Scientific Papers. Series A. Agronomy, Vol. LVII, 2014
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

ESTIMATES FOR BROAD SENSE HERITABILITY AND HETEROSIS OF AGRONOMIC AND QUALITY CHARACTERS OF SAFFLOWER (*Carthamus tinctorius* L.)

Hasan BAYDAR, Sabri ERBAŞ

Suleyman Demirel University, Faculty of Agriculture, Department of Field Crops, Isparta, Turkey

Corresponding author email: hasanbaydar@sdu.edu.tr

Abstract

The present research was conducted in between 2008 and 2011 at Suleyman Demirel University, Faculty of Agriculture, Department of Field Crops, Isparta Turkey (latitude 37°45'N, longitude 30°33'E, altitude 997 m). In study was estimated to genotypic (σ_g^2) and phenotypic (σ_p^2) variances, broad sense heritability (h^2_b) and heterosis value of agronomic and quality characters of F_1 and F_2 plants derived from a cross between Dinçer 5-118 and Montola 2000 cultivars. In F_1 generation, heterosis and heterobeltiosis were high and positive for plant height, head number per plant, 1000 seed weight, seed yield per plant, palmitic acid and linoleic acid. In addition, heterosis and heterobeltiosis were low and positive for branches number, harvest index and oil content. On the other hand, heterobeltiosis was negative for seed number per head and oleic acid. The highest broad sense heritability was estimated seed number per head, 1000 seed weight, oleic acid and linoleic acid (80.1, 81.1, 99.4 and 99.3%, respectively). The broad sense heritability were estimated as 64.1% for plant height, 54.3% for primary branches, 74.7% for head number per plant, 72.1% for harvest index, 55.2% for seed yield per plant, 67.6% for oil content, 47.3% for palmitic acid and 48.2% for stearic acid. The results of this study indicated that plant height, head number per plant, 1000 seed weight, seed number per head, harvest index, oil content, oleic acid and linoleic acid firstly be evaluated for increase to succeed in practical selection in early generation.

Key words: *safflower, yield and quality characters, broad sense heritability, heterosis.*

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the humanity's oldest oilseed crops and has been grown commercially for edible oil and natural dye source throughout around the world. Although it is cultivated in more than 20 countries worldwide, although Mexico, India, USA, Ethiopia, and Argentina account for 95% of world's production. Safflower was cultivated in 812.195 ha in the world and 780.677 tonnes seed was harvested in 2012. Cultivation of safflower in Turkey has been increasing during the last decade from 40 ha in 2002 to over 15,600 ha in 2012 (Anonymous, 2014).

As safflower is more tolerant to drought and salinity than some other oilseed crops, it is especially suited for dry and salty areas where other oilseeds are difficult to grow (Weiss, 2000). However, seed yield and oil content of safflower is generally lower than the other oil crops, such as soybean, rapeseed, groundnut and sunflower. For this reason, introduction of a crop depends on economic value of the crop. Therefore it is necessary to improve modern growing systems and but also necessary to obtain new cultivars with high oil content and seed yield by using advanced to breeding methods (Baydar and Erbaş, 2007).

The seed yield and oil content are the mainly selection criteria for safflower breeding programs. A successful safflower breeding program enables select is not the superior genotypes from the hybrid populations. But the performance of selected genotypes change at different environments (Toker, 2004; Çamaş and Esendal, 2006). Plant breeders are challenged with different environments or years to achieve their targets (Welsh, 1981). Therefore the information of character associations between the traits themselves and with the yield is important for the breeding material subjected to selection for yielding genotypes (Iqbal et al., 2006). Plant height, primary branches number per plant, head number per plant, head diameter, seed number per head, seed weight per plant, harvest index, 1000 seed weight and husk ratio are the main traits in safflower improvement for increasing seed yield and oil content (Ramachandram and

Goud, 1981; Reddy et al., 2004; Arslan, 2007; Mohammadi and Pourdad, 2009; Rudra Naik et al., 2009; Eslam, 2010; Golkar et al., 2011). Therefore, heritability estimate should be determined for traits in a safflower breeding program (Aslan, 2007), and highly heritable traits allow better selection in early generations thus reduce cost, material and time (Mary and Gopalan, 2006). Because heritability vary among traits, within population heritability estimates among the characters could be used to identify indirect selection schemes that may be more effective than direct selection schemes (Holland et al., 2003). In present study, genotypic (σ_g^2) and phenotypic (σ_p^2) variances, broad sense heritability (h^2_b) and heterosis value for agronomic and quality characters were determined using F_1 and F_2 plants derived from a cross between Dinçer 5-118 and Montola 2000 cultivars.

MATERIALS AND METHODS

This study was carried out in 2011 at the experimental area of Department of Field Crops in Faculty of Agriculture at Suleyman Demirel University, Isparta Turkey (latitude 37°45'N, longitude 30°33'E, altitude 997 m).

The parents [Dinçer 5-118 (non-spiny capitulum's-*ss*, orange petal-*OO*) x Montola 2000 (spiny capitulum's-*SS*, yellow petal-*oo*)], and their F_1 and F_2 generations were obtained by synthetic male sterility induction by gibberellic application (Baydar and Gökmen 2003). These lines were obtained as following: In 2008, Dinçer 5-118 selected as female parent and sprayed with 3x100 (three sprays each with 7 days interval), ppm (mg/l) concentrations of gibberellic acid (GA_3) (Merck) during budding stage before flowering (with <0.5 cm diameter capitulate). Pollinations were done among the pollen fertile spiny (Montola 2000) and chemically pollen sterile non-spiny (Dinçer 5-118) cultivars. At maturity, heads of the non-spiny female parent plants exposed to GA_3 were harvested (F_1). In 2009, F_1 seeds were grown and non-spiny types have been removed, in this way, F_1 plants were all true hybrids (*SsOo*). In 2010, four different phenotypes (*SSoo, ssOO, SsOo, ssoo*) were selected based on Mendelian digenic heritability in F_2 generations. In 2011, parents (20 plants per parent) and their F_1 (17 plants) and F_2 (256 plants) progeny were sown at the end of March. Spacing between rows was 0.50 m and within rows was 0.25 m. Fertilization was applied 15 kg nitrogen (Ammonium sulfate) and 10 kg phosphorus (Diammonium phosphate) per decare. Weed control was performed by mechanical rotary tillage and manual weeding. When the crop reached maturity (in the second week of October), rows were harvested by hand.

All agronomic and quality characters were determined by mean using parents and F_1 plants and F_2 plants. The following observations were taken: plant height (PH, cm), primary branches number per plant (PBN, no/plant), head number per plant (HNP, no/plant), head diameter (HD, mm), seed number per head (SNH, no/head), seed weight per plant (SWP, g/plant), harvest index (HI, %), 1000 seed weight (1000 SW, g), husk ratio (HR, %), seed yield (SY, kg ha^{-1}), oil content (OC, %), oil yield (OY, kg ha^{-1}), palmitic acid content (PA, %), stearic acid content (SA, %), oleic acid content (OA, %) and linoleic acid content (LA, %). The oil content and fatty acid composition were determined in Nuclear Magnetic Resonance (NMR, Oxford) and Gas chromatography (GC, Perkin Elmer Auto System XL), respectively. GC analysis was carried out as follows: capillary column, MN FFAP (50 m×0.32 mm i.d., film thickness, 0.25 m), oven temperature was kept at 120 °C for 1 min and programmed to 250 °C at a rate of 6 °C/min, and then constant at 240 °C for 15 min, total run time 60 min, injector temperature, 250 °C, detector (70 eV) temperature, 260 °C, flow rate for helium, 40 ml/min, split ratio, 1/20 ml/min, injection volume, 0.5 µl. Broad sense heritability (h^2_b), genotypic (σ_g^2) and phenotypic (σ_p^2) variances were calculated following equations reported by Poehlman and Sleper (1995).

$$\boldsymbol{\sigma_e^2} = (\sigma_{P1}^2 + \sigma_{P2}^2 + \sigma_{F1}^2)/3$$

$$\boldsymbol{\sigma_{F2}^2} = \sigma_g^2 + \sigma_e^2, \quad \boldsymbol{\sigma_p^2} = \sigma_{F2}^2, \quad \boldsymbol{\sigma_g^2} = \sigma_{F2}^2 - \sigma_e^2$$

$$\boldsymbol{h^2_b} = \sigma_g^2 / \sigma_p^2 = (\sigma_{F2}^2 - \sigma_e^2) / \sigma_{F2}^2$$

(σ_e^2= Environment variance, $\sigma_{P1}^2 = P_1$ variance, $\sigma_{P2}^2 = P_2$ variance, $\sigma_{F1}^2 = F_1$ variance, $\sigma_{F2}^2 = F_2$ variance)

Percent heterosis over midparent (MP) and percent heterobeltiosis over the better parent

(BP) were estimated using the formulas, [(F_1-MP)/MP]/100 and [(F_1-BP)/BP]/100, respectively for all the agronomic and quality characters measured. Their significance was determined with f-test using MSTAT-C package programme (Freed et al., 1989) and orthogonal contrast comparisons described between hybrid and its parents for heterosis and between hybrid and better parent for heterobeltiosis.

RESULTS AND DISCUSSIONS

A wide genetic variability in the base population after crossbreeding plays an important role for a successful breeding program. The extent of diversity in a crop species determines the limits of selection for improvement. The most of economic characters are generally quantitatively inherited and show genotype x environment interactions. Therefore, it is necessary to determine variability in the base breeding material. The variance, range, means and coefficient variation of agronomic and quality characters in safflower genotypes are given Table 1. While seed yield per plant ranged from 10.82-27.27 g in P_1 plants, 6.75-18.66 g in P_2 plants, 9.33-32.77 g in F_1 plants, this character ranged from 4.82-45.36 g in F_2 plants. Oil content, oleic acid and linoleic acid in F_2 plants showed more wide variation than parents and F_1 plants. The magnitude of variation in this population was 25.5-36.5%, 8.68-77.85% and 13.11-81.22%, respectively. In F_2 population, while mean oleic acid content close to parent with low oleic acid, mean linoleic acid content of genotypes was similar to parent with high linoleic acid.

Table 1. Variance, range, means and coefficient variation of agronomic and quality characters in safflower genotypes

Variance components	**Seed yield per plant (g)**				**Oil content (%)**			
	P_1	**P_2**	**F_1**	**F_2**	**P_1**	**P_2**	**F_1**	**F_2**
Range	10.82-27.27	6.75-18.66	9.33-32.77	4.82-45.36	24.5-28.7	31.1-35.6	29.9-33.1	25.5-36.5
Means ± SE	16.7 ± 1.16	10.6 ± 0.90	19.8 ± 1.87	16.0 ± 0.48	26.4 ± 0.33	33.5 ± 0.38	31.4 ± 0.24	31.1 ± 0.14
σ^2	21.57	12.91	45.32	59.34	1.84	1.98	0.73	4.68
CV	27.70	33.80	34.00	48.20	5.10	4.20	2.70	7.00
Variance components	**Oleic acid (%)**				**Linoleic acid (%)**			
	P_1	**P_2**	**F_1**	**F_2**	**P_1**	**P_2**	**F_1**	**F_2**
Range	8.64-12.21	73.95-78.91	18.23-35.16	8.68-77.85	75.96-79.92	11.79-16.61	53.27-71.12	13.11-81.22
Means ± SE	10.84 ± 0.28	76.89 ± 0.74	26.98 ± 3.02	25.95 ± 2.86	77.95 ± 0.35	13.84 ± 0.76	62.12 ± 3.12	62.97 ± 2.75
σ^2	1.59	3.31	45.73	523.97	2.00	3.49	48.57	484.73
CV	11.60	2.42	25.13	88.24	1.82	13.52	11.23	35.04

σ^2: variance, CV: Coefficient variation.

The characters showing significant heterotic effects at 0.05 and 0.01 significance levels for F_1 progeny and broad-sense heritability, phenotypic and genotypic variance for parents, F_1 and F_2 progeny are given in Table 2. The highest significant negative heterosis (-38.5%) was estimated for oleic acid. However, the lowest significant positive heterosis (44.6%) was determined for seed yield per plant followed by that for linoleic acid (35.4%), 1000 seed weight (26.8%), head number per plant (18.7%), plant height (14.6%) and palmitic acid (14.4%). The highest significant positive heterobeltiosis of 18.2% was observed for seed yield per plant. This was followed by head number per plant and plant height. The highest significant negative heterobeltiosis was observed for oleic acid (-64.9%). Present characters are in conformity with the earlier findings of Manjare and Jambhale (1995) Singh et al. (2008) and Shivani et al. (2010) who reported positive heterosis and heterobeltiosis for plant height, head number per plant, 1000 seed weight, and seed yield per plant. On the other hand, heterosis and heterobeltiosis for branches number was statistically not significant. Ranga et al. (1982) reported to be low heterosis for branches number. While, heterosis for oleic acid was statistically significant positive (5.0%), heterobeltiosis value of this characters was significant negative (-6.1%). Occurrence of low and positive

heterosis estimates was also reported by Shivani et al. (2010). While, the low heterosis estimate was found for oleic acid, high heterosis estimate was linoleic acid. The negative correlation between oleic and linoleic acid in safflower was reported by Knowles (1989) and Erbaş (2012). Joksimovic (2006) reported to be low heterosis for oleic acid and high heterosis for linoleic acid in sunflower.

Table 2. Statistical analysis of variance components, heterosis and heritability values of agronomic and quality characters

Characters	Heterosis	Heterobeltiyosis	σ_p^2	σ_g^2	h^2_b
Plant height	14.6**	12.6**	11.9	21.3	64.1
Branches number	3.2	-2.9	2.0	2.4	54.3
Head number per plant	18.7**	13.4**	10.1	29.8	74.7
Seed number per head	-0.7	-12.4**	44.1	185.1	80.8
Harvest index	5.38*	-7.8*	13.9	35.8	72.1
1000 seed weight	26.8**	7.8*	5.8	24.8	81.0
Husk ratio	-1.1	-8.7*	2.3	6.1	72.6
Seed yield per plant	44.6**	18.2**	26.6	32.7	55.2
Oil content	5.0*	-6.1*	1.5	3.2	67.6
Palmitic acid	14.4**	2.5	0.2	0.2	47.3
Stearic acid	1.7	-6.5*	0.1	0.1	48.2
Oleic acid	-38.5**	-64.9**	3.3	520.7	99.4
Linoleic acid	35.4**	-20.3**	3.4	481.3	99.3

A large portion of total variation in population was determined by genotypic and phenotypic variances for all the characters. The genotypic variance was higher than the phenotypic variance for all the characters and showing the predominant role of the environment. Although the genotypic variance was greater than the phenotypic variance, the difference between these two parameters was minor, except for branches number, palmitic acid and stearic acid, indicating that the characters were stable between years but still influenced slightly by the environment. Moreover, the large differences between phenotypic and genotypic variance indicated that the variability in population was owing to genetic effects. Especially, differences between genotypic and phenotypic variance were large for seed number per head, 1000 seed weight, oleic and linoleic acid. Similar results have also been reported by Reddy et al. (2004), Arslan (2007), Mohammadi and Pourdad (2009) and Safavi et al. (2011).

Genotypic variance was not enough to determine the amount of variation present in genetic resources (Mohammadi and Pourdad, 2009). The heritability is determined by the ratio of genotypic variance to phenotypic variance and shows the association between genetic factors and environment (Arslan, 2007). The low heritability estimates were found for palmitic acid (47.3%), stearic acid (48.2%), branches number (54.3%) and seed yield per plant (55.2%). Heritability was high for oleic acid (99.4%), linoleic acid (99.3%), 1000 seed weight (81.0%) and seed number per head (80.8%). Also, the medium heritability values were showed for plant height, head number per plant, harvest index, husk ratio and oil content, 64.1%, 74.7%, 72.1% and 67.7%, respectively. The medium and high heritability for plant height were reported by Reddy et al. (2004), and Mohammadi and Pourdad (2009). Also, heritability for harvest index and oil content were medium, this characters generally was less affected by environmental factors and variations in population were due to genetic factors (Parameshwar, 2009; Golkar et al., 2011). Parameshwar (2009) reported that heritability for harvest index was 67.3%. Increasing seed yield of safflower is one of the most important breeding objectives. But the heritability of seed yield per plant has been reported to be low (Çamaş and Esendal, 2006), medium (Reddy et al., 2004) and high (Mohammadi and Pourdad, 2009).

In this study, seed yield per plant was influenced by both genetic factors and environmental factors. 1000 seed weight in safflower breeding is one of the significant selection criteria's. The most research reported to be was high heritability for 1000 seed weight

of safflower (Reddy et al., 2004; Çamaş and Esendal, 2006; Pahlavani, 2007; Golkar et al., 2011). Examined inheritance of fatty acid, in the present study, effect of environment was more pronounced on palmitic and stearic acids than oleic and linoleic acids. Erbaş (2012) reported that heritability was medium for palmitic and stearic acids, and high for oleic and linoleic acids. Bartolomew (1971) found that palmitic and stearic acids content were changed at different temperatures during safflower seed development. Golkar et al. (2011) indicated that additive and dominance gene action in genetic controlling oleic acid were played an important role. Thus, heritability for this character was high (broad and narrow sense heritability, 92.0-81.0% in F_1 progeny and 93.0-73.0% in F_2 progeny, respectively)

CONCLUSIONS

As a result, head number per plant, seed number per head, harvest index, 1000 seed weight, husk ratio, oil content, oleic and linoleic acid were the least affected characters over environment and variations in the population due to genetic factors. So these characters firstly be evaluated for increase to succeed in practical selection in early generation.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of the Scientific and Technical Research Council of Turkey (TUBİTAK-111 O 380).

REFERENCES

Anonymous, 2014. FAO/STAD Database. http://www.fao.org. (accessed February 2014).

Freed R., Einmensmith S.P., Guetz S., Reicosky D., Smail V.W., Wolberg P., 1989. User's guide to MSTAT-C, an analysis of agronomic research experiments. Michigan State University, USA.

Poehlman J.M., Sleper D.A., 1995. Breeding Field Crops. Iowa State University Press, USA, p. 494.

Arslan B., 2007. Assessing of heritability and variance components of yield and some agronomic traits of different safflower (*Carthamus tinctorius* L.) cultivars. Asian J Plant Sci., 6:554-557.

Bartholomew S.B., 1971. Temperature effects on the fatty acid composition of developing in safflower (*Carthamus tinctorius* L.). MS Thesis, University of California, Davis.

Baydar H., Gökmen O.Y., 2003. Hybrid seed production in safflower (*Carthamus tinctorius* L.) following the induction of male sterility by gibberellic acid. Plant Breeding, 122:459-461.

Baydar H., Erbaş S., 2007. Safflower breeding for edible oil and biodiesel production in Turkey. 1th National Oil Seed Crops and Biodiesel Symposium, Samsun, Turkey, p. 378-386.

Çamaş N., Esendal E., 2006. Estimates of broad-sense heritability for seed yield and yield components in safflower (*Carthamus tinctorius* L.). Hereditas, 143:55-57.

Erbaş S., 2012. Development of safflower (*Carthamus tinctorius* L.) lines with high oil, oleic acid content and seed yield through hybridization breeding. PhD Suleyman Demirel University, Isparta, Turkey.

Eslam B.P., Monrifar H., Ghassemi T., 2010. Evaluation of late season drought effects on seed and oil yields in spring safflower genotypes. Turk J Agric For, 34:373-380.

Golkar P., Arzani A., Rezaei A.M, 2011. Genetic analysis of oil content and fatty acid composition in safflower (*Carthamus tinctorius* L.). J Am Oil Chem Soc, 88:975–982.

Holland JB., Nyguist W.E., Cervantes-Martinez C.T., 2003. Estimating and interpreting heritability for plant breeding: An update. Plant Breeding Rev Vol. 22, Edited by Juler Janick, John Wiley & Sons, Inc p.12.

Iqbal M., Hayat K., Khan R.S.A., Sadiq A., Islam N., 2006. Correlation and path coefficient analysis for earliness and yield traits in cotton (*G. hirsitum*). Asian J Plant Sci, 5:341-344.

Mary S.S., Gopalan A., 2006. Dissection of genetic attributes yield traits of fodder cowpea in F_3 and F_4. J Appl Sci Res, 2 (6):805–808.

Joksimović J., Jovanka A., Marinković R., Jovanović D., 2006. Genetic control of oleic and linoleic acid contents in sunflower. Helia, 29 (44):33-40.

Mohammadi R., Pourdad S.S., 2009. Estimation, interrelationship and repeatability of genetic variability parameters in spring safflower using multi-environment trial data. Euphytica, 165:313-324.

Manjare M.R., Jambhale N.D., 1995. Heterosis for yield and yield contributing characters in safflower (*Carthamus tinctorius* L.). Indian J. Genet. and Plant Breed., 55 (1):65-68.

Shivani D., Sreelakshmi C.H., Sameer Kumar C.V., 2010. Heterosis and inbreeding depression for yield and yield components in safflower (*Carthamus tinctorius* L.). Electronic Journal of Plant Breeding, 1(6):1492-1494.

Pahlavani M.H., Saeidi G., Mirlohi A.F., 2007. Genetic analysis of seed yield and oil content in safflower using F_1 and F_2 progenies of diallel crosses. International Journal of Plant Production, 2:129-140.

Parameshwar K.B., 2009. Stability of non-spiny breeding lines in safflower (*Carthamus tinctorius* L.). Master Thesis, Dharwad University of Agricultural Sciences, Dharwad, India.

Ramachandram M., Goud J.V., 1981. Genetic analysis of seed yield, oil content and their components in safflower *(Carthamus tinctorius* L.). Theor Appl Genet, 60:191-195.

Reddy M.V.S., Chand P., Vidyadhar B., Devi I.S.L., 2004. Estimation of genetic parameters for yield and its component in F_4 generation of safflower (*Carthamus tinctorius* L.). Prog. Agric, 4 (1): 16-18.

Ranga R.V., 1982. Heterosis for agronimic characters in safflower. Indian Journal of Genetics and Plant Breeding, 42 (3):364-371.

Rudra Naik V., Bentur G.M., Salimath P.M., Parameshwarappa K.G., 2009. Introgression of non spiny and high oil content in adapted generations of safflower (*Carthamus tinctorius* L.). Karnataka J Agric Sci, 22 (1):39-43.

Safavi S.A., Pourdad S.S., Safavi S.M., Safavi A.S. 2011. Heritability and genetic gain of some morphological traits in safflower (*Carthamus tinctorius* L.). American Journal of Scientific Research, 17:14-18.

Knowles P.F., 1989. Safflower. In. Oil Crops of the World.

Toker C., 2004. Estimates of broad-sense heritability for seed yield and yield criteria in faba (*Vicia faba* L.). Hereditas 140:222-225.

Weiss E.A. 2000. Oilseed Crops, 2nd ed. Blackwell Sci Ltd, Victoria, Australia.

Welsh J.R. 1981. Fundamentals of plant genetics and breeding. John Wiley Sons, Inc.

Singh V., Kolekar N.M., Nimbkar N., 2008. Breeding strategy for improvement of flower and seed yields in safflower. 7th International Safflower Conference, New South Wales, Australia.