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Stability and Adaptability Estimates of Some Safflower Cultivars and Lines in Different Environmental Conditions

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ABSTRACT

The stability of ten winter safflower cultivars and lines was evaluated in three different environmental conditions in Karaj, Isfahan and Darab in Iran, a randomized complete block design with 4 replications over three years (1995, 1996 and 1997). Simple analysis of variances of grain and oil yields from each experiment showed significant differences among the genotypes. After conducting a homogeneity test for error variances, combined analysis of variance was performed. An F. test of different sources of variation revealed that the effect of genotype × year × location interactions was significant (P<1%). Analysis of the grain and oil yields using the Eberhart and Russel method showed significant difference for the main effects of genotype and genotype × environment (linear) interactions and non-significant difference for deviation from regression. According to the classification of genotypes based on the mean of grain and oil yields, coefficient of regression and deviation from regression, the new line L.R.V.51.51 with its high grain and oil yields and stability was selected as a desirable genotype.

Keywords: Adaptability, Grain and oil yields, Safflower, Stability

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) has been grown since ancient times (4500 BC) in Egypt, Morocco, China and India to obtain carthamin from the flowers, a dye that may be either yellow or red. It is a drought tolerant plant and suitable for growing in dry and marginal areas (Li and Mündel, 1996). Safflower has been cultivated in Iran for centuries in small quantities for the extraction of dye from its florets, while its importance, as an oil seed crop, has only been realized since 1970 (Ahmadi and Omidi, 1997). Iran is one of the richest germplasm sources of safflower. For instance, of the total 2042 safflower genotypes deposited at the Western Regional Plant Introduction Station, Pullman, WA, USA, 199 were found to be of Iranian origin (Deharo *et al.*, 1991). The safflower cropped area in Iran has increased over the last few years, reaching about 20000 hectares in 2001, whereas it was only 200-300 hectares in 1999 (Omidi Tabrizi, 2001).

Genotypes × environment interactions are of the major importance to plant breeders in developing improved varieties. When varieties are compared, under different environmental conditions their relative performances usually differ. To overcome this constraint, stability analyses should be carried out. (Eberhart and Russell, 1966).

Plaisted and Peterson (1959) presented a method for characterizing the stability of yield performance when several varieties were tested at a number of locations within one year, the variety with the smallest mean value being a stable variety. Francis and Kannenberg (1978) used the coefficient of variation (C.V.) to measure varietals stability in multi-environment trials. Finlay and Wilkinson (1963) used the re-

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gression coefficient (bi) as a stability parameter. Eberhart and Russell (1966) suggested that a stable variety will be the one with high mean $(\overline{X}_i)$, regression coefficient of unity (bi=1.0) and less deviation from regression (S^2di=0). Lin and Binns (1982) proposed variance within locations (MS/L) as the stability parameter. Using this method, genotypes were grouped according to similarity of response to environment and then assessed for average effect within the group.

Deharo *et al*., (1991), in a study of 199 safflower genotypes collected from 37 different countries, showed that the oil percent varied by genotype and environmental conditions. Longkui, (1993) reported that variety FO2 is an adaptable and stable safflower genotype because it had desirable traits for drought, cold and salinity tolerance and was disease-resistant and thus it can be grown easily under various environmental conditions. Narkhede and Patil (1990) studied the environmental interaction of nine safflower genotypes for yield and yield components and reported that variety J.S.LF-48 was a stable genotype.

R. Honarnejad *et al*., (1998) studied the adaptability of 11 rice cultivars for three years, 1994-1996, in three locations of Gilan province in Iran. They used yield stability analysis proposed by the Eberhart and Russell method (1966) and then showed significant variance differences for cultivars, environments (linear) and deviation from regression. They also reported that cultivar 211 with the coefficient of regression of 0.22, which was different from unity (b=1) and highly stable, is a suitable cultivar for poor conditions. Pourshahbazi (1998) in a soybean seed trial in East Azarbaijan showed that cultivar S.R.F was the most stable and high yielding variety. Banai (1998) in a study to evaluate yielding ability and adaptability of twelve chickpea varieties, reported that variety 12-60-31 with its high yielding ability was classified in the group A (+) based on the Eberhart and Russell method (1966) of stability analysis.

The objective of this research was to evaluate the stability of some safflower cultivars for seed oil and grain yields, using the Eberhart and Russell method of stability analysis.

MATERIALS AND METHODS

Ten new winter type safflower lines and cultivars were evaluated for their stability of seed oil and grain yields based on the Eberhart and Russel (1966) method in a randomized complete block design with four replications for three years (1995, 1996 and 1997) and in three locations (Karaj, Esfahan and Darab) where the years and locations were considered as random variables, while genotypes were treated as fixed variables. Experimental plots consisted of 4 rows, 3-m long and 0.5-m apart. After the emergence, manual seedlings, thinning was used to obtain

Table1. List of safflower lines and cultivars.

No	Name	Selected from
1	Varamin-295	Urumieh safflower landraces
2	K.A.72	CH353 variety
3	K.B.72	Zarghan safflower landraces
4	K.C.72	Aceterio variety
5	L.RV.51.51	Urumieh safflower landraces
6	K.D.72	3147 variety
7	Zarghan-279	L.R.V.51.279
8	K.E.72	CH65 variety
9	K.J.72	Urumieh safflower landraces
10	K.F.72	Isfahan safflower landraces

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Table 2. Some geographical conditions and annual precipitation of experimental locations.

Location	Altitude	Longitude	Latitude	Rainfall (mm)
Karaj	1300	57°.00	35°.48	250-300
Isfahan	1650	50°.49	33°.7	150
Darab	1100	54°.55	28°.29	250

normal plant density. In these experiments, 70 kg/ha of P_2O_5 and 25 kg/ha of nitrogen were applied prior to sowing and 30 kg/ha of nitrogen was used as a top dressing at the start of stem elongation. Weeds were controlled by hand, prior to stem elongation, bud formation, beginning of flowering, 50% of flowering, finishing of flowering and seed filling. The data of seed oil and grain yield over 3 years and in 3 locations were analyzed according to Duncan's multiple range test. After conducting a homogeneity test for error variances, combined analysis of variance was performed. A list of the safflower genotypes and some geographical conditions of the locations are given in Table 1 and 2 respectively. The genotypes, based on the mean grain and oil yields, coefficient of regression and deviation from regression were classified in different groups.

RESULTS AND DISCUSSION

Simple and Combined Analysis of Variance

The results of simple analysis of variance demonstrated that differences among genotypes were highly significant ($P<0.01$) for seed oil and grain yields in three locations and over three years (Tables 3 and 4).

This means that there were large variations in seed yields among the locations over 3 years, ranging from 916 kg/ha to 3547 kg/ha in Isfahan (1995 and 1996). In most locations and years one or more lines and varieties yielded as well as or higher than the check variety, except in Isfahan and Darab (in 1995 and 1996) where the check variety (Zargan-279) ranked first. According to Duncan's multiple range test the line L.R.V.51.51 was classified as class A for grain yield in Karaj (1995, 1997), Isfahan (1995) Darab (1996) with 1979 kg/ha, 2329.2 kg/ha, 1425 kg/ha and 2433 kg/ha, respectively.

The oil seed yield data in Table 4 showed that the performance of lines and varieties were different among the various locations over 3 years. Mean oil yield ranged from 238 kg/ha to 966.6 kg/ha in Isfahan (1995 and 1996).

The results of combined analysis of variance for seed oil and grain yields are given in Tables 5 and 6, and they show that the year × location and also year × location × genotypes interactions are highly significant. This means that the genotypes respond differently under climatic conditions, thus they could be classified according to experimental sites.

Stability Analysis

Stability analyses of seed oil and grain yields in different environments were presented in Tables 7 and 8, where the sums of the squares due to the environment and varieties × environment were partitioned into environment (linear) and varieties × environment (linear), and deviations from the regression.

The variance of genotypes and genotypes × environment (linear) interactions were significant at 1% probability level, but the mean squares of deviations from the regression were not significant for grain and

Table 3. Means for grain yield (kg.ha $^{-1}$) of safflower cultivars and lines in different locations and years.

Cultivar/line	1995			1996			1997		
	Karaj	Isfahan	Darab	Karaj	Isfahan	Darab	Karaj	Isfahan	Darab
1[a]	1681.2 a	1439.6 a	1681.0 b	1858.3 a	2156.2 d	1760.4 a	1545.0 bcd	1911.6 ab	1691.7 d
2	1841.7 ab	1047 a	1747 b	1842.9 b	3547.6 a	2120 a	1430 bcd	1882.5 ab	2862.5 abc
3	1303.3 b	1140 a	2372.9 ab	1861.6 ab	2687.5 cd	1750 a	1330 cd	1931 ab	2214 cd
4	2000 a	1282.5 a	2073.7 b	2218.7 a	2880.4 bc	2737 a	1752. b	1708.3 b	2420 bc
5	1979 a	1425 a	1997 b	1878.3 ab	3203.3 abc	2433.3 a	2329. a	2125 ab	2470 bc
6	1787.5 ab	1564 a	2029 b	1697 b	2755.4 c	2112.5 a	1792.9 b	1850 ab	2418.8 bc
7	1825 ab	1404 a	1777 b	2117.9 ab	3447.9 ab	2183.3 a	1707.5 bc	1739.6 b	2978.3 ab
8	1733.3 ab	1104.2 a	1935.4 b	1765.8 b	3255.4 abc	2417.9 a	1564.6 bcd	2608 a	2889.6 abc
9	1645.8 ab	916 a	1760.4 b	1784.6 ab	3367.9 a	2170.8 a	1308.3 d	1954. ab2	3172.9 a
10	1756.3 ab	1266 a	3030.4 a	1697 b	3411.6 ab	2154.2 a	1299.2 d	1833.3 ab	2783 abc

[a] For names, see Table1˙
Similar letters in each column indicate no significant difference(Duncan's multiple range test).

Table 4. Means for oil yield (kg.ha $^{-1}$) of safflower cultivars and lines in different locations and years.

Cultivar/line	1995			1996			1997		
	Karaj	Isfahan	Darab	Karaj	Isfahan	Darab	Karaj	Isfahan	Darab
1[a]	458.3 ab	417 a	461.6 b	490.8 b	581.6 c	487.5 a	428.8 d	556.6 b	461.2 d
2	512.9 ab	273 a	250.8 b	477.5 b	930.4 a	606.6 a	440 d	567.9 b	820.8 abc
3	334.58 b	285.3 a	663.3 ab	542.9 ab	735 abc	502.1 a	376.3 d	558.7 b	620.4 cd
4	582.9 a	369.6 a	597.0 ab	629.1 a	793.5 abc	596.6 a	551.6 b	535.4 b	689.5 bc
5	539.6 a	387.5 a	547.9 b	520 ab	858.3 ab	652.1 a	700 a	661.2 ab	712.5 bc
6	460 ab	395.5 a	365.8 b	500 b	619.6 bc	553.7 a	525.4 bc	534.5 b	646.2 bcd
7	447.0 ab	347.2 a	503.3 b	537 b	837.5 abc	616.6 a	516.2 bc	566.2 b	822. abc
8	508.9 ab	319.6 a	540 b	479 ab	918.3 a	638.8 a	403.5 cd	774.1 a	831.2 ab
9	448.4 ab	238.2 a	497.9 b	486.2 b	966.6 a	631.2 a	373.4 d	565 b	946.6 a
10	453.3 ab	317.1 a	855.4 b	428.3 b	895.4 a	601.6 a	386 d	533 b	783.3 abc

[a] For names see Table1.
Similar letters in each column indicate no significant difference(Duncan's multiple range test).

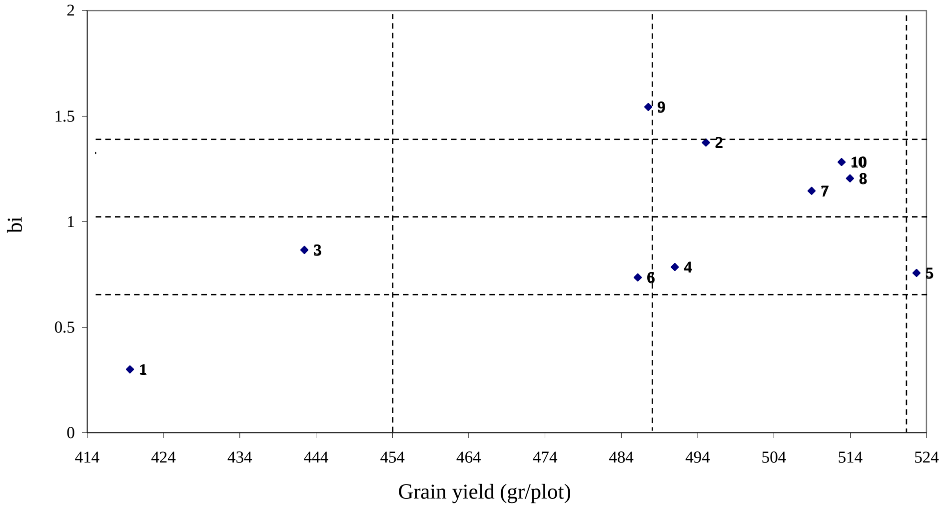

Figure 1. Scatter diagram for varieties based on grain yield and regression.

oil yields. It can be concluded that there was a clear linear relationship between grain and oil yields and environmental indices.

Scatter diagrams for different varieties, based on seed oil and grain yields and the regression coefficient are shown in Figures 1, 2, 3, 4 and Tables 9 and 10. The figures give a graphic summary that is useful for selecting stable lines and varieties. The vertical lines are one standard deviation above and below the population mean, whereas the horizontal lines are one standard deviation above and below the average slope (b=1.0), therefore, the genotypes were classified as stable and adaptable when they were placed to the right side of vertical lines (the means of grain and oil yields exceeded the of the population mean) the coefficient regression is equal to unity and also due to deviation from regression (Figures 2 and 4).

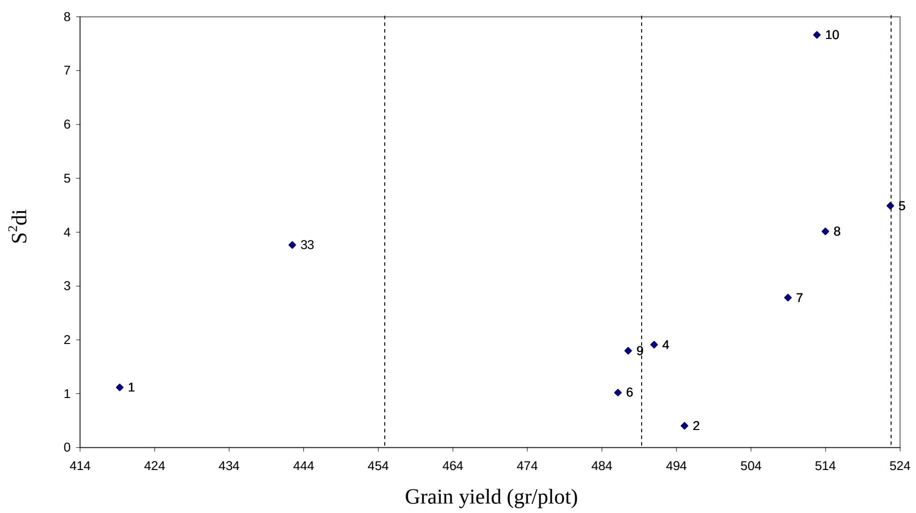

Figure 2. Scatter diagram for varieties based on grain yield and deviation from regression.

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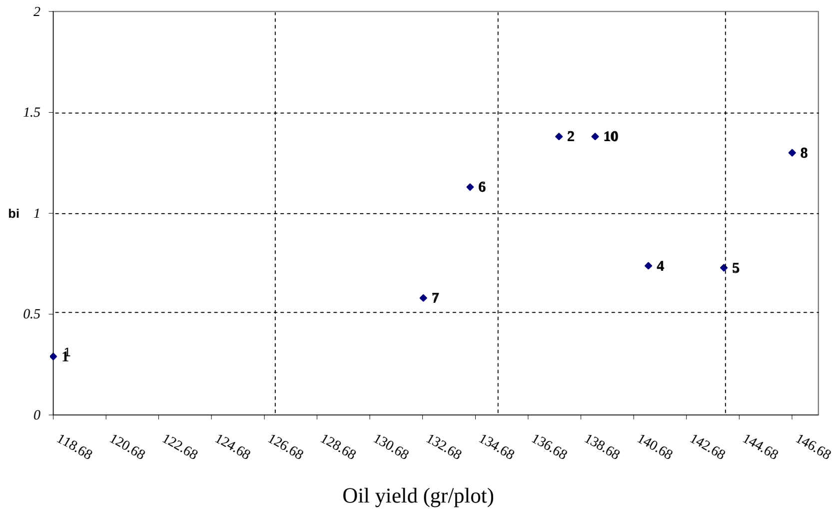

Figure 3. Scatter diagram for varieties based on seed oil yield and regression coefficient

Classification of the Genotypes Based on Grain Yield

Group A (+)

This group has well-adapted genotypes whose grain yields exceeded the population means in all environments. The genotype L.R.V.51.51 was assigned to this group. It produced above-average yields in all years at all locations, which indicated that it has good general adaptability. This result is in agreement with studies by Azari (1993), Motalebipour (1994), Soltani (2000), Pasebaneslam (2001) and Alhani (1999) that reported the superiority and adaptability of L. R. V. 51. 51 for seed oil and grain yields. Honarnejad *et al.* (1998) used yield stability analysis as proposed by the Eberhart and Russell method (1966) for 11 rice varieties and showed significant variance differences for cultivars, environments (linear) and deviation from regression and reported that cultivar 211 was

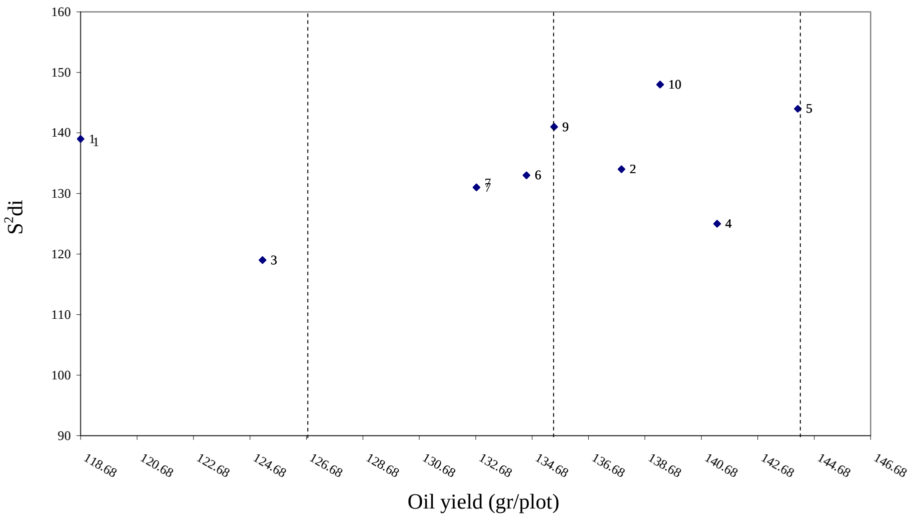

Figure 4.Scatter diagram for varieties based on seed oil yield and deviation from regression.

Table 5. Combined analysis of variance for grain yield of 10 safflower cultivars and lines in 3 different locations and years.

S.O.V.	df	SS	MS	F
Year (Y)	2	1533610.017	76680.000	0.100
Location(L)	2	965132.069	482566.033	0.670
YL	4	2843855.017	710963.754	26.10**
E1	27	734998.575	27222.169	
Cultivar(V)	9	35216.169	391272.352	17.66**
VY	18	305635.539	16979.725	2.547
VL	18	375533.989	20862.999	3.129
VLY	36	797555.428	22154.317	3.323**
E2	243	1619794.175	6665.820	
Total	359	9528260.975		CV=16.73%

** Significant at the 1% probability level.

classified in group A (+).

Pourshahbazi (1998) in a soybean seed trial in East Azarbijan showed that cultivar S. R. F fell into group (A+) as the most stable and high yielding variety.

Banai (1998) in a study of the yielding ability and adaptability of twelve chickpea varieties reported that variety 12-60-31 with its high yielding ability was classified in group A (+), on the basis of the Eberhart and Russell method (1966).

The Eberhart and Russell method was used by Longkui (1993) to estimate the adaptability of FO2 safflower variety in different climatic conditions in China. The results showed that the variety FO2 had good adaptation to various environmental conditions.

Akmal and Rana (1993) evaluated adaptability and stability of different safflower genotypes for grain yield by the Eberhart and Russell method (1966). They reported that the variety P1-250539 had the highest adaptability and stability. Narkhede and Patil, (1990), by using the Eberhart and Russell method (1966), showed that the Indian variety (J. S. LF-48) had the highest adaptability and stability for grain and oil seed yields.

Table 6. Combined analysis of variance for oil yield of 10 safflower cultivars and lines in 3 different locations and years.

S.O.V.	df	SS	MS	F
Year (Y)	2	110702.52	55351.27	1.19
Location(L)	2	81463.80	40731.90	0.87
YL	4	185502	46375.67	18.80**
E1	27	66611	246.09	
Cultivar(v)	9	23426.66	2602.96	1.29
VY	18	20998.88	1166.6	0.57
VL	18	38552.30	2141.79	1.06
VLY	36	72530.3	2014.73	3.52**
E2	243	139028.65	572.13	
Total	359	738817.30		CV=17.65%

** Significant at the 1% probability level.

[DOR: 20.1001.1.16807073.2006.8.2.5.5]

Table 7. Stability analysis of grain yield of safflower cultivars and lines in different environments.

S.O.V.	df	SS	MS	F
Total	82	1793364.00		
Cultivar(v)	9	88037.78	9781.98	3.38**
Environment(ENV)	8	1335649		
V×ENV	72	369677.50		
ENV(Linear)	1	1335650		
V× ENV(Linear)	9	166934	18548.02	
Pooled DEV	70	202746.80	2896.38	6.40**
V1	7	7816.43	1116.63	0.17
V2	7	2830.98	404.43	0.06
V3	7	26347.53	3763.93	0.56
V4	7	13371.95	1910.28	0.29
V5	7	31419.49	4488.5	0.67
V6	7	7145.26	1020.75	0.75
V7	7	19490.89	2784.41	0.42
V8	7	28099.66	4014.24	0.60
V9	7	12586.63	1798.09	0.27
V10	7	53637.95	7662.56	1.15
Pooled error	243	1619794	6665.85	

V1 –V10 = Cultivars or lines
** Significant at the 1% probability level.

[DOR: 20.1001.1.16807073.2006.8.2.5.5]

Group A (O)

This group has an average stability over all environments and a grain yield equal to mean population. The genotypes K.E.72, K.C.72 (less deviation from regression), K.D.72 and Zarghan-279 were classified in this group.

Group A (-)

The genotype K.B.72 was classified in this group, that produced below-average grain yield and it is poorly adapted to all environments.

Group B

This group has those genotypes specially adapted to unfavorable environments. The genotypes K.J.72 and K.A.72 with less deviation from regression were classified in this group.

Group C

The genotypes in this group are suitable for favorable environments. The cultivar varamin-295 with the lowest grain yield and least deviation from regression was classified in this group.

Classification of Genotypes Based on Oil Yield

Group A (+)

Mean seed and oil yields of the genotypes in this group exceeds that of population mean in all environments. The genotypes L.R.V.51.51 and K.E.72 were classified in this group.

Group A (O)

This group has an average stability value of oil yield equal to the mean population over all environments. The genotypes K.F.72, K.C.72 (less deviation from regression), K.D.72 and K.A.72 were classified in this group.

Table 8. Stability analysis of oil yield of safflower cultivars and lines in different environments**.**

S.O.V.	df	SS	MS	F
Total	82	133294.10		
Cultivar (V)	9	5856.79	650.75	2.49*
Environment (ENV)	8	94418.33		
V×ENV	72	33019.01		
ENV(Linear)	1	94418.56		
V× ENV(Linear)	9	14697	1633	
Pooled DEV	70	18321.93	261.74	6.24**
V1	7	683.59	97.66	0.17
V2	7	566.65	80.95	0.17
V3	7	2440.88	348.7	0.14
V4	7	1955.56	165.08	0.61
V5	7	3312.67	473.27	0.29
V6	7	911.15	130.16	0.83
V7	7	12125.51	173.22	0.23
V8	7	2222.93	317.52	0.3
V9	7	1032.65	147.52	0.56
V10	7	4783.32	683.33	0.26
Pooled error	243	139027.60	572.13	

** Significant at the 5% and 1% probability levels, respectively.

[DOR: 20.1001.1.16807073.2006.8.2.5.5]

Group A (-)

The genotype K.B.72 due its below average seed oil and grain yields is placed in this group. This indicates that it is poorly adapted to all environments.

Group B

The group with genotypes specially adapted to unfavorable environments. The genotype K.J.72 was classified in this group.

Group C

The genotypes in this group are suitable for favorable environments. The cultivars including varamin-295 and Zarghan-279 (less deviation from regression) fall into this group.

Based on Eberhart and Russell (1966), it can be concluded that when stability parameters exceed the grain yield of the population mean, the coefficient of regression is equal to unity (bi=1.0) and also the

Table 9. Mean grain yields (kg. ha^{-1}) of cultivars/lines and their related stability parameters.

Cultivar/line	Mean yield	R^2	bi	S^2di
1	1747.3	61.7	0.310**	1116.63ns
2	2062.8	98	1.375**	404.43 ns
3	1843.6	79.2	0.86 ns	3763.9 ns
4	2119.2	86	0.785 ns	1910.2 ns
5	2205.5	70.9	0.757 ns	4488.5 ns
6	2025.6	91	0.736 ns	1020.7 ns
7	2120.5	90	1.146 ns	2784.4 ns
8	2141	87.3	1.205 ns	4014.2 ns
9	2031.3	96.2	1.543 ns	1798 ns
10	2136.9	80.3	1.280 ns	7662.5 ns

** Significant at the 1% level of probability.
ns Non significant.

Table 10. Mean oil yields (kg. ha $^{-1}$) of cultivars/lines and their related stability parameters.

Cultivar/line	Mean yield	R^2	bi	S^2di
1	494.5	53.91	0.29^{**}	97.66^{ns}
2	574.37	96.94	1.38^{**}	80.95^{ns}
3	521.37	75.64	0.90^{ns}	348.7^{ns}
4	588.50	81.82	0.74^{ns}	165.08^{ns}
5	600.41	60.04	0.73^{ns}	473.24^{ns}
6	552.90	77.71	0.58^{ns}	130.16^{ns}
7	560.30	90.89	1.13^{ns}	173.22^{ns}
8	611.2	87.80	1.30^{ns}	317.56^{ns}
9	564.40	95.79	1.58^{ns}	147.52^{ns}
10	580	78.89	1.38^{ns}	683.33^{ns}

** Significant at the 1% level of probability.
^{ns} Non significant.

deviation from regression is as small as possible ($S^2di = 0$). Line no.5 L.R.V.51.51, by having grain and seed oil yields of 2205 Kg/ha and 600 Kg/ha respectively, can be recommended for cultivation in the areas where this study was carried out (Tables 9 and 10).

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تخمین پایداری و سازگاری عملکرد دانه و روغن در چند رقم و لاین گلرنگ زمستانه در شرایط مختلف آب و هوایی

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چکیده

به منظور تعیین سازگاری و واکنش ارقام و لاین های گلرنگ زمستانه به شرایط مختلف محیطی ، تعداد ۱۰ رقم و لاین در سه منطقه کرج ، اصفهان و داراب در قالب یک طرح بلوک‌های کامل تصادفی در چهار تکرار و به مدت سه سال (۱۳۷۴ , ۱۳۷۵ و ۱۳۷۶) مورد بررسی قرارگرفتند. نتایج حاصله از تجزیه واریانس ساده نشان داد که در اکثر مناطق و سال های مورد بررسی تفاوت معنی دار بین ارقام وجود دارد. سپس با توجه به معنی دار نبودن آزمون یکنواختی واریانس خطاهای آزمایشی، تجزیه واریانس مرکب برای سال ها و مناطق مورد بررسی انجام شد که اثر متقابل سال × مکان و همچنین سال × مکان × رقم در سطح احتمال ۱٪ معنی دار بودند. برای تعیین معنی دار بودن اثر متقابل سه جانبه سازگاری و پایداری ارقام براساس روش تجزیه رگرسیونی ابرهارت و راسل اقدام گردید. نتایج تجزیه رگرسیونی برروی عملکرد دانه و روغن نشان داد که اثر متقابل ژنوتیپ × محیط (خطی) معنی دار بوده و برازش مدل رگرسیونی مناسب است، لذا ارقام مورد بررسی بر اساس شیب رگرسیونی و میانگین عملکرد دانه و روغن و همچنین انحراف از خط رگرسیون گروه بندی شدند و لاین LR.V.51.51 با سازگاری عمومی خیلی خوب در تمام محیط‌ها و عملکردی بالا به عنوان ژنوتیپ مطلوب انتخاب گردید.