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Evaluation of Genetic Variations in Iranian Confectionery Sunflower Landraces (*Helianthus annuus* L.) under Various Water Treatment Conditions

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Abstract

In order to evaluate morpho-physiological traits of confectionery sunflower under different irrigation regimes, an experiment was carried out under field conditions in Agricultural Research Center of West-Azerbaijan province, Urmia, Iran in 2012. Fifty six confectionery sunflower landraces were arranged in 7 × 8 rectangular lattice design with two replications in each one of well-watered, moderate and severe stress conditions with 50%, 70% and 90% depletion of available water, respectively. Combined analyses of variance revealed significant effect of genotype, irrigation regime and their interaction on studied traits including grain yield, chlorophyll content, grain and kernel weight, grain length and width and kernel/grain ratio. 'Urmia-Anghane 4', ' Urmia-Gharagoz 1' and 'Salmas-Sadaghian' produced the highest grain yield (6310.31), (3778.83) and (2217.95 kg/h), under well-watered, moderate and sever stresses, respectively. In contrast 'Mashhad', 'Piranshahr-Andizeh' and ‘‘Mashhad’’ presented the lowest values. Severe drought stress caused 49% reduction in grain yield compared to well-watered condition. 'Shabestar-Kouzeh Kanan 2' (46.05) and 'Urmia-Heydarlou 1' (19.47) showed the highest and lowest chlorophyll content under well-watered and severe drought stress conditions, respectively. The high grain length was seen in 'Marand-Dizaj-Ghalami' landrace (29.59 mm). Under the well-watered, moderate and severe stress conditions, grain yield had significantly positive correlations with kernel and grain weight and grain width and length. Based on cluster analysis, the studied landraces were grouped in three clusters both in well-watered and severe stress conditions. But under moderate stress conditions, the studied landraces were grouped in five clusters. Considering all studied traits, the landraces 1, 2, 3, 4, 5, 11, 12, 13, 49, 55, 56 were superior genotypes under well-watered conditions. In moderate and severe stress conditions, the best landraces were (12, 35, 26, 31, 32, 56) and (2, 3, 5, 7, 9, 11, 12, 14, 15, 18, 22, 25, 27, 30, 31, 42, 43 46, 47, 55), respectively.

Keywords: Chlorophyll content; Drought stress; Grain yield; Landraces; Sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops due to its high content of unsaturated fatty acids and a lack of cholesterol (Goksoy *et al*. 2004). Sunflower as an important annual oil seed crop has been cultivated for centuries, particularly in the developing countries of Asia and Africa, for its high content of edible oil (42-54%) and protein (22-25%) (Afkari Bajehbaj 2010). Presently, sunflower is cultivated in an area of 24.8 million hectare with a production of 37.4 million ton (FAO 2012). Length and width of grain in confectionery sunflower varies between 6 to 25 and 3 to 13 mm, respectively. Grain length is one of the most important factors that play a main role in determining the price of confectionery sunflower. Drought stress decreases growth and crop productivity due to reductions in leaf water potential and cell division and enlargement rate (Kiani *et al*. 2007; Hussain *et al*. 2012). Drought stress reduces dry matter accumulation in all plant organs, although different organs manifest varying degrees of reduction (Asrar and Elhindi 2011). Drought stress decrease grain filling period, grain length and yield potential (De Souza *et al*. 1997).

Drought stress increase the proline, soluble sugars and total chlorophyll content as well as unfilled or hollow grains in sunflower (Oraki *et al*. 2012). Dwarf sunflower genotypes are more tolerant than tall ones; they have shown small decrease in leaf osmotic potential in response to drought stress (Angadi and Entz 2012). Tabatabaei *et al*. (2012) showed that deficit irrigation significantly affected yield, yield components and qualitative traits in sunflower. Mirshekari *et al*. (2012) declared that the limited irrigation stress resulted in reduction in seed yield in sunflower due to limiting vegetative and reproductive developmental period.

The objective of the present study was to assess the effects of different water treatment levels on morpho-physiological traits in Iranian confectionery sunflower landraces (*Helianthus annuus* L.).

Material and Methods

A field study was carried out in Agricultural Research Center of West-Azerbaijan province, Urmia (37°44'N, 45°2'E, elevation 1352 m), Iran in 2012. Fifty six confectionery sunflower landraces were arranged in a 7 × 8 rectangular lattice design with two replications in each one of three irrigation regimes including well-watered, moderate and severe stresses with 50%, 70% and 90% depletion of available water, respectively. Irrigation volume was calculated by equation 1 (Alizadeh 2009):

$$V = \frac{(fc - \theta m) \times \rho \times D_{root} \times A}{Ei}$$

where, V= irrigation water volume (m^{-3}), θm=soil moisture weight percentage per replication, A= irrigated area (m^{-2}), FC= field capacity, ρ = soil density (g cm^{-3}), Droot= depth of root system development(m).

Each landrace was sown with 6 rows spaced 60 cm apart and interplant spacing was 30 cm. The distance between blocks was 4 m. Harvesting area was 3.6 m^2 from the two middle lines. Ten gram of grain was weighed and the kernels were separated for measuring the kernel/grain ratio. Grain length and width was measured from the 10 grains by caliper. Chlorophyll content was measured by using chlorophyll meter (OPTI SCIENCE CCM 200).

After testing the equality of error variances, the combined analysis of experiments was performed in the SAS 9.2 software (SAS Institute Inc., Cary, NC, USA). Genotypes mean were compared by the Tukey's test at a probability level of five percent. Classification of genotypes by using all traits data was performed via Ward algorithm based on squared Euclidean distances in the SPSS 20.00 software (SPSS/PC-20, SPSS Inc., Chicago, IL, USA; http://www.spss.com). Prior to squared Euclidean distance calculation, the data were standardized to have a mean of zero and a variance of one.

Results

Effects of different water treatment levels on morpho-physiological traits

Combined analysis of variance revealed significant effect of genotype and irrigation regimes on grain yield, chlorophyll content, kernel/grain ratio, kernel weight, grain weight and grain length and width. The effect of genotype × irrigation regime was only significant on grain yield, kernel/grain ratio and kernel weight (Table 1). The highest grain yield in well-watered

Table 1. Combined analysis of variance for traits of sunflower genotypes at different drought stress conditions

Source of variation	Degree of freedom	Mean of Square						
		Grain yield	Chlorophyll content	Kernel/grain ratio	Kernel weight	Grain weight	Grain length	Grain width
Environment	2	46277099.58**	1818.17**	1686.06**	11000.25**	16178.93**	87.43**	25.66**
Replication (Environment)	3	540221.39	8.44	50.63	381.43	996.33	2.22	3.39
Block (Replication /Environment)	42	507269.85**	23.15ns	48.98**	297.89**	1229.71**	20.32**	3.66**
Genotype	55	1380455.49**	50.75**	178.35**	618.24**	2675.40**	52.97**	11.57**
Environment × Genotype	110	298849.20*	16.28ns	14.04**	211.10**	962.71*	8.12ns	2.53**
E_e	123	213565.1	16.68	0.92	126.24	675.89	6.33	1.62
C.V.(%)	-	22.58	13.27	2.16	19.79	20.31	12.00	16.15

*,**,ns significant at the 5% and 1% probability levels and non-significant, respectively

conditions was related to 'Urmia-Anghane 4, Salmas- Gharagheshlagh-Ghalami, Urmia-Karimabad, Urmia-Babaghanje 6, Urmia-Vaghaslou-Olya 3, Urmia-Gharagoz 1, Urmia-Vaghaslou-Sofla 1, Urmia-Abajalou 1 and Hamadan 1' (Table 2). In the moderate stress condition, the maximum values of grain yield allocated to 'Urmia-Gharagoz 1, Urmia-Karimabad, Urmia-Abajalou 1, Urmia-Maranghalou 6, Salmas-Gharagheshlagh-Badami, Hamadan 1, Urmia-Heydarlou 1 and Urmia-Vaghaslou-Sofla 1 ' (Table 3). The highest grain yield in severe stress condition obtained by 'Salmas-Sadaghian, Saghez 3, Marand-Dizaj-Ghalami, Urmia-Saribaglou 5, Urmia-Maranghalou 6, Urmia-Karimabad and Salmas-Gharaghashlagh-Pesteii' (Table 4). Under moderate and severe drought stress conditions, grain yield averagely decreased 25% and 49% in comparison to the well-watered condition, respectively (Tables 2, 3, 4). The results are in concordance with Safavi *et al*. (2011). Farahvash *et al*. (2011) showed that with increasing water stress severity, seed yield per hectare, above ground dry weight of plant, stem diameter, head diameter, number of seeds per head, 100 seeds weight, harvest index and number of photosynthetically active leaves are decreased (Farahvash *et al*., 2011). Nezami *et al*. (2008) reported that sunflower grain yield is declined under dry and semi-dried conditions. Elena and Paula (2010) demonstrated that drought stress reduced grain yield. Esmaeilian *et al*. (2012) revealed that sunflower grain yield decreased significantly due to water stress imposed at either of the growth stages. Generally, drought stress reduces leaf area, stem extension and physiological activities as well as photosynthesis rate of plants resulting in decreasing seed yield (Anjum *et al*., 2011). Under well-watered, moderate and severe stress conditions, grain yield had significantly positive correlations with kernel and grain weight and grain width and length (Table 5, 6, 7). There was negative and significant correlation between kernel/grain ratio and grain width (Tables 5, 6, 7).

Table 2. Means of sunflower genotypes for different traits under optimum irrigation condition

No	Genotype	Grain yield Kg ha^{-1}	Chlorophyll content	Kernel/grain ratio	Kernel weight (mg)	Grain weight (mg)	Grain length (mm)	Grain width (mm)	No cluster
1	Saghez 1	3241.16	35.89	40.27	67.12	165.25	23.20	9.02	1
2	Urmia-Anghane 4	6310.31	39.52	47.95	81.76	169.37	27.11	8.76	1
3	Urmia-Barouj	3356.1	30.66	43.97	57.23	129.53	23.33	9.49	1
4	Urmia-Maranghalou	3001.29	38.15	57.89	87.50	149.59	26.61	9.68	1
5	Marand-Dizaj-Ghalami	3055.14	27.81	39.59	76.41	192.24	29.59	12.22	1
6	Urmia-Jabalkandi 2	2694.85	32.04	53.75	78.27	145.39	19.88	5.61	2
7	Salmas - Sadaghian	3177.57	41.01	52.12	65.75	123.09	21.62	8.78	3
8	Urmia-Babaghanje 6	3505.71	40.60	49.81	63.80	127.43	24.66	8.20	3
9	Miyaneh-Basin	1222.01	35.39	47.78	58.57	121.29	25.52	6.08	2
10	Boucan	2103.41	32.78	55.10	68.44	122.23	21.74	6.51	2
11	Urmia -Nuoshinshahr	3012.69	35.44	46.02	83.37	180.85	24.92	10.49	1
12	Urmia-Karimabad	3727.6	36.48	45.72	83.87	183.68	26.70	8.53	1
13	Urmia-Vaghaslou-Olya 1	2767.66	34.20	47.28	76.08	160.95	29.04	9.48	1
14	Urmia-Vaghaslou-Olya 3	3500.63	28.58	47.45	70.33	145.46	26.54	9.10	1
15	Urmia-Ordoshahi 1	2853.15	41.35	44.14	44.50	103.15	21.71	6.13	3
16	Marand-Yamchi-Pesteii	2802.66	32.80	47.13	39.77	83.91	14.97	8.38	2
17	Mazandaran-Tirtash	1674.6	36.22	39.28	55.50	144.19	19.00	7.74	2
18	Sardasht	2356.28	27.89	56.95	77.92	136.53	23.48	7.63	1
19	Marand-Yamchi 4	1783.79	32.33	49.45	51.79	107.10	20.16	5.97	2
20	Salmas 2	3037.05	30.10	58.41	80.20	138.67	21.19	8.01	1
21	Urmia-Vaghaslou-Olya 4	3055.31	29.42	44.03	71.63	162.55	23.39	8.04	1
22	Salmas-Gharaghashlagh- Pesteii	2691.58	28.91	50.30	72.37	144.69	17.95	8.62	1
23	Urmia-Lalalou-Torab 2	3418.23	41.27	45.39	76.22	166.85	24.01	6.46	1
24	Urmia-Shirabad 2	2591.88	34.60	41.77	63.57	150.33	26.21	6.79	1
25	Urmia-Gharagoz 1	3527.86	37.15	44.62	71.50	160.50	25.21	6.81	1
26	Urmia-Vaghaslou-Sofla 1	3635.87	27.54	47.82	54.46	115.78	26.10	6.45	1
27	Urmia-Khanneshan 1	3038.18	39.92	49.32	68.80	141.18	21.53	6.69	3
28	Urmia-Heydarlou 1	3103.74	31.64	42.54	58.99	136.20	24.43	7.42	1
29	Urmia-Saribaglou 5	3104.84	42.99	44.55	59.89	135.01	25.71	6.70	3
30	Urmia-Chongharalou-Yekan 4	2242.85	31.79	55.24	61.86	110.68	20.07	4.94	2
31	Urmia-Maranghalou 6	2961.75	37.62	48.12	71.99	150.12	26.08	7.88	1
32	Urmia-Abajalou 1	3505.04	36.36	48.34	74.24	154.25	25.70	7.81	1
33	Hamadan 1	3513.83	34.22	35.06	45.24	131.16	25.16	7.74	1
34	Saghez 2	2523.74	37.84	44.82	79.29	179.47	20.29	10.38	1
35	Piranshahr-Serokani	1529.61	36.56	56.19	57.43	99.95	18.69	8.21	2
36	Piranshahr Andizeh	1222.54	31.62	47.05	58.89	124.92	18.44	7.63	2
37	Mashhad	807.29	36.17	62.24	55.62	87.83	11.90	5.37	2
38	Shahroud 1	1700.84	31.40	45.72	40.06	86.60	16.21	4.71	2
39	Hamadan 2	2072.38	32.34	56.04	65.96	116.46	20.03	7.74	2
40	Shabestar-Kouzeh-Kanan 3	1425.82	31.76	51.66	22.86	43.90	17.11	6.23	2
41	Saghez 4	1458.13	34.82	46.17	65.20	141.29	20.33	8.71	2
42	Saghez 5	3036.85	42.39	48.24	85.92	175.33	25.33	10.69	1
43	Saghez 3	2381.37	43.57	46.16	55.28	121.27	24.03	7.18	3
44	Shahroud 2	1942.98	36.87	38.10	33.34	84.90	11.88	6.12	2
45	Urmia-Alibaglou 1	2332.27	28.95	45.68	51.77	114.21	17.39	7.06	2
46	Baneh 2	3241.16	35.89	40.27	61.91	131.85	16.71	12.79	1
47	Salmas-Gharagheshlagh- Ghalami	4283.31	39.52	47.95	85.28	184.15	20.19	10.67	1
48	Marand-1389-2	3356.1	30.66	43.97	80.69	165.54	16.47	10.41	1
49	Salmas-Gharaghashlagh- Badami	3341.03	35.69	33.74	61.54	180.84	25.21	12.88	1
50	Shabestar-Kouzeh Kanan 1	2389.97	37.12	47.88	50.48	105.11	15.78	6.72	2
51	Sanandaj	2757.08	36.33	57.26	73.98	127.08	18.04	6.46	2
52	Shabestar-Kouzeh-Kanan 2	2030.62	46.05	53.15	69.00	128.90	21.64	9.39	3
53	Baneh 3	2624.02	30.19	53.92	88.58	162.76	25.57	9.03	1
54	Piranshahr-Baleban	1759.35	28.76	51.69	51.01	97.82	18.04	6.61	2
55	Baneh 1	3141.86	29.80	47.19	91.77	195.62	19.53	14.15	1
56	Marand-1389-1	3307.52	36.37	55.09	88.42	160.68	24.66	9.70	1
	LSD (P<0/05)	1153.9	10.29	1.95	23.36	49.67	4.09	2.47	
	HSD (P<0/05)	2500.8	22.30	4.23	50.64	107.66	8.87	5.35	

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey's Test.

Table 3. Means of sunflower genotypes for different traits under moderate drought stress condition

No	Genotype	Grain yield Kg ha^{-1}	Chlorophyll content	Kernel/grain ratio	Kernel weight (mg)	Grain weight (mg)	Grain length (mm)	Grain width (mm)	No cluster
1	Saghez 1	2169.72	25.09	39.09	66.92	169.74	24.92	10.62	1
2	Urmia-Anghane 4	1807.79	27.35	45.53	51.11	110.81	22.27	7.01	1
3	Urmia-Barouj	1883.44	25.38	42.34	48.55	114.29	21.77	7.73	1
4	Urmia-Maranghalou	1615.43	28.84	53.94	79.66	146.52	22.36	6.36	2
5	Marand-Dizaj- Ghalami	1917.77	22.05	38.58	34.45	87.66	22.53	7.99	3
6	Urmia-Jabalkandi 2	2085.56	29.39	50.28	65.88	130.62	21.18	8.43	1
7	Salmas -Sadaghian	2211.75	32.16	43.64	44.30	99.73	17.02	6.27	2
8	Urmia-Babaghanje 6	2048.18	37.02	46.63	54.29	116.21	17.20	7.43	2
9	Miyaneh-Basin	1273.47	35.33	44.27	55.01	123.08	22.79	6.33	2
10	Boucan	973.88	30.97	49.89	45.89	91.99	16.70	6.05	2
11	Urmia - Nuoshinshahr	2482.86	31.68	43.38	62.14	143.18	21.98	7.88	1
12	Urmia-Karimabad	3611.45	27.29	41.63	75.80	180.86	24.06	8.66	4
13	Urmia-Vaghaslou-Olya 1	1328.74	33.19	44.12	57.87	132.84	23.71	7.15	2
14	Urmia-Vaghaslou-Olya 3	2686.43	28.49	42.48	59.94	140.18	18.75	6.19	1
15	Urmia-Ordoshahi 1	2208.24	30.23	47.01	57.63	122.29	23.01	7.87	1
16	Marand-Yamchi-Pesteii	2889.97	27.80	42.46	58.90	138.32	19.90	9.28	1
17	Mazandaran-Tirtash	1832.44	31.95	38.42	49.44	128.04	17.25	7.10	2
18	Sardasht	1816.67	32.01	55.36	61.38	111.85	23.24	6.62	2
19	Marand-Yamchi 4	1299.26	21.92	46.01	51.77	110.40	19.81	7.01	1
20	Salmas 2	2367.56	29.16	55.40	70.16	127.42	20.96	7.89	2
21	Urmia-Vaghaslou-Olya 4	1927.74	22.12	25.96	22.82	87.07	19.60	5.33	3
22	Salmas-Gharaghashlagh- Pesteii	2371.90	28.31	47.59	65.68	141.59	20.04	9.51	1
23	Urmia-Lalalou-Torab 2	2002.13	34.49	44.49	63.63	146.55	24.53	6.72	2
24	Urmia-Shirabad 2	2026.19	26.15	32.33	48.06	147.59	20.28	7.21	1
25	Urmia-Gharagoz 1	3778.83	32.34	41.94	83.34	201.72	27.36	8.36	4
26	Urmia-Vaghaslou-Sofla 1	2965.42	29.03	35.59	68.68	192.12	25.64	9.75	4
27	Urmia-Khanneshan 1	2467.21	34.79	49.28	67.02	141.86	24.09	7.03	2
28	Urmia-Heydarlou 1	2908.40	31.66	35.45	51.91	145.95	23.63	7.27	1
29	Urmia-Saribaglou 5	2853.26	32.85	40.34	49.29	122.14	30.31	7.73	2
30	Urmia-Chongharalou-Yekan 4	2344.98	28.27	50.55	56.62	112.91	25.40	8.65	1
31	Urmia-Maranghalou 6	3146.80	26.78	44.18	82.58	184.89	32.85	10.44	4
32	Urmia-Abajalou 1	3596.70	29.82	43.50	71.56	165.37	26.56	6.86	4
33	Hamadan 1	3033.53	30.09	34.69	50.33	144.53	22.42	8.57	1
34	Saghez 2	1799.07	33.43	40.43	44.31	111.20	14.57	9.86	5
35	Piranshahr-Serokani	1439.76	35.64	50.60	69.45	134.98	17.71	7.49	2
36	Piranshahr Andizeh	493.39	28.86	38.07	32.23	86.64	20.26	7.29	3
37	Mashhad	515.86	35.04	58.07	53.31	91.58	13.35	7.71	2
38	Shahroud 1	1315.93	28.65	36.71	24.31	68.20	14.70	7.30	3
39	Hamadan 2	1285.08	33.94	52.57	62.18	117.61	17.20	8.72	2
40	Shabestar-Kouzeh-Kanan 3	1324.07	33.59	48.32	51.85	108.22	21.38	6.25	2
41	Saghez 4	1177.20	34.44	45.06	76.67	171.70	19.21	9.72	2
42	Saghez 5	1645.39	34.36	45.62	49.58	107.53	17.55	7.65	2
43	Saghez 3	2183.06	39.96	42.66	63.22	148.39	22.82	10.25	2
44	Shahroud 2	1502.04	34.48	36.66	27.89	75.29	15.21	7.36	3
45	Urmia-Alibaglou 1	1948.10	32.09	42.10	41.75	98.29	21.46	8.46	2
46	Baneh 2	2009.26	35.38	41.02	62.02	152.83	15.51	11.18	5
47	Salmas-Gharagheshlagh- Ghalami	1987.24	30.59	45.01	55.27	123.15	14.44	15.01	5
48	Marand-1389-2	1721.08	27.80	45.76	59.72	128.89	15.62	11.89	5
49	Salmas-Gharaghashlagh- Badami	2949.06	31.40	31.61	55.21	178.07	21.81	14.91	5
50	Shabestar-Kouzeh Kanan 1	2305.50	32.60	45.52	69.66	152.06	19.23	8.19	1
51	Sanandaj	2045.97	32.48	53.42	68.97	130.20	19.32	7.30	2
52	Shabestar-Kouzeh-Kanan 2	1403.79	30.84	49.46	62.39	125.21	20.77	6.20	2
53	Baneh 3	1979.44	26.08	49.08	54.93	111.49	23.27	7.62	1
54	Piranshahr-Baleban	1522.93	26.39	48.57	56.67	116.81	16.76	5.74	1
55	Baneh 1	1902.77	23.05	40.52	76.28	184.95	20.74	9.43	1
56	Marand-1389-1	3228.56	31.13	52.31	102.69	197.40	23.38	8.71	4
	LSD (P<0/05)	1035.7	8.11	1.93	25.53	58.01	6.78	3.06	
	HSD (P<0/05)	2244.7	17.59	4.18	55.33	125.73	14.70	6.63	

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey's Test.

Table 4. Means of sunflower genotypes for different traits under severe drought stress condition

Code	Genotype	Grain yield Kg ha^{-1}	Chlorophyll content	Kernel/grain ratio	Kernel weight (mg)	Grain weight (mg)	Grain length (mm)	Grain width (mm)	No cluster
1	Saghez 1	1272.33	25.29	36.94	42.81	116.84	21.82	6.78	1
2	Urmia-Anghane 4	1461.19	24.60	44.66	56.44	127.24	24.52	6.40	2
3	Urmia-Barouj	1575.41	22.71	39.47	52.77	133.69	21.44	6.71	2
4	Urmia-Maranghalou	1170.91	26.80	45.00	59.72	132.11	22.50	4.87	2
5	Marand-Dizaj- Ghalami	2065.43	22.82	34.31	33.85	98.69	27.99	10.40	3
6	Urmia-Jabalkandi 2	1415.56	21.91	48.82	46.21	94.22	18.87	6.85	1
7	Salmas - Sadaghian	2217.95	29.50	40.49	58.02	135.87	26.44	7.87	2
8	Urmia-Babaghanje 6	1002.17	22.75	44.24	41.34	93.12	19.31	5.43	1
9	Miyaneh-Basin	1462.42	30.40	42.55	53.50	125.96	22.53	7.17	2
10	Boucan	769.14	26.27	47.56	51.21	109.27	19.99	6.88	1
11	Urmia - Nuoshinshahr	1783.14	29.65	41.14	52.16	126.86	21.70	7.79	2
12	Urmia-Karimabad	1982.66	27.43	39.55	57.67	146.06	20.79	8.17	2
13	Urmia-Vaghaslou-Olya 1	1439.29	23.47	28.01	24.67	87.28	22.28	7.62	3
14	Urmia-Vaghaslou-Olya 3	1453.18	26.36	40.48	53.91	126.85	21.74	7.19	2
15	Urmia-Ordoshahi 1	1611.69	27.03	45.23	62.91	143.98	20.50	5.93	2
16	Marand-Yamchi-Pesteii	1434.58	27.63	41.62	45.99	115.58	17.01	8.45	1
17	Mazandaran-Tirtash	996.16	26.25	37.25	49.37	136.58	16.98	7.33	1
18	Sardasht	1500.16	29.18	51.98	73.17	145.40	25.19	6.54	2
19	Marand-Yamchi 4	1177.18	22.96	43.74	50.04	121.48	19.48	6.47	1
20	Salmas 2	965.81	20.70	47.40	44.83	98.05	18.56	6.82	1
21	Urmia-Vaghaslou-Olya 4	1693.70	20.38	14.87	19.21	114.14	22.83	7.34	3
22	Salmas-Gharaghashlagh- Pesteii	1901.66	25.16	34.21	33.31	100.80	16.24	12.33	2
23	Urmia-Lalalou-Torab 2	1056.05	29.81	41.91	39.67	94.28	20.06	7.15	1
24	Urmia-Shirabad 2	1588.41	21.86	30.62	42.65	135.69	22.06	7.57	3
25	Urmia-Gharagoz 1	1746.63	30.11	40.11	51.52	128.28	23.94	7.99	2
26	Urmia-Vaghaslou-Sofla 1	1471.15	21.14	33.87	38.59	113.82	23.83	7.37	3
27	Urmia-Khanneshan 1	1703.78	31.53	45.28	55.21	119.82	19.91	6.32	2
28	Urmia-Heydarlou 1	981.17	19.47	32.45	30.18	86.57	20.18	7.24	3
29	Urmia-Saribaglou 5	2030.66	33.68	38.85	39.94	104.27	22.37	5.57	1
30	Urmia-Chongharalou-Yekan 4	1567.05	30.53	46.04	54.92	119.55	21.69	6.79	2
31	Urmia-Maranghalou 6	1985.41	25.83	38.96	84.07	213.08	25.99	9.02	2
32	Urmia-Abajalou 1	1115.13	29.35	41.37	33.54	82.03	20.05	5.82	1
33	Hamadan 1	1453.90	30.81	33.81	38.95	115.09	20.45	5.51	1
34	Saghez 2	1807.28	31.95	37.72	60.68	160.54	20.64	10.36	2
35	Piranshahr-Serokani	860.42	22.78	47.84	49.91	98.07	16.01	6.48	1
36	Piranshahr Andizeh	497.26	24.25	35.61	23.51	69.83	17.43	5.35	1
37	Mashhad	490.16	31.90	55.21	42.15	73.52	10.54	6.87	1
38	Shahroud 1	1242.51	26.10	31.17	25.85	81.46	13.85	6.50	1
39	Hamadan 2	1217.73	32.57	50.13	51.58	103.55	16.51	7.10	1
40	Shabestar-Kouzeh-Kanan 3	689.73	31.60	38.86	29.27	75.42	19.22	6.66	1
41	Saghez 4	525.13	32.17	41.33	27.52	66.06	15.70	5.64	1
42	Saghez 5	1801.78	24.80	42.45	63.80	142.54	23.56	8.26	2
43	Saghez 3	2143.35	32.71	42.20	57.75	138.33	23.88	8.21	2
44	Shahroud 2	1062.24	31.55	34.39	21.31	63.86	13.90	5.23	1
45	Urmia-Alibaglou 1	1396.10	28.81	40.71	45.01	111.02	22.70	6.75	1
46	Baneh 2	1727.82	24.32	39.02	59.90	154.34	17.11	11.86	2
47	Salmas-Gharagheshlagh- Ghalami	1134.32	31.06	41.90	53.29	127.86	24.17	9.67	2
48	Marand-1389-2	1377.34	26.38	42.76	50.58	120.96	15.96	8.75	1
49	Salmas-Gharaghashlagh- Badami	1788.36	33.56	30.79	50.30	158.16	20.52	10.42	2
50	Shabestar-Kouzeh Kanan 1	1370.58	33.01	41.07	40.55	98.84	16.47	7.40	1
51	Sanandaj	1335.47	23.76	49.61	38.03	74.88	16.79	5.42	1
52	Shabestar-Kouzeh-Kanan 2	1222.83	21.71	45.08	41.58	92.25	18.79	6.05	1
53	Baneh 3	1153.55	24.18	43.29	58.44	134.18	22.65	7.26	2
54	Piranshahr-Baleban	828.05	25.21	46.12	32.50	68.50	14.76	5.47	1
55	Baneh 1	1844.57	21.44	27.83	38.20	135.06	14.46	8.75	2
56	Marand-1389-1	1489.70	27.63	46.44	56.66	120.25	22.39	8.70	2
	LSD (P<0/05)	497.03	5.68	1.92	18.69	49.36	3.83	2.09	
	HSD (P<0/05)	990.51	12.31	4.17	40.35	106.99	8.31	4.54	

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey’s Test.

Chlorophyll content

Chlorophyll content is one of the major chloroplast components for photosynthesis (Rahdari *et al*., 2012). Comparisons of means demonstrated that there were significant differences among sunflower accessions in each one of the water stress levels for chlorophyll content (Table 2). Under the moderate and severe drought stress conditions, chlorophyll content decreased 14% and 23% in comparison to the well-watered condition, respectively (Tables 2, 3, 4). By increasing drought stress from control (non-stress) to severe drought stress, chlorophyll content reduced. In the optimum irrigation level, the highest and lowest chlorophyll content was observed in genotypes 'Shabestar-Kouzeh Kanan 2' (46.05) and 'Urmia-Vaghaslou-Sofla 1' (27.54), respectively (Table 2). In moderate stress level, the maximum and minimum values of chlorophyll content allocated to genotypes 'Saghez 3' (39.96) and 'Marand-Yamchi 4' (21.92), respectively (Table 3). In the severe stress condition, 'Salmas-Gharaghashlagh-Badami' (33.56) and 'Urmia-Heydarlou 1' (19.47) had maximum and minimum chlorophyll content, respectively (Table 4). Drought stress is considered as the main factor for chloroplast proteins hydrolysis, leaf pigments decreasing and chlorophyll destruction as a primary stage in degradation of proteins (Synerri *et al*., 1993). Babaeian *et al*. (2011) reported the maximum leaf chlorophyll content under water stress applied during seed filling stage.

Kernel/grain ratio

Comparison of accession means for kernel/grain ratio showed that with increasing stress intensity the mean values are decreased and the moderate and severe drought stress caused a reduction of 9% and 17% in kernel/grain ratio as compared to well-watered, respectively (Tables 2, 3, 4). In the optimum irrigation conditions, the highest kernel/grain ratio obtained from 'Mashhad, Salmas 2, Sardasht, Urmia-Maranghalou, Piranshahr-Serokani, Hamadan 2 and Sanandaj' (Table 2). In the moderate stress level, the maximum and minimum kernel/grain ratio was observed in 'Mashhad' (58.07%) and 'Salmas–Garaghashlagh-Badami' (31.61%), respectively (Table 3). In the severe drought stress conditions, 'Mashhad' (55.21%) and 'Urmia-Vaghaslou-Olya 4' (14.87%) presented the highest and lowest value for kernel/grain ratio, respectively (Table 4). The reason for more kernel/grain ratio in some landraces can be related to its thin shells. Our findings are in concordance with Hadi *et al*. (2012) results.

Kernel weight

There was large variation among accessions for the kernel weight in each one of water treatment conditions (Tables 2, 3, 4). Mean comparison among accessions for kernel weight revealed that in well-watered conditions the highest amount was observed in 'Urmia-Maranghalou, Saghez 5, Salmas-Gharagheshlagh- Ghalami, Baneh 3, Baneh 1 and Marand-1389-1' accessions (Tables 2, 3, 4). In the moderate stress level, the maximum kernel weight was observed in 'Marand-1389-1, Baneh 1, Saghez 4, Urmia-Maranghalou 6, Urmia-Maranghalou and Urmia-Karimabad' (Table 3). In the severe drought stress conditions, 'Urmia-Maranghalou 6, Sardasht, Saghez 4 and Urmia-Ordoshahi 1' presented the highest value for kernel weight (Table 4). Ghafari and Mirzapour (2009) reported the high kernel weight for 'Badami' accession.

Table 5. Linear correlation coefficients among different traits in the well-watered conditions

	Grain yield	Kernel/ grain ratio	Chlorophyll content	Grain width	Grain length	Grain weight	kernel weight
Kernel/grain ratio	-0.25^{*}	1					
Chlorophyll content	0.16^{ns}	-0.04^{ns}	1				
Grain width	0.39^{**}	-0.29^{*}	0.001^{ns}	1			
Grain length	0.51^{**}	-0.17^{ns}	0.11^{ns}	0.25^{*}	1		
Grain weight	0.58^{**}	-0.27^{*}	0.08^{ns}	0.66^{**}	0.59^{**}	1	
Kernel weight	0.47^{**}	0.25^{ns}	0.06^{ns}	0.52^{**}	0.48^{**}	0.84^{**}	1

^{*,**,ns} significant at the 5% and 1% probability levels and non-significant, respectively

Table 6. Linear correlation coefficients among different traits in the moderate drought stress conditions

	Grain yield	Kernel/grain ratio	Chlorophyll content	Grain width	Grain length	Grain weight	Kernel weight
Kernel/grain ratio	-0.25^{*}	1					
Chlorophyll content	-0.11^{ns}	0.26^{*}	1				
Grain width	0.26^{*}	-0.17^{ns}	0.03^{ns}	1			
Grain length	0.59^{**}	-0.08^{ns}	$- 0.17^{ns}$	$- 0.03^{ns}$	1		
Grain weight	0.67^{**}	-0.07^{ns}	0.01^{ns}	0.40^{**}	0.51^{**}	1	
Kernel weight	0.45^{**}	0.46^{**}	0.12^{ns}	0.22^{ns}	0.40^{**}	0.83^{**}	1

^{*,**,ns} significant at the 5% and 1% probability levels and non-significant, respectively

Table 7. Linear correlation coefficients among different traits in the severe drought stress conditions

	Grain yield	Kernel/grain ratio	Chlorophyll content	Grain width	Grain length	Grain weight	Kernel weight
Kernel/grain ratio	-0.29^{*}	1					
Chlorophyll content	0.07^{ns}	0.23^{ns}	1				
Grain width	0.52^{**}	-0.27^{*}	0.001^{ns}	1			
Grain length	0.55^{**}	-0.12^{ns}	$- 0.03^{ns}$	0.16^{ns}	1		
Grain weight	0.64^{**}	-0.07^{ns}	0.04^{ns}	0.48^{**}	0.53^{**}	1	
Kernel weight	0.41^{**}	0.48^{**}	0.17^{ns}	0.25^{*}	0.44^{**}	0.82^{**}	1

^{*,**,ns} significant at the 5% and 1% probability levels and non-significant, respectively

Table 8. Means foe groups in homogeneous subsets are displayed based on cluster analysis

clusters	Grain yield Kg ha-1			Chlorophyll content			Kernel/grain ratio			Kernel weight (mg)		
	W	M	S	W	M	S	W	M	S	W	M	S
1	3274.21[a]	2217.16 [b]	1107.85[b]	34.06[b]	27.77[bc]	27.27[a]	46.48[a]	43.49[a]	42.43[a]	74.18[a]	58.49[b]	40.12[b]
2	1890.65[b]	1716.31[bc]	1667.24[a]	33.47[b]	33.41[a]	27.85[a]	50.17[a]	47.89[a]	41.11[b]	54.77[b]	58.96[b]	56.59[a]
3	2870.20[a]	1431.37[c]	1539.85[a]	42.21[a]	27.23[c]	21.52[b]	48.46[a]	35.19[b]	29.02[b]	61.00[b]	23.34[c]	31.52[b]
4	-	3387.96[a]	-	-	29.39[bc]	-	-	43.19[a]	-	-	80.77[a]	-
5	-	2093.14[bc]	-	-	31.72[ab]	-	-	40.76[ab]	-	-	55.30[b]	-

W= Well-watered conditions M= Moderate drought stress conditions S= Severe drought stress conditions
Means with the same letter(s) in each column are not significantly different.

Table 8 Continued

clusters	Grain weight (mg)			Grain length (mm)			Grain width (mm)		
	W	M	S	W	M	S	W	M	S
1	158.69[a]	135.42[b]	95.34[b]	23.99[a]	21.40[b]	17.83[b]	9.23[a]	8.01[b]	6.48[b]
2	108.67[b]	123.72[b]	137.36[a]	18.16[b]	20.49[bc]	21.85[a]	6.67[b]	7.38[b]	8.10[a]
3	125.71[b]	80.97[c]	106.03[b]	22.98[a]	18.46[bc]	23.19[a]	7.58[b]	7.05[b]	7.92[a]
4	-	187.06[a]	-	-	26.64[a]	-	-	8.79[b]	-
5	-	138.82[b]	-	-	16.39[c]	-	-	12.57[a]	-

W= Well-watered conditions M= Moderate drought stress conditions S= Severe drought stress conditions
Means with the same letter(s) in each column are not significantly different.

Grain weight

Maximum amount of grain weight in the well-watered (non stress) conditions was observed in 'Marand-Dizaj-Ghalami, Urmia-Nuoshinshahr, Urmia-Karimabad, Salmas-Gharagheshlagh-Ghalami, Salmas-Gharaghashlagh-Badami and Baneh 1' accessions (Table 2). In the moderate drought stress, the highest grain weight was observed in 'Urmia-Gharagoz 1, Urmia-Vaghaslou-Sofla 1, Urmia-Maranghalou 6, Baneh 1 and Marand-1389-1' (Table 3). In the severe drought stress conditions, 'Urmia-Karimabad, Sardasht, Urmia-Maranghalou 6, Saghez 2, Saghez 5, Baneh 2 and Salmas-Gharaghashlagh-Badami presented the highest value for grain weight (Table 4). High grain weight can be attributed to greater length. Ghafari and Mirzapour (2009) reported the high grain weight in Badami accession. According to experiments of Hadi *et al*. (2012), the high grain weight attained from cv. Lakomka under both optimum and medium stress conditions.

Grain length

Mean comparisons indicated that in well-watered conditions, the highest grain length was observed in 'Urmia-Anghane 4, Urmia-Maranghalou, Marand-Dizaj-Ghalami, Urmia-Karimabad, Urmia-Vaghaslou-Olya 1, Urmia-Vaghaslou-Olya 3, Urmia-Shirabad 2, Urmia-Vaghaslou-Sofla 1 and Urmia-Maranghalou 6' (Table 2). 'Urmia-Maranghalou 6' (32.85 mm) and 'Marand–Dizaj-Ghalami' (27.99 mm) showed the higher grain length in moderate and severe drought stresses, respectively (Tables 3, 4). According to experiments of Hadi *et al*. (2012) high grain length and width attained from cv. Lakomka under both optimum and medium stress conditions. It seems that grain length was genetically controlled. There were the negative effects of water stress on the physical traits of grain such as length, width and diameter (Vannozi *et al*. 1999).

Grain width

Drought stress significantly reduced grain size. The differences among landraces for grain width were significant in all three water treatment conditions. The highest grain width was seen in 'Baneh 1, Salmas-Gharagheshlagh-Badami, Baneh 2 and Marand-Dizaj- Ghalami' accessions (Table 2). In moderate and severe drought stresses, the highest grain width was related to accessions 'Salmas-Gharagheshlagh-Ghalami' (15.01 mm) and 'Salmas-Gharagheshlagh-Pesteii' (12.33 mm), respectively (Tables 3, 4). Hadi *et al*. (2012) reported that drought stress reduces grain width and the most grain width in their studies was obtained by genotype 'Alestar'.

Cluster analysis

Based on cluster analysis, the studied accessions were grouped in three clusters both in well-watered and severe stress conditions. But under moderate stress conditions, the studied accessions were grouped in five clusters. Under well-watered conditions, the accessions 1, 2, 3, 4, 5, 11, 12, 13, 49, 55, 56 were superior genotypes for all traits studied. In moderate and severe stress conditions, the best accessions were (12, 35, 26, 31, 32, 56) and (2, 3, 5, 7, 9, 11, 12, 14, 15, 18, 22, 25, 27, 30, 31, 42, 43 46, 47, 55), respectively. However, the pattern of genotypes grouping was different depending on water treatment conditions. There was considerable variation among accessions for drought tolerance. The dendrogram of accessions did not divide the accessions into distinct groups resembling the similar geographical distribution (Figures 1, 2, 3). Therefore, it is suggested that selection of parents for hybridization does not need to be based on the geographic diversity. According to the dendrogram 1, 53.5, 34 and 12% of accessions settled in groups 1, 2 and 3 under well-watered conditions (Figure 1). In contrast, in moderate drought stresses, 32.3, 39.2, 8.9, 10.7 and 8.9% of accessions placed in groups of 1, 2, 3, 4 and 5, respectively (Figure 2). In severe stress conditions, 46.4, 42.8 and 10.8% of accessions situated in groups of 1, 2 and 3, respectively (Figure 3).

Discussion

The present study revealed that the confectionary sunflower accessions under investigation have different tolerances to drought stress. A large genetic variation was observed for grain yield among accessions in each one of well-watered and water deficit conditions. The results showed that grain yield decreased significantly due to water stress. Decreasing of grain yield in drought stress should be due to reduction in physiological activities of plants, cell division, photosynthesis rate, leaf area index, stem extension and vegetative growth (Anjum *et al*. 2011).

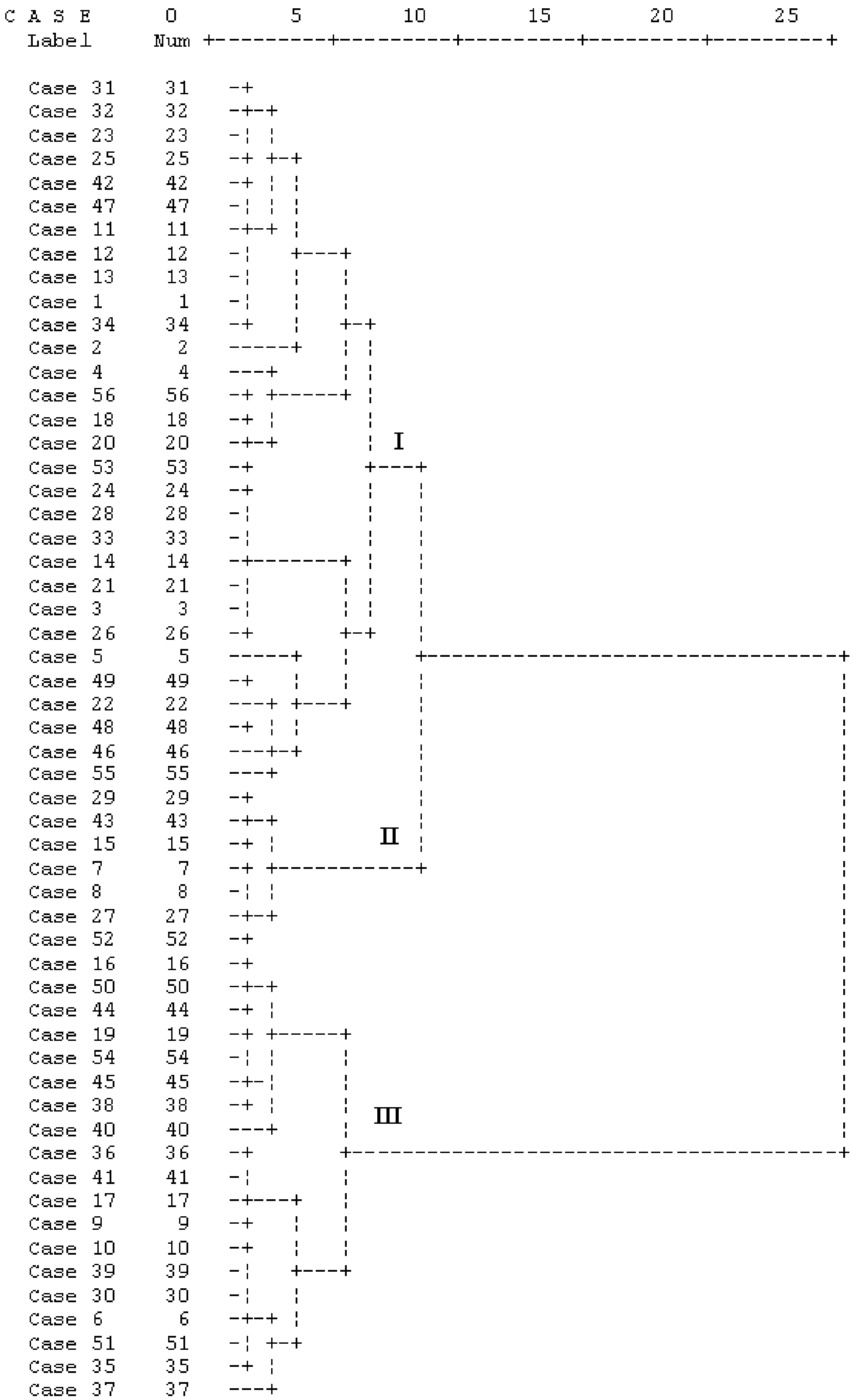

Figure 1. Dendrogram of 56 Iranian sunflower landraces generated by Wards clustering method based on square Euclidean distance after data standardized under well-watered conditions

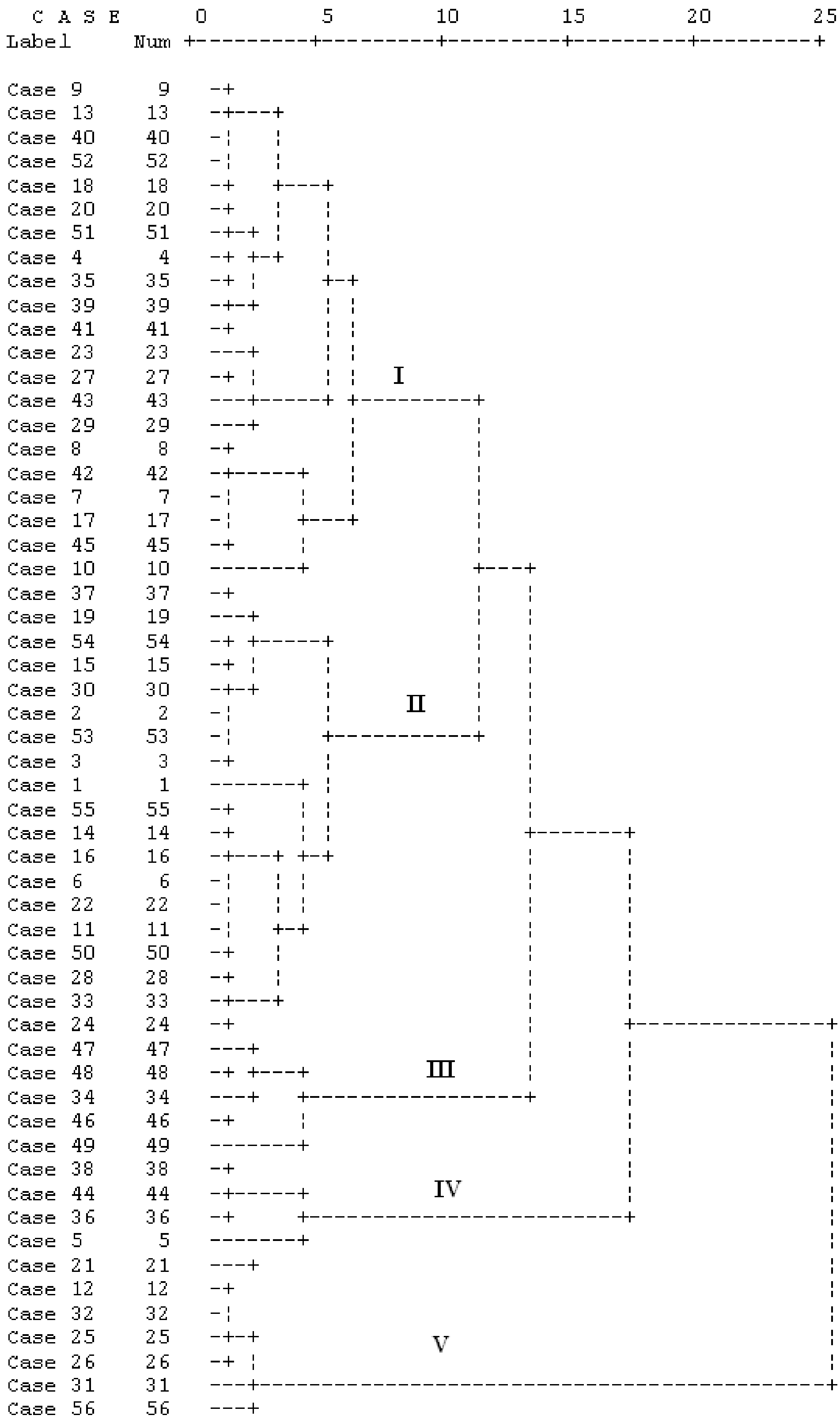

Figure 2. Dendrogram of 56 Iranian sunflower landraces generated by Wards clustering method based on square Euclidean distance after data standardized under moderate drought stress conditions

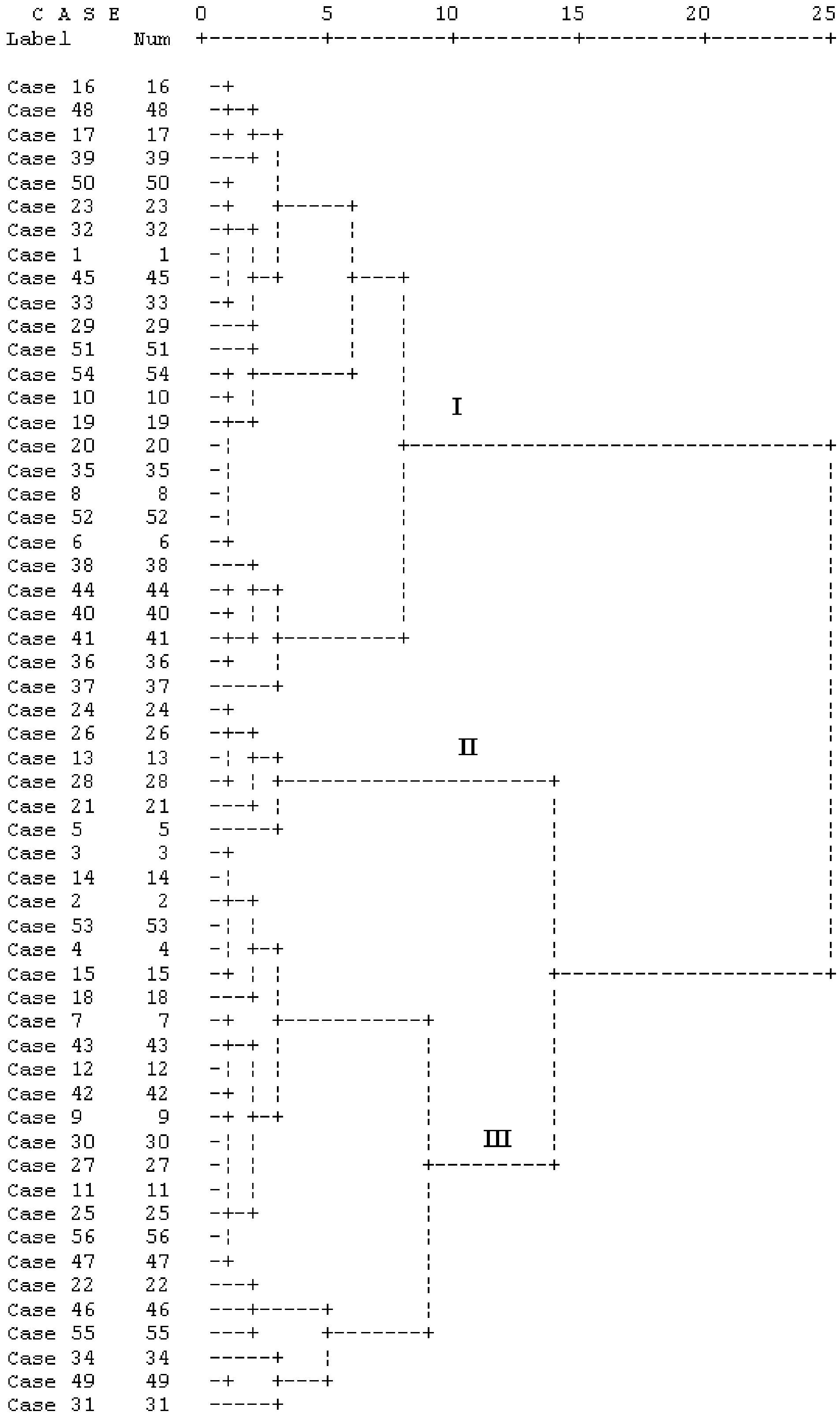

Figure 3. Dendrogram of 56 Iranian sunflower landraces generated by Wards clustering method based on square Euclidean distance after data standardized under severe drought stress conditions

The results are in line with the findings of Farahvash *et al*. (2011) for grain yield in sunflower. In the present study, a decrease in the chlorophyll content was observed in all genotypes under drought stress that it is agreement with the findings of Santos *et al*. (2002) and Hossein *et al*. (2010). This indicates that drought stress significantly reduce chlorophyll content in sunflower. Any change in chlorophyll content under drought stress condition is due to its degradation. Drought stress via effect on chlorophylaze and peroxidaze enzymes and phenolic compounds cause degradation and reduction in chlorophyll content (Ganji Arjenaki *et al*. 2012). Decreasing of chlorophyll content in plants such as *Paulownia imperialis* (Astorga and Melendez 2010), *Phasaeolus vulgaris* (Beinsan *et al*. 2003) and *Carthamus tinctorius* (Siddiqi *et al*. 2009) has been reported under drought stress. The decrease in chlorophyll content under drought stress considers a typical symptom of pigment photo-oxidation and chlorophyll degradation (Anjum *et al*. 2011). Decreasing of chlorophyll content during drought stress depend on the duration and severity of drought stress level (Zhang and Kirkham 1996). A decrease of total chlorophyll content with drought stress implies a lowered capacity for using light.

With increasing drought stress, kernels to grain ratio significantly decreased. The reason for reduction in the kernel/grain ratio under drought stress is due to reducing kernel weight and increasing shell weight. Our results are in agreement with the findings of Akbari *et al*. (2008) and Roshdi *et al*. (2006). A large kernel to grain ratio, grain diameter and length was observed in some accessions. The reason for more kernels to grain ratio in some accessions can be related to their thin shell. Researchers showed that grain shell is influenced meaningfully by genotype especially in relation to grain width and diameter (Nel 2001). Genotypes had different responses in different moisture condition. Based on the results of this study, sunflower genotypes grouped into several groups. Therefore, we should select accessions for cultivation based on moisture condition.

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