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Variation for Some Important Agronomic Traits in 100 Spring Safflower (*Carthamus tinctorius* L.) Genotypes

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Abstract: The present study was aimed to examine different agronomic traits in 100 safflower genotypes. The experimental design was a 10 x 10 simple lattice. The results of analysis of variance demonstrated that the differences among genotypes were highly significant (P<0.01) for all studied traits. Phenotypic and genotypic correlations showed that the grain yield per plant is significantly correlated with grain yield per plot, biomass, number of capitula, 100 - seed weight, number of secondary branches and oil yield per plant. There was also a positive correlation between kernel% and oil content, therefore selection for high oil content can be based on thin-hull seeds. High values of phenotypic and genotypic coefficients of variation were obtained for most traits, indicating high variability in the traits under study. Phenotypic coefficients of variation (PCV) ranged from 3.3% in days to maturity to 42% in ineffective capitula and genotypic coefficients of variation (GCV) ranged from 3.65% in days to bud formation to 35.7% in oil yield. The recorded data were subjected to principal component analysis. The results showed that seven principal components with eigen values more than one explained 80.7% of the total variability. The genotypes were classified in four groups: A, B, C and D for safflower breeding goals (high grain and oil yield, short growth duration) based on PC1 and PC2 (as the most important principal components).

Key words: Safflower · Grain and oil yield · Phenotypic and genotypic variability

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. India and Ethiopia are the countries with the longest tradition of growing safflower as an oil plant [1]. India is the biggest safflower producing country, following by the USA and Mexico [2]. Safflower has tolerance to drought and is suitable for growing in dry and marginal areas. Safflower has been cultivated in Iran for centuries on limited areas for dye extraction from its florets. Its importance as an oil seed crop has only been realized since 1970 in Iran [3]. Iran is one of the richest germplasm sources of safflower. For instance, out of the 2042 safflower genotypes deposited at the Western Regional Plant Introduction Station, Pullman, WA, USA, 199 are from Iran [4, 5].

Safflower is being grown in over 60 countries but India is contributing about 50% of production. In Iran the safflower crop area has increased over the last few years reaching about 7500 ha in 2001, whereas in 1997 it was 200-300 ha [6].

Evaluating yield components and their interrelationships and detecting suitable selection indexes is very important in safflower breeding programme, especially the direct components of yield that are related to the various morphological characters regarded as indirect components of yield. Ashri *et al.* [7] and Corleto *et al.* [8] reported that the most important yield component in safflower is the number of capitula per plant. Abel *et al.* [9] showed that the number of capitula per plant or number of seeds per capitula or both traits could be responsible for high yielding safflower lines.

Digming and Yuguang [10] in a study of 30 safflower cultivars, reported that the number of effective branches, main stem diameter, diameter of top seed, 100 - seed weigh, oil content and angle of the first branch were the six principal components. Omidi [11] reported that the number of seeds per capitula is associated with the increase of seed yield in safflower. Uslu *et al.* [12] concluded that selection for number of capitula per plant

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was effective for the improvement of the yield. Consentino *et al.* [13] showed that the number of capitula per plant and seeds per capitula were significantly and positively correlated. Bagawan and Ravikumar [14] studied 10 safflower populations from F2 and M2 generation and reported that the number of capitula per plant is the most important character contributing to grain yield per plant and the number of capitula recorded the highest positive correlation with grain yield. Johnson *et al.* [15] indicated that grain yield was positively correlated with seed weight and plant height.

The objective of this study was to evaluate 100 safflower cultivars for yield and their components as well as other important agronomic traits.

MATERIALS AND METHODS

One hundred Iranian and introduced safflower varieties and advanced lines were planted for study yield and yield components and other agronomic characters, using a simple lattice design (10 x 10) in Karaj-Iran. Seeds were sown by hand on an inter-row spacing of 0.5m and with an intra-row spacing of 5 cm, each plot consisted of rows 3m long. After emergence, manual thinning was used to obtain normal density. For the experiment, 70kg/ha of P_2O_5 as ammonium phosphate and 25kg/ha of nitrogen as urea were supplied prior to sowing and 30kg/ha of nitrogen as urea at the start of stem elongation. Weeds were controlled by manual weeding before stem elongation. Irrigation was applied at 7 stages: After emergence, stem elongation, bud formation, beginning of flowering, 50% of flowering, finishing of flowering and seed filling. Data on yield per plant and yield components and other agronomic traits were recorded on plants randomly selected from the two middle rows:

- Days from sowing to bud formation
- Days from sowing to flowering
- Days from sowing to maturity

Plant Height (cm): from ground level to the tip of main stem at maturity time.

Capitula and seeds number per capitula recorded on 5 plants selected from middle rows.

Branch number: number of secondary and tertiary branches recorded on the selected plants.

Kernel%: 25 seeds were weighed and soaked in water for 4 hours and then the seeds were hulled. Kernel% Obtained by calculating the kernel weight (after dried at 25°C for 24 hours in oven) above total 25 seeds weight ratio.

Biomass was determined from the oven-dried samples at 80°C for 48 hours.

100 seed weight, oil% (determined by N.M.R instrument), seed and oil yields per plant, seed and oil yields per plot were recorded after harvesting.

Phenotypic and Genotypic Variances Were Estimated:

$$\sigma_g^2 = \frac{(MSt - MSe) - [(MSb - MSe)(2/k+1)]}{2}$$

$$\sigma_p^2 = \sigma_g^2 + MSe/r$$

Where MST is the mean square of the genotypes, MSe is the mean square of error, MSb is the mean square of the block, K is the number of genotypes in a block and r is replication. Phenotypic and genotypic correlations, phenotypic and genotypic coefficients of variation (PCV, GCV) were calculated as follows [16].

$$\gamma_p = \frac{COV_p(x,y)}{\sigma_{px}\sigma_{py}}$$

$$PCV = \frac{\sigma_{px}}{\bar{x}} \text{x}100 \quad GCV = \frac{\sigma_{gx}}{\bar{x}} \text{x}100$$

$$\gamma_g = \frac{COV_g(x,y)}{\sigma_{gx}\sigma_{gy}}$$

All analyses employed standard SAS/STAT procedures [17].

RESULTS

Phenotypic and Genotypic Correlations: The phenotypic and genotypic correlation of yield per plant and its components with each other are shown in Table 1. These values also confirm that grain yield per plant is significantly correlated with grain yield per plot (0.970, 0.994), biomass (0.875, 0.930), number of capitula (0.850, 0.916), 100- seed weight (0.300, 0.300), number of secondary branches (0.547, 0.636) and oil yield per plant (0.963, 0.962). There was also a positive correlation between kernel% and oil content (0.682, 0.689).

Analysis of Variance, Phenotypic and Genotypic Coefficients: The results of analysis of variance demonstrated that the differences among genotypes

Table 1: Phenotypic and genotypic correlations

Traits	Grain yield/plant	Grain yield/plot	Biomass	100 seed weight	No. Capitula	No. Sub branches	Oil %	Oil yield/plant	Kernel %
Grain yield/plant	1								
Grain yield/plot	0.970**(0.994)	1							
Biomass	0.875**(0.930)	0.822**(0.866)	1						
100 seed weight	0.300**(0.300)	0.369**(0.266)	0.307**(0.326)	1					
No. Capitula	0.850**(0.916)	0.874**(0.938)	0.789**(0.879)	0.226**(0.269)	1				
No. secondary branches	0.547**(0.636)	0.578**(0.664)	0.452**(0.481)	0.059(0.085)	0.459**(0.591)	1			
Oil %	-0.101(-0.101)	0.082(-0.082)	0.090-0.101	0.223*(-0.231)	0.060(0.060)	-0.156(0.239)	1		
Oil yield/plant	0.936**(0.962)	0.944**(0.966)	0.846**(0.896)	0.236**(0.231)	0.866**(0.931)	0.531**(-0.119)	0.149(0.155)	1	
Kernel %	-0.117(-0.139)	-0.076 (-0.082)	-0.105-0.113	-0.179(-0.186)	0.052(0.031)	-0.193(0.222)	0.682**(0.689)	0.066(0.048)	1

*and **significant at 0.05 and 0.01 probability levels, respectively

Table 2: Phenotypic and Genotypic Parameters of Safflower Traits

Traits	Mean	Range	σ^2_g	CV%	PCV	GCV	Treatment adj	Treatment unadj
Grain yield/plant (g)	11.6	4-25	16.4	17.1	36.8	34.8	36.6**	36.5**
Grain yield/plot (kg)	232.4	91-395	513.8	6.8	32.4	31.9	11.2**	11.2**
Biomass (kg)	36.7	22-57	42.4	9.9	19	17.7	98**	98**
100 seed weight (g)	32.20	20-47	20.9	5.2	16.4	14.3	45.2**	44.8**
No. Capitula	11.3	3.5-20	9	17.3	29.4	26.4	22**	22**
No. seed/ capitula	32.7	17-43	26.9	6.9	16.8	15.9	59.8**	59.9**
Capitula weight (g)	23	12-23	18.6	9	19.9	18.8	41.5**	41.5**
No. ineffective capitula	3.4	1.1-10	1.4	31.4	42	34.8	4.5**	4.3**
Distance of branching	39	5-61	60	11.3	21.5	19.8	146.7**	144.8**
No. Nodes	19.3	5-32	15.3	14.5	23	20.3	40.5**	39.9**
Distance between nodes	2.1	1-3	0.14	10.3	20.4	18.2	0.34ns	0.34ns
No. secondary branches	8.5	3-13	3.52	14.4	24.5	22.2	8.4**	8.5**
Height (cm)	67.2	39-99	181.4	5.9	20.6	20.1	381.6**	381.8**
Days to bud formation	52.2	48-56	3.63	3	3.7	3.7	7.5**	7.5**
Days to flowering	67.2	61-75	8.4	6.2	4.3	4.4	16.9**	16.9**
Days to 50% flowering	77.6	62-86	10.8	7.6	4.3	4.3	23.3**	23.3**
Days to 100% flowering	88.4	76-97	12.2	7.4	4	3.9	24.8	24.9**
Days to maturity	109.9	100-120	13	5.1	3.3	3.3	26.2**	26.4**
Oil %	30	23-40	8.9	3.2	10.2	9.9	19**	18.86**
Oil yield/plant (g)	3.48	1.2-7.3	1.5	17.2	37	35	3.3**	3.3**
Oil yield/plot (g)	69.7	25-161	519.7	7.6	33	32.7	1064**	1068**
Kernel %	0.55	0.39-0.7	0.003	3.7	10.2	9.8	0.006ns	0.006ns

**significant at 0.01 probability level, ns: Non significant

Table 3: Eigen value and eigenvectors of the seven selected principal components

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Grain yield/plant	0.96523	0.02285	-0.12873	-0.07841	-0.04368	-0.01276	0.00736
Grain yield/plot	0.97142	0.05613	-0.10181	-0.027134	-0.02677	0.03353	-0.01217
Biomass	0.88686	-0.07752	-0.11204	0.08997	-0.02768	-0.1158	0.05404
100 seed weight	0.25597	-0.17202	-0.28683	-0.38046	-0.34754	0.55251	0.02911
No. Capitula	0.92659	-0.04012	0.04498	0.05893	-0.08841	-0.01390	-0.12612
No. seed/capitula	-0.07054	0.03195	0.26198	0.82246	0.11408	0.11679	0.13732
Capitula weight	0.03492	0.05984	-0.0938	0.89883	0.03144	-0.0404	0.09179
Ineffective capitula	0.28728	0.08490	-0.09923	-0.37114	0.19213	0.66.67	0.016204
Distance of branching	-0.12167	0.24487	-0.0222	0.15119	0.75255	-0.07668	0.040089
No. Nodes	-0.09706	0.22534	-0.03671	0.04485	0.84110	0.062232	-0.38401
Distance between nodes	-0.00784	0.06439	-0.02744	0.18928	-0.03075	0.04197	0.94898
No. secondary branches	0.58363	0.10705	-0.24350	-0.0340	-0.06503	0.26065	-0.05897
Height	0.68909	-0.20484	0.17022	0.01464	0.00896	0.09096	0.0031
Days to bud formation	-0.00107	0.11060	-0.07547	0.21490	-0.32019	0.68086	-0.21595
Days to flowering	-0.02191	0.67837	-0.14645	0.18351	0.30378	0.27472	0.01136
Days to 50% flowering	0.01431	0.90931	-0.01143	-0.3116	0.00259	0.16110	-0.02579
Days to flowering finishing	0.07693	0.93263	0.0210	-0.04747	0.08844	-0.05528	0.05553
Days to maturity	-0.10111	0.85159	-0.01219	0.11367	0.10353	-0.14474	0.03757
Oil %	0.02583	-0.03778	0.91034	0.09261	-.007681	-0.0173	0.0091
Oil yield/plant	0.96627	0.02692	0.10312	-0.0539	-0.04547	-0.02233	0.01533
Oil yield/plot	0.95931	0.06366	0.16344	0.01029	-0.03286	0.1845	-0.00288
Kernel %	-0.00164	-0.03651	0.88382	0.01974	0.03879	-0.04070	-0.02868
Eigenvalue	29/44	16.4	10.5	7.3	6.6	5.8	4.6
Percentage accumulative contribution	29.44	46	56.4	63.8	70.5	76.4	80.7

were highly significant ($p < 0.01$) for all traits (Table 2). These results indicated good variation among the genotypes for most traits that can be divided into genotypic and phenotypic components. The range, mean, genotypic variations (σ^2_g), Coefficients of variation (CV), phenotypic and genotypic coefficients (PCV and GCV) are presented in Table 2. Coefficients of variation ranged from 3% for days to bud formation to 31.4% in ineffective capitula (capitula without seed). Phenotypes coefficients of variation (PCV) ranged from 3.3% in days to maturity to 42% in ineffective capitula and genotypic coefficients of variation (GCV) ranged from 3.65% in days to bud formation to 35.7% in oil yield.

Principal Components Analysis (PCA): The results showed that seven principal components and factors with eigen values more than one explained 80.7% of total variability (Table 3). The first principal component (PC1) is grain and oil yield characters that explained 29.4% of total variability. Among the property vectors of PC1, grain yield/plant, grain yield/plot, biomass, No. capitula, No. branches, height, oil yield/plant and oil yield/plot have higher values. The second principal component (PC2) is plant phenologic characters which explain 16.4% of total variability. Among the property vectors of PC2, days to flowering, days to 50% flowering, days to 100% flowering and days to maturity have higher values. The third principal component (PC3) is seed characters that explain about 10.5% of total variability. Among the property vectors of PC3, oil% and kernel% have higher values. The fourth principal component (PC4) is capitula characters which explain about 7.3% of total variability.

Among the property vectors of PC4 No. seed/capitula and capitula weight have higher values. The fifth principal component (PC5) is branch characters that explain about 6.6% of total variability. Among the property vectors of PC5, Distance of branching, No. nodes have higher values. The sixth principal component (PC6) is capitula and 100 - seed weight which explain about 5.8% of total variability. Among the property vectors of PC6 ineffective capitula, days to bud formation and 100- seed weight. have higher values. The seventh principal component (PC7) is stem characters which explain about 4.6% of total variability. Among the property vectors of PC7 Distance between nodes has higher value.

DISCUSSION

The results of phenotypic and genotypic correlations showed that the most important yield components (capitula/plant, seed/capitula and 100- seed weight) were intercorrelated with the exception of number of capitula per plant that was not correlated to number of seed per capitula. The grain yield per plant is significantly correlated with grain yield per plot, biomass, number of capitula, 100 seed weight and number of secondary branches. As the number of capitula can be recorded on filed easily, selection for grain and oil yield, in F2 generations or safflower landraces population, can be based on number of capitula per plant. These results are in agreement with those obtained by Ashri *et al.* [7], Corleto *et al.* [8], Abel and Discroll [9], Uslu *et al.* [12], Bagavan and Ravikumar [14] and Amini *et al*. [18].The new safflower lines such as: Varamin -295, K.A.72, L.R.V.51.51, Zargan 279 and I.L111 have improved for number of capitula per plant at Oil Research Department of Seed and Plant Improvement Institute (SPII).

A positive correlation between kernel% and oil content (0.682), shows that selection for high oil content can be based on thin-hull seeds, such as the new line K.H.48.154 with high oil content (40%), that have been selected among F2 generation (N.S.1016 x Rinconada) at SPII. These results are in agreement with those obtained by Corleto *et al*. [8], Johnson *et al*. [15], Amini *et al*. [18], Parameswarppa [19] and Patil and Deshmukh [20]. The highest correlation coefficient was obtained between yield of plant and yield of plot (0.97), which means that the average value of traits measured on five single plants, can be used as a plot representative. Such significant and positive correlations among the traits probably are related to poliotropic effect [21]. For the most traits, phenotypic coefficients of variation were higher than genotypic coefficients, that it may be due to environmental effect. These variations help us to select different genotypes with desirable characteristics.

The Genotypes Were Classified in Four Groups: A, B, C and D for safflower breeding goals (high grain and oil yield, short growth duration) based on PC1 and PC2 (as the most important principal components). The obtained results revealed that genotypes could be more effectively clustered when considering traits related to grain yield rather than with geographical origin.

REFERENCES

1. Weiss, E.A., 2000. Oil Seed Crops. Blackwell Science Ltd, Oxford, UK.
2. Li, D. and H. Mundel, 1996. Safflower: (*Carthamus tinctorius* L.), Promoting the conservation and use of underutilized and neglected crops. IPGCPR, Catersleben/ IPGRI, Rome, Italy. pp: 83.
3. Ahmadi, M.R. and A.H. Omidi, 1997. Evaluation of 25 safflower (*Carthamus tinctorius* L.) genotypes for their morpho-agronomic characters. IV International Safflower Conference. Italy, pp: 218-221.
4. De Haro, A., M. del Rio, J.C. Lopez, M.A. Garcia, M.J. palomares and J. Fernandez Martinez, 1997. Evaluation of the world collection of safflower for oil quality and other seed characters. Sesame Safflower Newsl., 6: 94-99.
5. Jaradat, A.A. and M. Shahid, 2006. Patterns of phenotypic variation in a germplasm collection of *Carthamus tinctorius* L. from the Middle East. Genet. Resour. Crop Evol., 53: 225-244.
6. Omidi Tabrizi, A.H., 2001. Correlation between traits and path analysis for grain and oil yield in spring safflower. Proceeding of the Vth International Safflower Conference, USA, July, 23-27, pp: 95-98.
7. Ashri, A., E. Zimmer, L. Urie and A. Ghaner, 1976. Evaluation of the world collection of safflower for yield and yield components and their relationship. Crop Sci., 14: 799-802.
8. Corleto, A., E. Cazzato and P. Ventricelli, 1997. Performance of hybrid and open pollinated safflower in two different Mediterranean environments. IV International Safflower Conference, Italy, pp: 276-278.
9. Abel, G.H. and M.F. Discroll, 1976. Sequential traits development and breeding for high yield. Crop Sci., 16: 213-216.
10. Digming, K. and J. Yuguang, 1993. Principal component agricultural properties of 30 safflower cultivars. Third International Safflower Conference, China, pp: 520-527.
11. Omidi, A.H., 1994. Evaluation of safflower genotypes for yield and yield components. Second Iranian Congress on Crop Production and Breeding, Karaj-Iran.
12. Uslu, N., A. Akin and M. Basi, 1997. Weed and row spacing effects on some agronomic characters of safflower spring planted. IV International Safflower Conf. Italy, pp: 128-132.
13. Consentino, S., V. Copani and M. Camarata, 1997. Relations between meteorological parameters yield and seed oil content in safflower in Mediterranean environment. IV International Safflower Conference, Italy, pp: 149-155.
14. Bagavan, I. and R.L. Ravikumar, 2001. Strong undesirable linkages between seed yield and oil components- A problem in safflower improvement. Proceeding of the Vth International Safflower Conference, USA, July 23-27, pp: 103-107.
15. Johnson, R.C., P.B. Ghorpade and V.C. Bradley, 2001.Evaluation of the USDA core saffiower collection for seven quantitative traits. V International Safflower Conf. USA., pp: 143-149.
16. Singh, M., 1991. Genotypic and phenotypic correlation in plant traits. Computer Service. ICARDA, Aleppo, Syria. pp: 279.
17. SAS Institute, Inc 1999. SAS/STAT user's guide. Institute, Inc., Cary.
18. Amini, F., G. Saeidi and A. Arzani, 2008. Study of genetic diversity in safflower genotypes using agro-morphological traits and RAPD markers. Euphytica, 163: 21-30.
19. Parameswarppa, K.G., 1984. Genetic analysis of yield and other quantitative characters in safflower. J.Agric. Sci., 17: 83.
20. Patil, B.R. and M.P. Deshmukh, 1997.Studies on selection indices in safflower.Third International Safflower Conf. China, pp: 265-269.
21. Falconer, D.S., 1989. Introduction to quantitative genetics. Longman and technical co, USA.