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GENOTYPE X ENVIRONMENT INTERACTION IN THE REGIONAL TESTING OF SAFFLOWER CULTIVARS[1]

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ABSTRACT

Eighteen cultivars of safflower were evaluated with regard to seed yield at the same 7 locations in Iran for a 2-year period. The study was designed to obtain estimates of the relative magnitudes of the various types of cultivar x environment interactions in safflower cultivar tests, and to consider the implication of these interactions on cultivar evaluation procedures.

Genetic variation among the cultivars was relatively small and nonsignificant. This was related to the fact that these cultivars had been selected for their higher seed performances among many lines prior to the regional tests.

The cultivar x year and cultivar x location interactions were both small and statistically nonsignificant. The second order interaction of cultivar x year x location, however, was of substantial magnitude and significant. But, this could be a reflection of year x location interaction which was also significant.

There were no consistent location or year effects on differential cultivar response during this period of testing.

The lack of sizable cultivar x location interactions in the present study indicates

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that little if any advantage is to be gained from dividing the safflower growing area into subareas for breeding and testing purposes. Breeding for specific environments might be feasible where some important environmental factors could become under some degree of control or predictable.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) has been grown as a dye-producing crop in different agriclimatic regions of Iran for many centuries. In the last decade, the objective of safflower breeding has been shifted toward producing genotypes with high yielding ability accompanied by high percent edible oil. Since the available safflower cultivars are grown in widely different environments, considerable cultivar x year, cultivar x location and cultivar x year x location interactions might be expected. Cultivar x environment interaction has been recognized in several field crops (1, 2, 6, 7, 9, 10). By contrast no significant interaction of cultivar with years or location were found in some other experiments (5, 8).

The present study is the first such study on yield response of safflower cultivars under different environmental conditions in Iran. It was not known whether the available cultivars were adapted to a wide area or new cultivars were needed to fit a subset of environments. The objectives of our study were to estimate the components of variance and their relative importance for safflower cultivars grown at seven locations for two years and to consider the implications of first and second order interactions on cultivar evaluation procedures.

MATERIALS AND METHODS

Fifteen top yielding safflower cultivars from the local safflower populations of Iran were selected. The accession numbers for these cultivars were: V49-236, V49-251, V49-280, V49-287, V49-307, V49-415, V50-63, V50-165, V50-166, V50-167, V50-190, V50-237, V50-421, V50-243, and V49-338. Check cultivars, Ute, Ferio and Arak were also included. The experiments were conducted in 1973 and 1974 using a randomized complete block design with four replications at Karaj, Varamin, Kermanshah, Zerghan, Moghan, Khorramabad, and Mashad. Environmental conditions are very different at these locations (altitude ranged from 838m to 1322m, latitude varied from 28^{o} . 45′ N to 36^{o} . 12′N, longitude differed from 47^{o} . 20′ E to 59^{o} . 40′ E, annual rainfall ranged from 150 mm to 450 mm, annual mean temperature varied from 11.6 C to 22.0 C), soil types for locations 1 to 7 were coarse alluvial, brown and chestnut, saline alluvial, solonchak and solonetz, brown and chestnut, and fine alluvial, respectively. Each plot was four 11m rows spaced 0.5m apart with 0.1m spacing between plants within rows. Cultural practices such as seeding, harvesting, etc. were uniform within and between locations. Before harvesting, 0.5m was discarded from each end of the plots and only the two middle rows were harvested. Thus, seed yield was measured on 10 m^2 for each replication. The mean yield of the cultivars at Moghan were far below the grand mean due to severe disease problem. However, including or excluding the Moghan data in the analysis of variance did not change the pattern of cultivar x environment interactions.

Information on the importance of cultivar x environment interaction effects was obtained by performing an analysis of variance on the combined data (7 locations and 2 years). A mixed model was used: year and location were considered random and cultivar fixed. The form for the analysis of variance and the expected composition of the mean square are presented in Table 1. To evaluate the relative magnitudes of these different effects it was necessary to obtain separate estimates of the components of variance shown in each mean square expectation. Such estimates were obtained from the mean square of the analysis of variance by use of the following formula:

$$\text{Cultivars } (\hat{\sigma}^2_C) = \frac{M_5 + M_2 - M_3 - M_4}{r\,p\,y}$$

$$\text{Cultivars x years } (\hat{\sigma}^2_{CY}) = \frac{M_4 - M_2}{r\,p}$$

$$\text{Cultivars x locations } (\hat{\sigma}^2_{CL}) = \frac{M_3 - M_2}{r\,y}$$

$$\text{Cultivars x years x locations } (\hat{\sigma}^2_{CLY}) = \frac{M_2 - M_1}{r}$$

$$\text{Error } (\hat{\sigma}^2_E) = M_1$$

where $M_1, \ldots, M_5$ are the values of the appropriate mean squares as indicated in Table 1, and r, p, and y are the number of replicates, locations, and years, respectively, in which the cultivars were tested. Intraclass correlations among years and among locations were computed according to the procedures outlined by Hanson (4). The low intraclass correlation values for the trait indicate that years and locations may be treated as random environments without seriously biasing the estimated values.

RESULTS AND DISCUSSION

The combined analysis of variance for seed yield performance is given in Table 2. Intraclass correlation among years (ρ_Y) and among locations (ρ_L) were 0.02 and 0.26, respectively. Since the sum of the intraclass correlations ($\rho_Y + \rho_L = 0.28$) was not greater

Table 1. Form of variance analysis and mean square expectations

Source	df*	Mean square	Mean square expectation*
Year (Y)	(y−1)		$\sigma^2_E + C\sigma^2_R + rc\sigma^2_{YL} + rcp\sigma^2_Y$
Location (L)	(p−1)		$\sigma^2_E + c\sigma^2_R + rc\sigma^2_{YL} + rcy\sigma^2_L$
Y x L	(y−1) (p−1)		$\sigma^2_E + c\sigma^2_R + rc\sigma^2_{YL}$
Reps. in Y & L	yp (r−1)		$\sigma^2_E + c\sigma^2_R$
Cultivar (C)	(c−1)	M_5	$\sigma^2_E + r\sigma^2_{YLC} + ry\sigma^2_{LC} + rp\sigma^2_{YC} + rpy\sigma^2_C$
Y x C	(y−1) (c−1)	M_4	$\sigma^2_E + r\sigma^2_{YLC} + rp\sigma^2_{YC}$
L x C	(p−1) (c−1)	M_3	$\sigma^2_E + r\sigma^2_{YLC} + ry\sigma^2_{LC}$
Y x L x C	(y-1) (p−1) (c−1)	M_2	$\sigma^2_E + r\sigma^2_{YLC}$
Error	yp (c−1) (r−1)	M_1	σ^2_E

*y, p, r, and c are number of years, locations, replications, and cultivars, respectively; σ^2_E=error variance; σ^2_{YLC} = variance due to interaction of cultivars, locations, and years, etc.

Table 2. Analysis of variance for seed yield (ton/ha) of 18 safflower cultivars combined over 2 years and 7 locations.

Source	df	Mean squares
Year (Y)	1	85.364
Location (L)	6	112.314
Y x L	6	30.489**
Rep. in Y & L	42	0.401
Cultivar (C)	17	0.254
Y x C	17	0.153
L x C	102	0.175
Y x L x C	102	0.138*
Error	714	0.089

*, **Significant at the 5% and 1% level, respectively.

than 0.40, treating years and locations as random environments did not seriously bias the estimates of variance components. Estimates of variance components were as follows: $\hat{\sigma}^2C = 0.0012$, $\hat{\sigma}^2YC = 0.0005$, $\hat{\sigma}^2LC = 0.0046$, $\hat{\sigma}^2YLC = 0.0120^*$ and $\hat{\sigma}^2E = 0.0898$. The relative magnitude of these estimates indicate the importance of each component as a source of variation.

Both the year x cultivar and the location x cultivar sources of variation were small and statistically nonsignificant. The second order interaction of year x locations x cultivars, however, was significant. The relatively small values for the first order interactions indicated there were no consistent year effects or location effects on differential cultivar response. The source of variation due to cultivars was relatively small and nonsignificant. This is probably due to the fact that these cultivars have been tested and selected for their higher performances among many lines prior to the regional tests. Because there was no variation for either cultivars or cultivar x environments, one could conclude that the second order interaction is a reflection of year x location interactions. In the present experiment the lack of a significant year x cultivar interaction indicates that the relative performance of cultivars was essentially the same in each of the two years of testing. However, it is recognized that the 2 years upon which the present data are based may not represent an adequate sample of year x cultivar interaction effects. It is possible that the 2 consecutive years tested would be more alike than would have been a sample of 2 years drawn at random from a 10 or 15-year period. If so, the size of the year x cultivar interaction may have been underestimated. If this interaction is actually larger than the estimate obtained, it would certainly be necessary to test the cultivars in more than two years.

The lack of any significant location x cultivar interaction in the present study does not preclude the possibility of dividing the whole region of safflower growing into subareas for breeding and testing purposes. In order to recognize the subareas more data should be obtained.

The means performance in this study ranged from 1.503 ton/ha (V49-236) to 1.757 ton/ha (V49-338). Since there exists a great amount of genetic variation within and between local safflower populations of Iran (3), further selection within populations and interpopulation hybridization followed by selection would most probably increase the mean performance.

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