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Oil Contents, Mineral Compositions, and Their Correlations in Wild and Culture Safflower Seeds

Rahim Ada, Mustafa Harmankaya, Sadiye Ayse Celik

Abstract**—**The safflower seed contains about 25-40% solvent extract and 20-33% fiber. It is well known that dietary phospholipids lower serum cholesterol levels effectively. The nutrient composition of safflower seed changes depending on region, soil and genotypes. This research was made by using of nine natural selected (A22, A29, A30, C12, E1, F4, G8, G12, J27) and three commercial (Remzibey, Dincer, Black Sun1) varieties of safflower genotypes. The research was conducted on field conditions for two years (2009 and 2010) in randomized complete block design with three replications in Konya-Turkey ecological conditions. Oil contents, mineral contents and their correlations were determined in the research. According to the results, oil content was ranged from 22.38% to 34.26%, while the minerals were in between the following values: 1469, 04-2068.07 mg kg^{-1} for Ca, 7.24-11.71 mg kg^{-1} for B, 13.29-17.41 mg kg^{-1} for Cu, 51.00-79.35 mg kg^{-1} for Fe, 3988-6638.34 mg kg^{-1} for K, 1418.61-2306.06 mg kg^{-1} for Mg, 11.37-17.76 mg kg^{-1} for Mn, 4172.33-7059.58 mg kg^{-1} for P and 32.60-59.00 mg kg^{-1} for Zn. Correlation analysis that was made separately for the commercial varieties and wild lines showed that high level of oil content was negatively affected by all the investigated minerals except for K and Zn in the commercial varieties.

Keywords**—**Safflower, oil, mineral content, quality.

I. INTRODUCTION

SAFFLOWER (*Carthamus tinctorius* L.) is a multipurpose crop species which can be used as an edible oil, as well as for medicinal and industrial applications [21] and, it is also one of the main plant for the drought areas over the world [20]. Safflower seeds contain from 13 to 46% oil, and approximately 90% of this oil is composed from unsaturated fatty acids, which are called as oleic and linoleic acids [10]. It is unique for having highest polyunsaturated/saturated contents that play an important role in reducing blood cholesterol level [14]. Safflower is also an important source of tocopherol. Alpha-tocopherol is the main tocopherol in safflower seeds, accounting for more than 95% of the total tocopherol [10]. In addition, due to rapid drying, the oil is being high demanded in paint and emulsion industries [11].

Dordas, Sioulas [4] reported that safflower oil is quite suitable for biodiesel production. In addition, safflower oil cake is also a valuable feed for animals [13]. For this reason, it is necessary to evaluate of the available genetic sources.

Rahim Ada is with the Department of Field Crops, University of Selcuk, Faculty of Agriculture, Konya, Turkey (corresponding author, e-mail: rahimada@selcuk.edu.tr).
Sadiye Ayse Celik is with the Department of Field Crops, University of Selcuk, Faculty of Agriculture, Konya, Turkey.
Mustafa Harmankaya is with the Department of Soil Sciences and Plant Nutrition University of Selcuk, Faculty of Agriculture, Konya, Turkey.

Knowles [12] proposed seven diversity centers for safflower germplasm evolution including the Far East, India-Pakistan, the Middle East, Egypt, Sudan, Ethiopia and Europe. Related researches are not enough in Turkey although the country has an origin of the plant. Therefore, the plants of natural vegetation should be studied in terms of oil content and especially for the mineral contents that is important for animal feeding.

Minerals, such as calcium, iron, magnesium, manganese, and zinc are essential for the functioning of plant cells. Certainly, the first phase of seedling development depends on the amount of mineral nutrients present in seeds. These elements are also essential nutrients for animals and men [6].

In the present research, oil contents, mineral contents and their correlations of the natural selected and commercial varieties of safflower genotypes were determined.

II. MATERIAL AND METHODS

The research was conducted in research field of Faculty of Agriculture, Selcuk University, Konya, Turkey. Average altitude of the research area was 1050 m. In research area, long period (1991-2008; April-August) total precipitation was 104.0 mm average temperature is 19.0°C. In the years of 2009 and 2010, the amounts of total precipitations were 115.9 and 103.1 mm respectively. Average temperature was 19.5°C and 21.3°C in the first and the second vegetation periods.

Soil characteristics of the trial field for 0-30 cm of depth are: slightly alkaline (pH= 7.8), low organic matter (1.20%), no salt problem (EC (µS / cm) = 189), 10.74 ppm for P_2O_5, enough value (219.96 ppm) for K_2O and Zn (2.16 ppm), low value for Fe (1.28 ppm), enough value for Cu (0.82 ppm), normal value for Mn (4.95 ppm) and high value for Ca (5863.00 ppm).

In the study, 9 safflower promised lines in (A22, A29, A30, C12, E1, F4, G8, G12, J27), which were selected and collected from Turkey natural vegetation and developed by Dr. Rahim ADA, and 3 cultivars (Remzibey, Dincer, Black Sun1) were evaluated in two growing seasons (2009 and 2010). All of the safflower genotypes that used in the present research was *Catrhamus tinctorius* L. and diploid (2n=2x=24). Pure lines were derived through self-pollination of individual plants of each genotype. This research was conducted in "Randomized Complete Block Design" with three replications. In the experiments, a total of 40 kg ha^{-1} of P_2O_5 and 30 kg ha^{-1} of nitrogen were applied before sowing and 20 kg ha^{-1} of nitrogen was used as a top dressing during starting of stem elongation. Weeds were controlled by hand. The experiment was planted on 2th April and 24th March, 2010. Each genotype was sown in plots with 4 rows, 4 m of longitude with spacing 50 cm between rows. Plant harvests were made in August 2009 and 2010. A length of 50 cm on both sides of the rows in each plot was left as border effects.

Mineral composition was determined by using ICP-AES device (Varian Vista Model) according to Burt [2] method. Oil content was determined according to the soxhlet method [3]. Analysis of correlation and variance were performed using statistical software packages (Jmp, Sas Institute Inc. 1989-2002).

III. Results

Oil content was ranged from 22.38% to 34.26% in the research (Table II). All of the natural selected and developed lines was lower oil content than commercial varieties.

Content of the investigated mineral was in between 1469, 04-2068.07 mg kg^{-1} for Ca, 7.24-11.71 mg kg^{-1} for B, 13.29-17.41 mg kg^{-1} for Cu, 51.00-79.35 mg kg^{-1} for Fe, 3988-6638.34 mg kg^{-1} for K, 1418.61-2306.06 mg kg^{-1} for Mg, 11.37-17.76 mg kg^{-1} for Mn, 4172.33-7059.58 mg kg^{-1} for P, 32.60-59.00 mg kg^{-1} for Zn (Table II). Results of the mentioned traits showed on the graphics (Figs. 1-10).

Correlation analyses were made for the natural selected and developed lines, commercial varieties and for combined values as well (Table III). For the genotypes, K and Ca, B-Cu and Fe, oil content and Ca, B and Fe had a negative and important correlation. Additionally, positive correlation was shown between oil content and K. for the wild genotypes, all of the investigated minerals showed positive correlation coefficients. Only Cu and Fe had a positive but insignificant effect on oil content. Correlation analysis for the combined genotypes showed positive effects for all of the investigated minerals except there was a negative correlation between B and Cu. Oil content had a positive but non-significant correlation with only Cu. Rest of the minerals showed negative and significant affects on oil content except for Ca.

IV. Discussion

Oil content of seeds is a quite important for economic trait of safflowers and it considered as one of the most important factors, which is affecting the success of safflower entry in new areas [19]. Many factors such as climatic factors, variety etc. are influenced by the amount of oil in safflower seeds [5]. Uysal [18] and Ada [1] were reported that oil content was varied between 23.70-26.90%, 23.86-40.33%, 26.72-35.78%, 26.3-28.5%, 31.3-36.3%, and 24.05-33.18% respectively. The results are also supporting our findings.

Safflower seeds that were used in the present research were defined as normal level of Ca, P, K. Mg, Zn, Fe, Mn etc. minerals that are acting on several parts of body in human and animals. Former studies reported similar results for the mineral variations in the other plants. For example, iron content (%) was 3.0 - 3.4 [16], potassium content (mg kg^{-1}) was 11090.0-12720.0 [7] magnesium content (mg kg^{-1}) was 12200-12800 [8], phosphorus content (mg kg^{-1}) was 2400.0-8300.0 [17], zinc content (mg kg^{-1}) was 2100.0-5600.0 [17] in chickpeas and 150.3-280.2 ppm [15] in dry bean. Furthermore, the safflower seeds were also containing Cu – a heavy metal. Similar results were also reported [9] in the former researches.

V. Conclusions

Combined analysis of the present research showed that, increasing of oil content cause to decreasing of the minerals in the genotypes. This situation suggests a relation between seed coat content and mineral content. The mentioned safflower genotypes may be used by depending on the desired purposes. Following researches may be focused on the other characteristics (antioxidants, oil acids etc.) of the genotypes.

TABLE I
Variance Analyses of the Investigated Characteristics

SOV	DF										
General	71	Oil (%)	Ca	B	Cu	Fe	K	Mg	Mn	P	Zn
Years (Y)	1	ns	ns	ns	ns	*	*	*	ns	*	*
Genotypes	11	**	**	**	**	**	**	**	**	**	**
Y x G	11	ns	ns	ns	*	**	**	**	ns	ns	ns

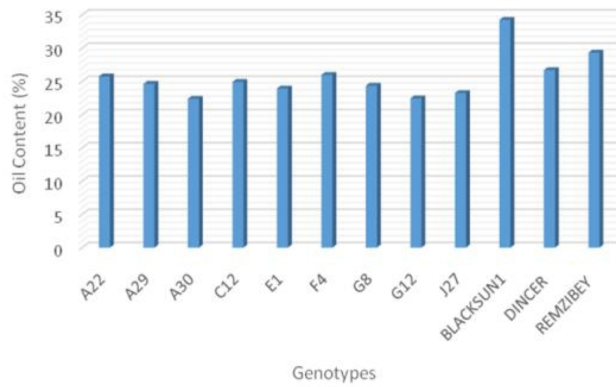

Fig. 1 Oil content of the genotypes (%)

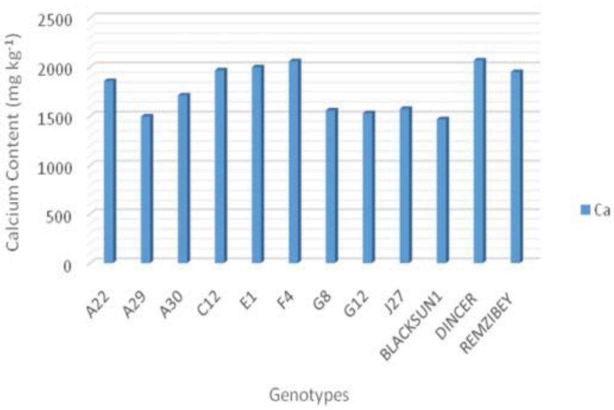

Fig. 2 Calcium content of the genotypes (mg kg^{-1})

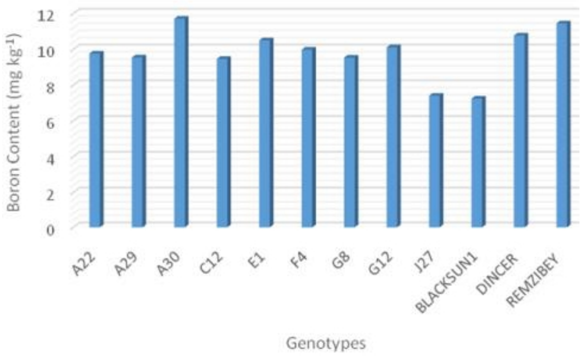

Fig. 3 Boron content of the genotypes (mg kg^{-1})

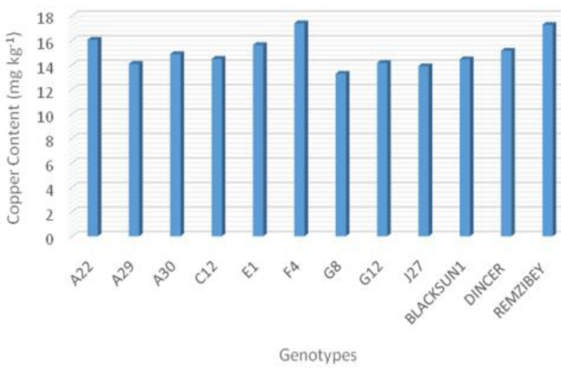

Fig. 4 Copper content of the genotypes (mg kg^{-1})

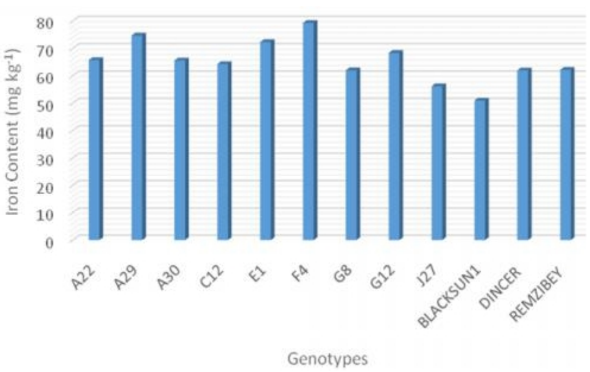

Fig. 5 Iron content of the genotypes (mg kg^{-1})

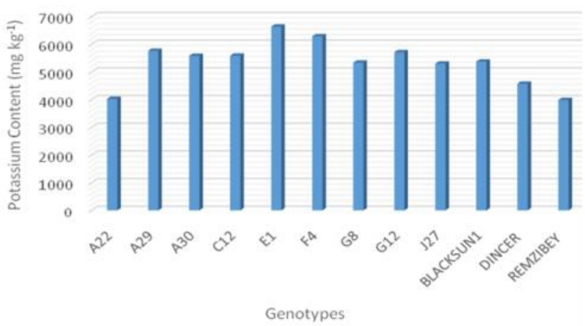

Fig. 6 Potassium content of the genotypes (mg kg^{-1})

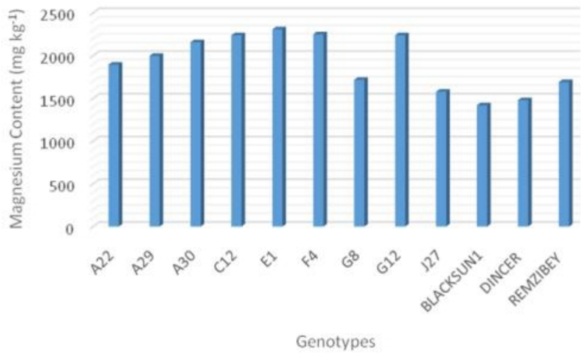

Fig. 7 Magnesium content of the genotypes (mg kg^{-1})

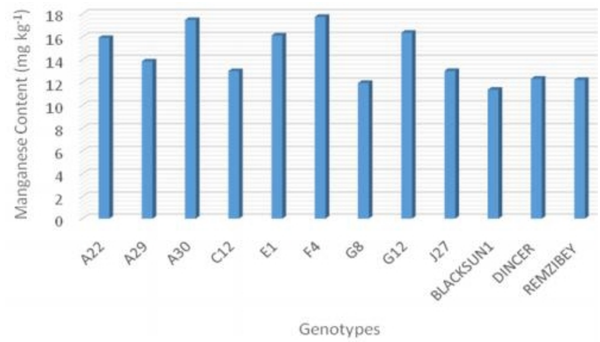

Fig. 8 Manganese content of the genotypes (mg kg^{-1})

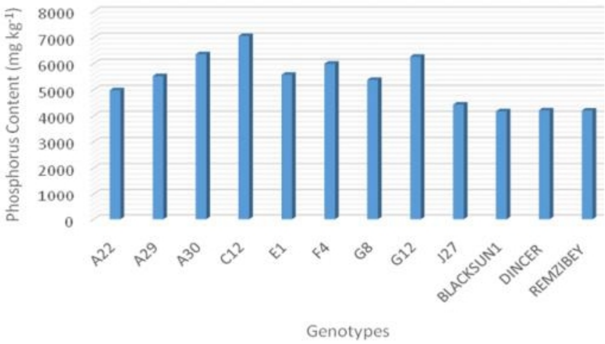

Fig. 9 Phosphorus content of the genotypes (mg kg^{-1})

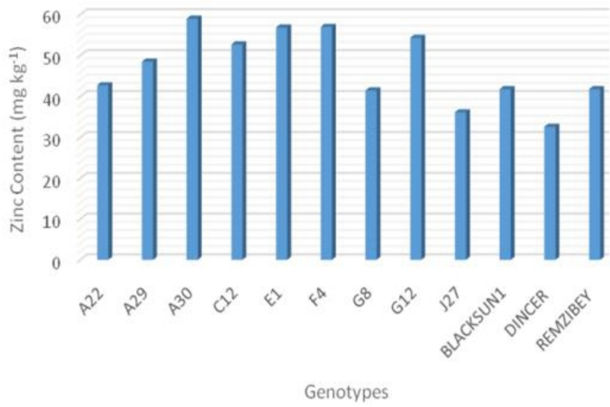

Fig. 10 Zinc content of the genotypes (mg kg^{-1})

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TABLE II
OIL AND MINERALS CONTENTS OF THE CHARACTERISTICS (MG KG-1)

Years	Oil (%)	Ca	B	Cu	Fe	K	Mg	Mn	P	Zn
2010	25.71	1711.82	10.13	14.74	66.38	5134.29	1799.14	13.79	5112.83	46.10
2011	25.60	1828.87	9.45	15.41	64.30	5562.73	2026.52	14.79	5579.93	48.06
Genotypes										
A22	25,75	1858,03	9,76	16,06	65,78	4031,07	1893,75	15,92	4980,64	42,76
A29	24,62	1497,54	9,54	14,09	74,74	5764,49	1996,73	13,86	5520,74	48,51
A30	22,38	1712,17	11,71	14,89	65,62	5582,02	2155,34	17,49	6361,27	59,00
C12	24,91	1967,11	9,46	14,50	64,30	5589,81	2237,77	13,01	7059,58	52,70
E1	23,93	1998,23	10,50	15,63	72,36	6638,34	2306,06	16,13	5571,30	56,86
F4	25,98	2058,07	9,98	17,41	79,35	6286,54	2248,24	17,76	5997,28	57,00
G8	24,35	1559,59	9,53	13,29	62,06	5336,57	1716,80	11,96	5380,01	41,47
G12	22,45	1531,25	10,11	14,17	68,39	5710,79	2237,62	16,37	6268,21	54,34
J27	23,25	1575,76	7,40	13,90	56,22	5300,37	1576,44	13,02	4429,73	36,14
BLACKSUN1	34,26	1469,04	7,24	14,46	51,00	5375,84	1418,61	11,37	4172,33	41,79
DINCER	26,70	2068,07	10,77	15,17	62,03	4578,19	1477,38	12,33	4212,46	32,60
REMZIBEY	29,33	1949,31	11,45	17,28	62,20	3988,10	1689,23	12,24	4203,05	41,79

TABLE III
CORRELATION COEFFICIENTS OF THE SEED CHARACTERISTICS

		Genotypes		
Variable	by Variable	**Cultivars** Correlation	**Wild Lines** Correlation	**United** Correlation
B	Ca	0,7408**	0,2521	0.4097**
Cu	Ca	0,5268*	0,4784**	0.5000**
Cu	B	0,5514*	0,0579	0.2066
Fe	Ca	0,8851**	0,2312	0.2694*
Fe	B	0,8631**	0,2803*	0.3646**
Fe	Cu	0,6315**	0,4409**	0.3370**
K	Ca	-0,5830*	0,3261*	0.0596
K	B	-0,7958**	0,1542	-0.0803
K	Cu	-0,4765*	0,1956	-0.0204
K	Fe	-0,6115**	0,3494**	0.3659**
Mg	Ca	0,5647*	0,5918**	0.4153**
Mg	B	0,3511	0,3982**	0.3063**
Mg	Cu	0,6207**	0,3409*	0.2348*
Mg	Fe	0,5737*	0,3578**	0.5502**
Mg	K	-0,2338	0,5977**	0.5968**
Mn	Ca	0,5900*	0,3769**	0.3032**
Mn	B	0,2906	0,3888**	0.3029**
Mn	Cu	0,5318*	0,4168**	0.2977*
Mn	Fe	0,5526*	0,3484**	0.5208**
Mn	K	-0,0780	0,3348**	0.4317**
Mn	Mg	0,7909**	0,5826**	0.7127**
P	Ca	0,3142	0,3851**	0.1886
P	B	-0,0427	0,3172*	0.1722
P	Cu	0,1386	0,2609	0.0690
P	Fe	0,2963	0,2063	0.4520**
P	K	0,1743	0,4250**	0.5642**
P	Mg	0,4794*	0,6945**	0.7793**
P	Mn	0,5079*	0,3134*	0.5302**
Zn	Ca	-0,3615	0,4236**	0.1621
Zn	B	-0,2477	0,5764**	0.3089**
Zn	Cu	0,2339	0,3242*	0.1685
Zn	Fe	-0,2244	0,4944**	0.5417**
Zn	K	0,2299	0,5973**	0.6523**
Zn	Mg	0,2431	0,7363**	0.7632**
Zn	Mn	0,0948	0,6367**	0.6746**
Zn	P	0,1365	0,7054**	0.7657**
Oil	Ca	-0,7477**	0,1160	-0.0620
Oil	B	-0,7657**	-0,1164	-0.2646*
Oil	Cu	-0,2302	0,2214	0.1525
Oil	Fe	-0,7184**	0,2004	-0.4092**
Oil	K	0,5481*	-0,1335	-0.2924*
Oil	Mg	-0,1360	-0,0832	-0.4599**
Oil	Mn	-0,2690	-0,1163	-0.4424**
Oil	P	-0,0048	-0,1005	-0.5220**
Oil	Zn	0,4915*	-0,1456	-0.3738**

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