0.17	0.34	-0.16	-0.27	1	
SY	0.79**	0.77**	0.80**	0.80**	0.84**	0.34	0.38	1

**.Correlation is significant at the 0.01 level
*.Correlation is significant at the 0.05 level

Table 4. Path analysis for different traits at tropical location (yield as dependent variable) in cumin.

		Indirect effects							
Variables	Direct effects	SPP	UPP	SPU	TSW	BY	EOP%	HI	Total
SPP	-0.57	-----	0.21	0.35	0.03	0.62	0.005	0.14	0.79
UPP	0.22	-0.54	------	0.30	0.04	0.53	0.004	0.21	0.77
SPU	0.37	-0.53	0.17	-----	0.03	0.66	0.0044	0.09	0.80
TSW	0.04	-0.50	0.20	0.29	------	0.58	0.003	0.18	0.80
BY	0.88	-0.40	0.13	0.28	0.03	-------	0.005	-0.08	0.84
EOP%	0.01	-0.27	0.09	0.15	0.01	0.48	---------	-0.14	0.34
HI	0.51	-0.15	0.09	0.06	0.01	-0.14	-0.003	-------	0.38
Residual	0.11								

Table 5. Correlation coefficients for studied traits at moderate location in cumin

	SPP	UPP	SPU	TSW	BY	EOP%	HI	SY
SPP	1							
UPP	0.92**	1						
SPU	0.93**	0.71**	1					
TSW	0.81**	0.84**	0.64*	1				
BY	0.57	0.52	0.60*	0.39	1			
EOP%	0.60*	0.49	0.65*	0.40	0.90**	1		
HI	-0.01	0.15	-0.08	0.06	0.13	0.02	1	
SY	0.45	0.46	0.47	0.32	0.88**	0.80**	0.57	1

**.Correlation is significant at the 0.01 level
*.Correlation is significant at the 0.05 level

Table 6. Path analysis for studied traits at moderate location (yield as dependent variable) in cumin.

		Indirect effects							
Variables	Direct effects	SPP	UPP	SPU	TSW	BY	EOP%	HI	Total
SPP	-0.05	------	-0.08	0.08	0.02	0.41	0.08	0.00	0.45
UPP	-0.08	-0.05	-------	0.06	0.02	0.37	0.06	0.07	0.46
SPU	0.07	-0.05	-0.06	------	0.01	0.43	0.08	-0.04	0.47
TSW	0.02	-0.04	-0.07	0.06	-------	0.28	0.05	0.03	0.32
BY	0.72	-0.03	-0.04	0.05	0.01	--------	0.12	0.07	0.88
EOP%	0.13	-0.03	-0.04	0.06	0.01	0.65	----------	0.01	0.80
HI	0.49	0.00	-0.01	-0.01	0.00	0.10	0.00	--------	0.57
Residual	0.086								

seed per umbel (r= 0.64*), number of umbel per plant (r= 0.84**) and number of seed per plant (r= 0.81**) positively and significantly. Between number of umbel per plant and number of seed per plant (r= 0.92**) correlation was positive and significant. Correlation of number of seed per umbel and number of seed per plant (r= 0.93**) was positive and significant.

Based on path analysis at moderate location biological yield (0.72), harvest index (0.49) and essence percent (0.13) had high, positive direct effect on seed yield, but, number of umbel per plant and number of seed per plant had negative direct effect on yield (Table 6). Biological yield through essence percent (0.65) and number of seed per umbel (0.43), number of seed per plant (0.41), number of umbel per plant (0.37) and thousand seed weight (0.28), through biologic yield had maximum, positive indirect effects on yield at tropical location (Table 6). Correlation of essence percent and other characters were not significant in tropical location

Table 7. Correlation coefficients for studied traits at cold location in cumin.

	SPP	UPP	SPU	TSW	BY	EOP%	HI	SY
SPP	1							
UPP	0.89**	1						
SPU	0.93**	0.69*	1					
TSW	0.77**	0.79**	0.60*	1				
BY	0.89**	0.86**	0.78**	0.72**	1			
EOP%	0.62*	0.56	0.50	0.78**	0.63*	1		
HI	-0.02	0.15	-0.22	0.18	-0.09	0.42	1	
SY	0.49	0.60*	0.25	0.59*	0.49	0.75**	0.82**	1

**.Correlation is significant at the 0.01 level
*.Correlation is significant at the 0.05 level

Table 8. Path analysis for studied traits at cold location (yield as dependent variable) in cumin.

		Indirect effects							
Variables	Direct effects	SPP	UPP	SPU	TSW	BY	EOP%	HI	Total
SPP	0.51	------	-0.33	-0.28	0.06	0.56	-0.03	-0.02	0.49
UPP	-0.37	0.46	-------	-0.21	0.07	0.54	-0.03	0.14	0.60
SPU	-0.30	0.48	-0.25	------	0.05	0.49	-0.02	-0.19	0.25
TSW	0.08	0.39	-0.29	-0.18	-------	0.46	-0.04	0.16	0.59
BY	0.63	0.46	-0.31	-0.23	0.06	--------	-0.03	-0.08	0.49
EOP%	-0.05	0.32	-0.21	-0.15	0.07	0.40	---------	0.37	0.75
HI	0.88	-0.01	-0.06	0.07	0.02	-0.06	-0.02	--------	0.82
Residual	0.05								

but were significant in moderate location. This result showed that control of essence percent in the moderate location was easier than in the tropical location, because 3 characters had significant correlation with essence percent.

Correlation and path analysis for cold location

Significantly positive correlations were observed between yield and number of umbel per plant (r= 0.60*), thousand seed weight (r= 0.59*), essence percent (r= 0.75**), and harvest index (r= 0.82**) in cold location (Table 7). Biological yield correlated positively and significantly with number of umbel per plant (r= 0.86**), number of seed per plant (r= 0.89**), number of seed per umbel (r= 0.78**) and thousand seed weight (r= 0.72**). Correlation of essence percent with number of seed per plant (r= 0.62*), thousand seed weight (r= 0.78**) and biologic yield (r= 0.63*) were significantly positive at cold location (Table 8). Correlation of thousand seed weight and number of umbel per plant (r= 0.79**), number of seed per plant (r= 0.77**), number of seed per umbel (r= 0.60*) was positive and significant. Between number of seed per umbel and number of umbel per plant (r= 0.69*) and number of seed per plant (r= 0.93**) correlation coefficients were positive and significant. Number of umbel per plant and number of seed per plant had positive, significant correlation (r= 0.93**). Path analysis results (Table 8) showed that there were highly positive direct effects for biologic yield (0.63), number of seed per plant (0.51) and harvest index (0.88) on seed yield at cold location, but the effect of number of seed per umbel (-0.30) and number of umbel per plant (-0.37) on yield were negative at cold location (Table 8).

Number of seed per plant (0.56), number of umbel per plant (0.54), number of seed per umbel (0.49), thousand seed weight (0.46) affected seed yield through biological yield positively and indirectly. Seed yield was affected by positive, indirect effects of biologic yield on essence percent (0.40) at cold location (Table 8). These indirect effects through biological yield upon seed yield were different from one location to another. These results showed that there were different correlation coefficients between yield and its components as well as between essence percent and yield components at different locations. There was no significant correlation between essence percent and yield components at tropical location. Panesar & Jadeja (2008) reported positive significant correlation for number of umbel per plant and yield and between biologic yield and yield in cumin. These results showed that yield was affected by different components at different locations. They carried out a path analysis for morphological traits in cumin**.** Path analysis for seed yield of black cumin (*Nigella sativa* L.) showed positive effect of number of seeds per plant on seed yield (D'Antuono 2002) as in this experiment was observed for cold location. Indirect effects of biological yield were high (Table 5, 6 and 8). This means biological yield affected the seed yield indirectly.

Conclusion and recommendation

Our research was a first investigation to evaluate the variation of path analysis and correlation in cumin at different locations. Based on our finding cumin yield was affected by different yield components at different locations. To gain maximum seed and essence of cumin, moderate location is recommended. Complicated relationships between seed yield and essential oil of cumin have needed to be detected, as we found similarity for maximum seed yield and essence in our experiment.

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