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Original article

Estimation general combining ability of fruit yield, essential oil content and physiological traits related to drought stress tolerance in coriander through polycross method

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Extended abstract

Introduction

Coriander (*Coriandrum sativum* L.) is an annual herb of the umbel family and is belonged from North Africa to south-western of Asia. Coriander is one of the important medicinal plant that used in the pharmaceutical industry and it mainly cultivated and widely distributed for the fruits. The dried fruits are widely employed as a condiment, especially for flavoring of sauces, meat products and bakery and confectionery items. Also, coriander fruits are as a source of essential oils and fatty oil. Water deficit stress is one of the most important factors limiting the growth and survival of plants in arid and semi-arid regions of the world. Water is a major component of the fresh produce and significantly effects on weight and quality of plants. Also, water deficit may cause significant changes in the yield and composition of essential oils in aromatic and medicine plants. So that, was reported that water deficit increased essential oil percentage in coriander but decreased essential oil yield. Iran with an average annual rainfall of 240 mm is included among arid and semi-arid regions of the world. Of the million hectares of cultivated region, only five millions are under irrigation because of intense water limitations. However, Iran is one of the world's commercial coriander producers. Coriander has been cultivated for many years in different parts of Iran. Therefore, development of drought-tolerant cultivars with high essential oil yield is important in coriander. The objective of this study was evaluation general combination ability of endemic coriander genotypes for fruit yield, yield components and essential oil content under different watering regimes .

Materials and Methods

F14 half sib families including TN-59-10, TN-59-36, TN-59-80, TN-59-158, TN-59-160, TN-59-164, TN-59-230, TN-59-306, TN-59-347, TN-59-353, TN-59-357, TN-59-422, TN-59-450 and commercial genotype were evaluated in randomized complete block design with three replications in each experiment during growing season of 2016 in the research field of Tarbiat Modares University. Plants were treated with different levels of water treatment: well watered (WW), moderate water stress (MWS) and severe water stress (SWS).

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Results and Discussion

Results of data analysis revealed that total chlorophyll (86.32%), fruit yield (98.56%) and essential oil content (48.85%) exhibited the most phenotypic coefficients of variation in non-stress, moderate stress and severe stress conditions, respectively. Also, the most genotypic coefficients of variation in non-stress, moderate stress and severe stress estimated for essential oil content (79.86%), fruit yield (43.76%) and essential oil content (45.5%) respectively. Results of cluster analysis using general combining ability (GCA) data revealed that F8, F9, F10 and F14 are suitable for synthetic variety production to cultivate in full irrigated condition because these genotypes had high GCA for fruit yield and its component. F1, F7 and F11 are suitable to produce high fruit and essential oil yielding variety in moderate drought stress. Also, F6, F7, F11, F13 and F14 suggested as donor for fruit yield and F1, F3, F7, F9 and F12 for essential oil content in severe drought stress.

Conclusion

Generally, the results indicated that that F8, F9, F10 and F14 are suitable for synthetic variety production to cultivate in full irrigated condition because these genotypes had high GCA for fruit yield and its component. F1, F7 and F11 are suitable to produce high fruit and essential oil yielding variety in moderate drought stress. Also, F6, F7, F11, F13 and F14 suggested as donor for fruit yield and F1, F3, F7, F9 and F12 for essential oil content in severe drought stress.

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***Keywords*:** Coriander, Essential oil yield, Ideal genotype, Stability

Table 1. The gene bank code of the Iranian endemic coriander accessions and their half sib family number

Family	Code	Family	Code
F8	TN-59-306	F1	TN-59-10
F9	TN-59-347	F2	TN-59-36
F10	TN-59-353	F3	TN-59-80
F11	TN-59-357	F4	TN-59-158
F12	TN-59-422	F5	TN-59-160
F13	TN-59-450	F6	TN-59-164
F14	Commercial	F7	TN-59-230

Table 2. Descriptive statistics and stress intensity (percent of reduction) on measured traits in Iranian endemic half-sib coriander families under different irrigation regimes

Trait	Well water			Mild drought stress				Severe drought stress			
	Min	Max	Mean	Min	Max	Mean	Percent of reduction	Min	Max	Mean	Percent of reduction
SPAD chlorophyll content	37.20	54.50	44.59	34.00	50.80	42.40	4.91	12.40	40.00	31.18	30.08
$T_{1.2}$*	0.20	0.50	0.37	0.17	0.56	0.34	14.43	0.15	0.66	0.40	7.50
F_M	0.13	0.25	0.17	0.15	0.23	0.19	-8.91	0.16	0.28	0.20	-15.98
F_0	0.12	0.16	0.14	0.13	0.17	0.15	-7.51	0.12	0.20	0.15	-13.67
F_V	0.03	0.11	0.10	0.02	0.08	0.04	17.76	0.01	0.10	0.05	20.00
$F_V.F_M$	0.02	0.44	0.20	0.09	0.35	0.21	2.60	0.06	0.38	0.22	9.09
Essential oil yield (µl g^{-1})	0.03	0.90	0.48	0.13	1.27	0.62	-133.92	0.20	1.17	0.60	-125.90
Fruit yield (g $plant^{-1}$)	2.80	12.20	6.75	0.48	5.14	1.89	71.92	0.25	2.16	1.01	84.97
Relative water content (%)	71.57	96.15	85.24	70.52	102.25	87.66	0.44	60.87	93.53	77.77	11.66
Ion leakage (%)	80.80	97.51	88.96	90.51	98.89	94.12	-5.81	84.99	97.16	91.98	-3.40
Chlorophyll a (mg g^{-1})	0.35	0.79	0.57	0.08	0.52	0.33	42.37	0.23	0.57	0.37	34.59
Chlorophyll b (mg g^{-1})	0.12	0.59	0.26	0.12	0.34	0.23	12.42	0.10	0.28	0.17	34.79
Carotenoids (mg g^{-1})	2.86	7.00	4.93	1.20	6.16	3.54	28.13	1.69	6.69	4.70	4.63
Total chlorophyll (mg g^{-1})	0.60	1.21	0.85	0.21	0.81	0.56	34.22	0.37	0.76	0.54	36.02
Chl a.b	0.93	4.10	2.41	0.51	3.07	1.47	38.76	1.27	3.86	2.30	4.28

* ½ time for reaching fluorescence from F_0 to F_M

Table 3. Inheritance related estimates of measured traits in Iranian endemic half-sib coriander families under different irrigation regimes

Trait	Phenotypic coefficient of variation (%)			Genotypic coefficient of variation (%)		
	Well water	Mild drought stress	Severe drought stress	Well water	Mild drought stress	Severe drought stress
SPAD chlorophyll content	10.51	10.40	19.01	9.72	6.05	18.51
$T_{1.2}$*	19.36	26.17	37.52	17.68	10.77	1.29
F_M	41.02	10.96	13.99	11.60	10.05	11.73
F_0	69.60	7.85	10.76	18.82	7.38	7.88
F_V	14.42	37.86	48.02	513.5	26.95	32.12
$F_V.F_M$	43.95	29.32	35.88	39.44	17.60	19.87
Essential oil yield (µl.g^{-1})	83.24	46.91	48.85	79.86	28.06	45.50
Fruit yield (g $plant^{-1}$)	27.24	98.56	39.34	22.13	43.76	37.34
Relative water content (%)	6.20	10.91	12.79	3.79	8.36	9.60
Ion leakage (%)	4.09	2.21	3.54	2.68	1.48	3.15
Chlorophyll a (mg.g^{-1})	19.27	33.80	20.86	16.66	2.73	18.84
Chlorophyll b (mg.g^{-1})	39.62	23.65	24.35	28.61	16.88	16.88
Carotenoids (mg.g^{-1})	22.77	24.73	21.61	19.16	24.73	14.49
Total chlorophyll (mg.g^{-1})	86.32	28.22	18.17	59.69	10.10	16.98
Chl a.b	59.82	23.57	27.88	53.48	0.68	11.80

Table 3. Continued

Trait	Broad sense heritability (%)			Genetic advance (%)		
	Well water	Mild drought stress	Severe drought stress	Well water	Mild drought stress	Severe drought stress
SPAD chlorophyll content	85.52	50.41	94.80	18.10	9.03	36.21
$T_{1.2}^{*}$	83.33	14.48	0.12	29.00	8.65	0.09
F_M	8.00	74.15	70.33	2.35	17.89	20.61
F_0	7.31	78.99	53.60	1.07	12.75	12.27
F_V	91.80	53.53	44.74	90.24	41.71	44.73
$F_V.F_M$	80.53	41.37	30.66	76.29	24.11	22.97
Essential oil yield ($\mu l.g^{-1}$)	92.05	38.37	86.78	93.85	36.31	85.18
Fruit yield ($g.plant^{-1}$)	65.99	68.48	90.12	46.11	75.29	79.67
Relative water content (%)	37.36	74.58	56.25	4.84	14.75	14.46
Ion leakage (%)	43.03	47.37	79.39	3.55	2.06	5.87
Chlorophyll a ($mg.g^{-1}$)	74.73	0.51	81.58	28.96	0.44	35.08
Chlorophyll b ($mg.g^{-1}$)	52.16	91.87	48.04	41.92	41.86	23.87
Carotenoids ($mg.g^{-1}$)	70.86	56.77	44.96	32.55	37.45	19.73
Total chlorophyll ($mg.g^{-1}$)	47.82	13.53	87.26	18.13	7.93	31.97
Chl a.b	79.93	0.03	17.90	49.54	0.03	10.37

جدول ۴. ترکیب‌پذیری عمومی فامیل‌های نیمه خواهری گشنیز در شرایط عدم تنش

Table 4. General combining ability of coriander half-sib families in non-stress conditions

صفت	families فامیل‌ها														
Trait	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**LSD**
محتوای کلروفیل **SPAD chlorophyll content**	-1.29	8.61	-2.46	1.81	-0.29	-6.19	-1.02	8.81	1.51	-0.16	-5.42	-4.29	-1.52	1.86	3.00
$T_{1.2}^{*}$	0.09	0.07	0.00	-0.05	0.07	-0.05	0.01	0.04	-0.05	0.08	-0.01	0.01	-0.16	-0.02	0.04
فلورسانس بیشینه F_M	-0.01	0.03	-0.02	-0.01	0.00	0.00	0.06	-0.03	0.00	-0.01	0.01	0.00	-0.01	-0.01	0.01
فلورسانس کمینه F_0	-0.01	-0.01	0.00	-0.01	-0.01	0.00	0.01	-0.01	0.01	0.00	0.01	0.02	-0.01	0.00	0.01
فلورسانس متغیر F_V	-0.01	0.04	-0.01	0.00	0.01	0.00	0.06	-0.02	-0.02	-0.02	0.00	-0.02	0.00	-0.01	0.01
عملکرد کوانتومی $F_V.F_M$	-0.01	0.18	-0.04	0.01	0.05	0.00	0.19	-0.08	-0.09	-0.08	0.01	-0.10	-0.01	-0.05	0.07
عملکرد اسانس **Essential oil yield** ($\mu l\ g^{-1}$)	-0.06	-0.23	-0.10	-0.23	0.10	0.60	0.35	-0.22	-0.09	0.02	-0.23	0.07	-0.15	0.14	0.11
عملکرد میوه دربوته **Fruit yield** ($g.plant^{-1}$)	-2.59	-3.01	-6.43	5.68	-4.26	-1.62	5.45	4.22	-0.40	-1.95	5.60	-4.78	2.97	1.17	2.98
محتوای رطوبت نسبی **Relative water content** (%)	-4.05	0.77	1.09	-0.39	1.88	-0.92	6.41	0.88	1.48	-1.70	0.92	-5.28	1.39	-2.52	7.26
نشت یونی **Ion leakage** (%)	-3.83	0.42	-1.35	1.01	-1.15	1.05	0.65	-1.58	-0.18	-1.05	4.02	1.02	-0.22	1.15	4.61
کلروفیل **a** **Chlorophyll a** ($mg.g^{-1}$)	-0.13	0.11	0.02	-0.06	-0.03	-0.12	-0.04	0.00	0.04	0.10	0.08	-0.08	-0.12	0.20	0.09
کلروفیل **b** **Chlorophyll b** ($mg.g^{-1}$)	-0.10	-0.02	-0.04	-0.10	0.20	-0.08	-0.07	0.02	0.00	0.03	-0.04	0.10	-0.01	0.11	0.12
کارتنوید **Carotenoids** ($mg.g^{-1}$)	-0.90	-0.28	-1.04	1.38	-0.83	-1.28	-1.32	0.59	1.61	1.30	-0.27	-0.08	0.31	0.68	1.02
کلروفیل کل **Total chlorophyll** ($mg\ g^{-1}$)	-0.15	0.07	-0.03	-0.17	0.16	-0.21	-0.12	0.02	0.03	0.11	0.03	0.00	-0.03	0.29	0.16
کلروفیل **a.b** **Chl a.b**	0.26	0.50	0.33	0.85	-1.19	-6.19	0.63	-0.30	-0.02	0.00	0.51	-1.03	-0.34	-0.26	0.88

جدول ۵. ترکیب‌پذیری عمومی فامیل‌های نیمه خواهری گشنیز در شرایط تنش ملایم

Table 5. General combining ability of coriander half-sib families in mild drought stress conditions

صفت Trait	فامیل‌ها families														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	LSD
محتوای کلروفیل SPAD chlorophyll content	1.20	-1.83	0.73	1.70	-4.57	0.40	-4.90	1.13	1.80	-4.87	0.33	2.50	1.50	4.87	4.27
$T_{1.2}^{*}$	0.09	0.05	-0.03	-0.02	0.04	-0.09	0.07	-0.10	-0.08	0.00	0.02	0.00	0.07	-0.06	0.15
فلورسانس بیشینه F_M	0.01	0.03	-0.01	-0.02	0.01	-0.02	0.01	0.03	0.02	0.03	-0.01	-0.01	-0.01	-0.03	0.02
فلورسانس کمینه F_0	0.02	0.00	-0.01	-0.01	0.02	-0.01	0.01	0.02	-0.01	0.02	-0.01	-0.01	0.00	-0.02	0.01
فلورسانس متغیر F_V	0.01	0.03	0.00	-0.02	-0.01	-0.01	0.00	0.01	0.00	0.01	-0.01	-0.01	-0.01	-0.01	0.02
عملکرد کوانتومی $F_V.F_M$	0.02	0.12	0.01	-0.05	-0.05	-0.05	0.02	0.03	0.03	0.01	-0.02	-0.02	-0.04	-0.02	0.08
عملکرد اسانس Essential oil yield ($\mu l.g^{-1}$)	0.50	0.22	-0.12	-0.03	-0.09	0.08	0.09	-0.21	-0.26	-0.06	-0.25	-0.04	-0.14	0.30	0.37
عملکرد میوه دربوته Fruit yield ($g.plant^{-1}$)	-0.63	-0.20	0.55	-0.35	0.28	0.47	0.81	-1.25	-0.71	-0.76	2.37	-0.07	-0.58	0.07	1.01
محتوای رطوبت نسبی Relative water content (%)	7.91	-14.39	3.18	0.07	-5.70	6.68	6.56	-12.07	4.14	-11.75	4.75	6.80	1.24	2.53	7.18
نشت یونی Ion leakage (%)	3.06	-1.26	-1.59	-0.72	0.12	-0.03	2.26	-0.97	0.23	-1.95	3.04	-0.55	-0.75	-0.88	2.47
کلروفیل a Chlorophyll a ($mg.g^{-1}$)	-0.03	0.01	0.09	0.05	0.07	-0.06	-0.16	-0.01	0.08	0.00	-0.06	0.02	-0.03	0.02	0.22
کلروفیل b Chlorophyll b ($mg.g^{-1}$)	-0.04	0.01	0.02	0.05	-0.03	-0.01	-0.07	0.02	0.05	-0.03	-0.03	-0.01	-0.02	0.08	0.06
کارتنوید Carotenoids ($mg.g^{-1}$)	0.07	0.63	0.98	0.90	-0.03	-0.60	-1.39	-1.30	2.09	-0.15	-0.16	0.53	-0.32	-1.26	1.28
کلروفیل کل Total chlorophyll ($mg.g^{-1}$)	-0.07	0.02	0.12	0.11	0.03	-0.07	-0.24	0.01	0.13	-0.03	-0.09	0.01	-0.05	0.10	0.24
کلروفیل a.b Chl a.b	0.18	-0.01	0.18	-0.12	0.54	-0.23	-0.49	-0.10	-0.01	0.36	-0.07	0.17	-0.08	-0.35	0.96

جدول ۶. ترکیب‌پذیری عمومی فامیل‌های نیمه خواهری گشنیز در شرایط تنش شدید

Table 6. General combining ability of coriander half-sib families in severe drought stress conditions

صفت Trait	فامیل‌ها families														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	LSD
محتوای کلروفیل SPAD chlorophyll content	-0.08	7.46	2.22	1.26	1.19	1.22	-17.74	1.72	0.29	6.26	-3.48	0.06	-2.01	1.62	2.27
$T_{1.2}^{*}$	-0.03	0.09	-0.04	0.03	0.06	-0.04	0.00	-0.03	0.14	-0.11	-0.06	0.01	-0.12	0.10	0.24
فلورسانس بیشینه F_M	-0.02	0.04	-0.02	0.01	0.02	-0.02	-0.02	0.03	-0.01	0.05	-0.02	0.00	-0.01	-0.02	0.03
فلورسانس کمینه F_0	-0.01	0.02	-0.01	0.00	0.03	-0.01	-0.02	0.00	-0.01	0.02	0.00	0.00	0.00	0.00	0.02
فلورسانس متغیر F_V	-0.01	0.01	-0.01	0.01	0.00	-0.02	0.00	0.02	-0.01	0.03	-0.02	0.00	-0.01	-0.02	0.02
عملکرد کوانتومی $F_V.F_M$	-0.03	0.03	-0.03	0.06	-0.03	-0.06	0.05	0.08	-0.01	0.08	-0.08	0.02	-0.01	-0.06	0.10
میزان اسانس میوه Essential oil yield (µl g^{-1})	0.14	-0.08	-0.29	-0.37	-0.32	0.46	0.25	0.21	0.20	-0.12	-0.16	0.45	-0.14	-0.24	0.18
عملکرد میوه دربوته Fruit yield (g $plant^{-1}$)	-0.05	0.05	0.27	-0.15	-0.38	0.12	0.85	-0.60	-0.47	-0.43	0.30	0.31	-0.15	0.37	0.38
محتوای رطوبت نسبی Relative water content (%)	7.87	-12.35	2.88	-0.17	-12.44	8.25	2.26	-5.40	-4.39	-8.57	11.29	7.70	-7.12	10.08	11.05
نشت یونی Ion leakage (%)	2.62	-2.31	1.08	-4.29	-3.92	0.95	4.19	0.29	0.58	1.42	1.72	-6.31	2.33	1.52	2.48
کلروفیل a Chlorophyll a (mg g^{-1})	-0.02	-0.05	-0.05	-0.02	0.12	0.04	-0.06	0.05	-0.08	-0.01	0.04	-0.13	0.13	0.02	0.06
کلروفیل b Chlorophyll b (mg g^{-1})	-0.02	-0.04	-0.01	-0.03	0.04	0.01	0.04	-0.02	-0.03	-0.02	0.06	-0.02	0.06	-0.03	0.05
کارتنوید Carotenoids (mg g^{-1})	-0.09	-0.02	-0.23	0.52	0.44	1.19	-2.15	-0.41	-0.71	-0.31	0.60	-0.10	0.65	0.63	1.27
کلروفیل کل Total chlorophyll (mg g^{-1})	-0.04	-0.08	-0.06	-0.04	0.15	0.05	-0.02	0.03	-0.10	-0.02	0.10	-0.15	0.17	0.00	0.06
کلروفیل a.b Chl a.b	0.11	0.23	-0.25	0.26	0.10	0.15	-0.84	0.63	-0.25	0.26	-0.43	-0.71	0.28	0.46	0.98

جدول ۷. انحراف میانگین ترکیب‌پذیری عمومی گروه‌ها از میانگین کل در شرایط بدون تنش، تنش ملایم و تنش شدید

Table 7. General combining ability mean value deviation of groups from their total mean in different irrigation regimes for measured traits in Iranian endemic half-sib coriander families

	شرایط بدون تنش Well water				تنش ملایم Mild drought stress			تنش شدید Severe drought stress				
صفت Trait	گروه اول Group 1	گروه دوم Group 2	گروه سوم Group 3	گروه چهارم Group 4	گروه اول Group 1	گروه دوم Group 2	گروه سوم Group 3	گروه اول Group 1	گروه دوم Group 2	گروه سوم Group 3	گروه چهارم Group 4	گروه پنجم Group 5
محتوای کلروفیل SPAD chlorophyll content	3.01	-2.29	-2.51	-2.51	1.93	-1.12	-2.53	0.62	-0.66	-17.74	4.18	1.19
$T_{1.2}^{*}$	0.01	0.04	-0.03	-0.03	-0.03	0.06	0.00	0.02	-0.03	0.00	-0.01	0.06
فلورسانس پیشینه F_M	-0.01	0.00	-0.01	-0.01	-0.01	0.00	0.02	-0.01	-0.02	-0.02	0.03	0.02
فلورسانس کمینه F_0	0.00	0.01	0.00	0.00	-0.01	0.00	0.01	-0.01	0.00	-0.02	0.01	0.03
فلورسانس متغیر F_V	-0.02	-0.01	0.00	0.00	-0.01	0.00	0.01	-0.01	-0.02	0.00	0.02	0.00
عملکرد کوانتومی $F_V.F_M$	-0.07	-0.02	-0.01	-0.01	-0.02	0.01	0.03	-0.01	-0.05	0.05	0.06	-0.03
میزان اسانس میوه Essential oil yield (µl g^{-1})	-0.04	0.09	-0.03	-0.03	-0.03	0.11	-0.03	0.13	-0.02	0.25	-0.09	-0.32
عملکرد میوه دریوته Fruit yield (g $plant^{-1}$)	0.76	-4.52	0.60	0.60	-0.09	0.85	-0.48	0.01	0.16	0.85	-0.29	-0.38
محتوای رطوبت نسبی Relative water content (%)	-0.46	-1.70	-0.32	-0.32	3.52	6.41	-10.97	3.52	5.63	2.27	-6.61	-12.43
نشت یونی Ion leakage (%)	-0.41	-0.06	0.11	0.12	-0.61	2.78	-1.01	-0.50	4.20	1.64	-1.21	-3.91
کلروفیل a Chlorophyll a (mg g^{-1})	0.09	-0.05	-0.05	-0.05	0.02	-0.08	0.03	-0.07	0.06	-0.06	-0.01	0.12
کلروفیل b Chlorophyll b (mg g^{-1})	0.04	0.15	-0.06	-0.06	0.03	-0.05	-0.01	-0.02	0.03	0.04	-0.03	0.04
کارتنوید Carotenoids (mg g^{-1})	1.05	-0.45	-0.29	-0.29	0.33	-0.49	-0.21	-0.28	0.77	-2.15	-0.06	0.44
کلروفیل کل Total chlorophyll	0.11	0.08	-0.09	-0.09	0.05	-0.13	0.01	-0.09	0.08	-0.02	-0.03	0.15
کلروفیل a.b Chl a.b	-0.14	-1.11	0.28	0.27	-0.06	-0.12	0.20	-0.28	0.12	-0.84	0.35	0.10

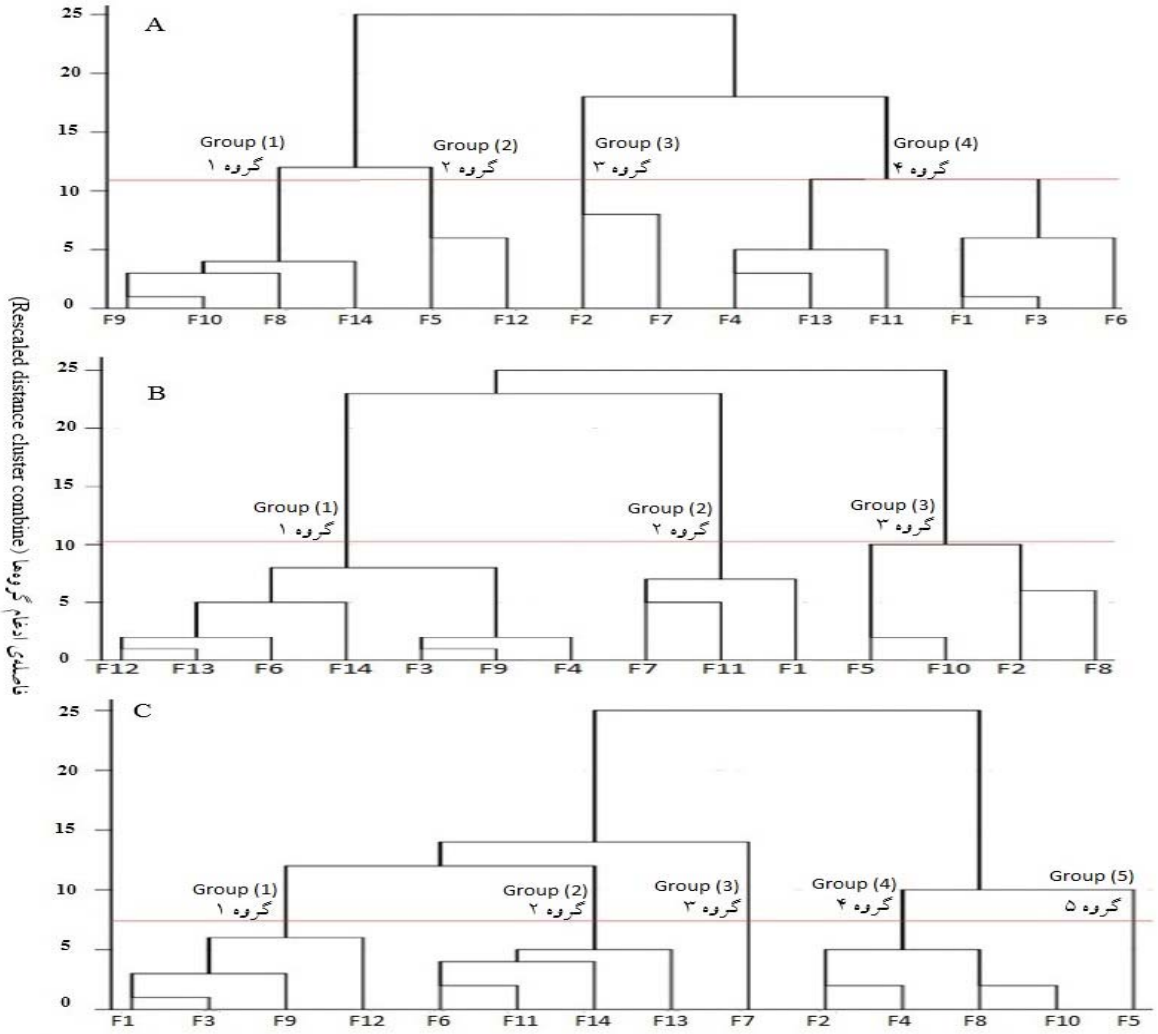

Fig. 1. Dendrogram clustering of 14 half-sib coriander families using general combining ability values in well watered (A), mild drought stressed (B) and severe drought stressed (C) conditions