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Safflower *(Carthamus tinctorius L.)* breeding activities at Trakya Agricultural Research Institute

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ABSTRACT

There is a vegetable oil deficit in Turkey. Oil crops production in Turkey does not meet the requirements of vegetable oil. About 60 % of vegetable oil consumed in Turkey is imported every year paying about 3 billion dollars. Safflower plant being resistant to drought may be one of the alternative oil crops in Turkey. Some of the main obstructions in safflower production in Turkey are low seed yield, low oil content, diseases and insects. The varieties in production have an oil content of about 28-32 %. New superior safflower varieties have to be developed by breeding and selection methods among the existing genetic variation. The Safflower breeding program at Trakya Agricultural Research Institute was initiated in 2000 with two different oil types, oleic and linoleic to develop new varieties which have high yielding capacity, yield stability, high oil content, wide adaptation ability, resistance to diseases and insects prevalent in the region and all over the Turkey. About 60 materials in oleic types and 250 materials in linoleic types collected around the World were tested in observation nurseries and crossing blocks every year. All the materials were planted in the middle of March. Pedigree method was utilized in segregating populations developed after hybridization. Single plant selection was started in F_2 population and ended in F_7. Each year about 500-600 single plants were selected and replanted next year as a new generation.

***Keywords*:** trakya, safflower, oil, oleic, linoleic, oil yield.

Introduction

Safflower (*Carthamus tinctorius* L.) is one of the alternative oil crops in Turkey. First research activities on safflower in Turkey were initiated in 1929-1930 in Eskisehir province. These activities lasted about 10 years; untill the beginning of World War II in 1939. During this period, a composite variety, "Yenice 1813", was developed and released to the farmers in the region. Due to the increase in population, vegetable oil deficit appeared. That's why research on safflower was reinitiated in 1958, after about a 20-year interruption (Dincer, 1964). Three varieties had been developed until 2011. Only two of them, Dincer and Remzibey-05, are still in production. The performances of these two varieties are acceptable but, oil contents are very low.

Safflower production is supported by Turkish Ministry of Food Agriculture and Livestock. Each farmer receives about 0.2 dollar for per kilo of safflower crop produced after selling in 2013. This amount was about 0.1 dollar in 2006 when the support was started (Anonymous, 2013a). The total safflower planted area was 150-170 hectares in 2005. Due to these supports, safflower planted areas have been increased. Safflower planted area in Turkey reached about 50.000-60.000 ha for the time being. The average yield per hectare is about 1300 kg (Anonymous, 2013b). Some of the main obstructions in safflower production in Turkey are low seed yield, low oil content, diseases and insects. The varieties in production have an oil content of about 28-32 %. They also

are susceptible to safflower rust (*Puccinia carthami*), Alternaria leaf blight (*Alternaria* spp.) and safflower fly (*Acanthiophilus helianthi* Rossi.).

There is a vegetable oil deficit in Turkey because oil crops production in Turkey does not meet the domestic requirements of vegetable oil. About 60 % of vegetable oil consumed in Turkey is imported every year paying about 3 billion dollars. Safflower plant being resistant to drought may be one of the alternative oil crops in Turkey. New superior safflower varieties have to be developed by breeding and selection methods among the existing genetic variation.

Successful results were obtained in genetic improvement in safflower such as seed yield and oil content (Ramachandran 1985) and combining high yield with high oil content (Harishbabu et.al. 2005). All the works must be emphasized on indirect selection of higher head number per plant and 1000 seed weight and lower number of branches along with thinner seed pericarp to improve seed and oil yield in safflower (Zheng, et al. 1993). Traits, such as 1000 seed weight and seed number per plant are the best selection criteria to improve oil yield genetically in drought stress conditions. On the other hand, in non-drought conditions, traits 1000 seed weight, days to physiological maturity and seed number per plant are the most important components for oil yield and must be improved (Golparvar, 2011). Head numbers per plant, head weight and thinner seed pericarp are the important traits for improving seed and oil yield in safflower cultivars (Rao et.al 1997; Corleto et.al 1997; Mozaffari et.al 2006). Seed yield per plant is positively and significantly correlated with heads per plant (r = 0.65**), seeds per head (r = 0.76**) and primary branches per plant (r = 0.38*). According to path analysis, days to maturity, primary branches per plant and seeds per head have the highest positive direct effect on seed yield, respectively. Seeds per head and head per plant are the most important selection criteria to improve seed yield in safflower (Golkar et.al 2011). There is a negative but significant correlation between dry matter and seed yield and between dry matter and oil yield in safflower (Jamshi-Moghadam and Pordad, 2006). The inheritance of the spininess trait was studied by many researchers. It was found out that spininess is dominant over spinelessness and four genes (namely, *Sa, Sb, Sc* and *Sd*) are involved in determining the level of spininess (Narkhede and Deokar 1990; Pahlavani et al. 2004). Grain yield is positively correlated with seed weight and plant height (Johnson 2001). The number of head per plant is the most important character determining grain yield per plant and the number of head has the highest positive correlation with grain yield (Bagawan and Ravikumar, 2001).

The safflower breeding program at Trakya Agricultural Research Institute was initiated in 2000 with two different oil types, oleic and linoleic. The main objectives of the safflower breeding program at Trakya Agricultural Research Institute (TARI) are to develop new varieties which have high yielding capacity, yield stability, high oil content, wide adaptation ability, resistance to diseases and insects prevalent in the region and all over the Turkey. Since TARI is the National Safflower Research Coordinator, all the research activities are conducted not only for Trakya region but also for throughout Turkey.

Materials and methods

Both oleic and linoleic type materials were collected from around the World. About 60 genotypes in oleic types and 250 genotypes in linoleic types were tested in observation nurseries and crossing blocks every year. After evaluation of the domestic and foreign materials in terms of earliness, single plot yield, oil content, reaction to prevalent diseases, etc, with the materials found promising, about 15 crossing combinations in total were made each year both in oleic and linoleic type safflowers. In crossing, emasculations were made in the late afternoon and pollinations were made in the next morning for the best results. Pedigree method was utilized in segregating populations getting after hybridization. Single plant selection was started in F_2 population. The selection was ended in F_7. Each year about 500-600 single plants were selected and replanted next year as a new generation. When the single plant selection reached to F_6 or/and F_7, the plots were harvested in bulk and put in the preliminary, and regional yield trials, respectively, for testing with present varieties in terms of mainly seed yield, oil content and oil yield. The performance of each new line was tested in each trial and calculated whether they were above or below the trial's average yield. The preliminary yield and yield trials were set up only in Edirne (headquarters) location. Three different locations (Edirne, Kırklareli and Tekirdag) were utilized for safflower regional yield trials.

All the materials were planted in the middle of March. Crossing blocks were planted as 3 rows in 2 m length. For yield trials, Randomized Complete Block Design (RCBD) with 4 reps was utilized. The six-row plots were 5.0 m long with the 0.17 m x 0.05 m plant spacing. Two rows in the middle were harvested and the border two rows were discarded as side effects. Harvested plot size was 3.4 m². Harvest was made in

the first week of August with combine in some years, by hand in some years. Some observations, such as seed yield (kg ha^{-1}), 1000 seed weight (g), flowering and physiological maturity (days), plant height (cm), oil content (%) and oil yield (kg ha^{-1}) were taken. All the data taken were analyzed statistically using JUMP program.

Results

The yield of various varieties in 2012 varied between 3550-4240 kg/ha. One of the check (C) varieties, Dincer, gave the highest seed yield with 4240 kg/ha. One of our new lines (TRE-ASL09/14) was the second after Dincer in terms of seed yield with 4160 kg/ha. Our other line, TRE-ASO12/08, was third with 4000 kg/ha in terms of seed yield (Table 1). The two new lines had higher oil content than two check varieties, Dincer and Remzibey-05. One of our lines, TRE-ASO12/08, ranked first among all check varieties with 42.0 % oil content. The same results are also valid for 2013 growing season. According to the 2-year (2012 and 2013) average; the check variety, Dincer, was the first among five entries with 4665 kg/ha seed yield. The line, TRE-ASL09/14, ranked second with 4365 kg/ha seed yield after the check variety, Dincer. In terms of oil content, the line, TRE-ASO12/08, ranked first among the five entries with a 42,1 % oil content. It means that the new line had higher oil content than all check varieties (Table 1). The line, TRE-ASL09/14, had been in state registration trial since 2009. The other line, TRE-ASO12/08, has also been in state registration trial since 2012. This line has been given a production permit untill it is registered. This is an oleic type variety which has an oil content of 40-42 % on dry matter basis. It also has an oleic fatty acid content of 73-75 %. One of the line, TRE-ASL09/14, was registered and named as “LINAS” on April 10, 2013. This variety is linoleic type and has an oil content of 37-38 % at a dry basis (at 0 % moisture).

Besides these two lines, many oleic and linoleic type new lines bulked in F_7 in 2013 were tested in preliminary yield trials (Table 2 and 3). In oleic type yield trial, seed yields varied between 2930 kg/ha and 5220 kg/ha. Five new oleic lines gave higher seed yield than the lowest check variety, Balci. In terms of oil content, twelve lines had higher oil content than all check varieites. One line had the highest oil content with 48,7 %. Oil yield (seed yield x oil content) of the entries varied between1391 kg/ha and 2019 kg/ha (Table 2). In linoleic type yield trial, seed yields varied between 3000 kg/ha and 5410 kg/ha. The newly registered variety, LINAS as a check, gave the highest seed yield with 5410 kg/ha. Four new linoleic lines gave higher seed yield than the lowest check variety, Balci. In terms of oil content, three lines had higher oil content than all check varieties. Oil yield varied between1072 kg/ha and 2159 kg/ha. Our newly registered variety, LINAS, had the highest oil yield with 2159 kg/ha among twenty entries.

Discussion

As a result of safflower breeding program at Trakya Agricultural Research Institute, two lines (TRE-ASL09/14 and TRE-ASO12/08) have been developed so far. One of them, TRE-ASL09/14, was registered and named as “LINAS” on 10.04.2013. This is a linoleic type safflower variety. The seeds of this variety will be multiplied in 2014 and sold to the farmers for 2014 autumn planting and 2015 spring planting. Other line, TRE-ASO12/08, is still at the state registration trial and will be registered in 2015. This line will be named as “OLAS” in 2015 when it is registered.

The other new lines bulked in F_7 in 2012 were at preliminary yield trials in 2013 growing season. Some of them will be offered for registration if their performances are better than the check varieties in the coming years (2014 and 2015 growing seasons). These two varieties, LINAS and OLAS, having high yielding and high oil capacity, will contribute to lessen the vegetable oil deficit in Turkey in coming years.

Table 1. Performance of Two New Safflower Varieties in 2012 and 2013

VARIETIES	2012		2013		2 Year Average Yield (kg/ha)*	2 Year Average Oil Content (%)**
	Yield (kg/ha)*	Oil Content (%)**	Yield (kg/ha)*	Oil Content (%)**		
DINCER (C)	4240	32,6	5090	29,8	4665	31,2
LINAS (TRE-ASL09/14)	4160	39,3	4570	40,3	4365	39,8
TRE-ASO12/08	4000	42,0	3670	42,2	3835	42,1
REMZIBEY-05 (C)	3790	34,4	4090	32,3	3940	33,4
BALCI (C)	3550	41,0	3690	39,2	3620	40,1
L.S.D (0.05)	353	0,5	369	0,4	235	0,5
C.V (%)	17,8	1,6	11,8	1,5	12,3	1,5

*- Based on 10 % moisture
**- At dry matter basis (0 % moisture)

Table 2. Performance of New Oleic Safflower Lines in 2013

OLEIC LINES	Flowering Period (day)*	Physiological Maturity Period (day)*	Plant Height (cm)	1000 Seed Weight (g)**	Oil Content (%)***	Oil Yield (kg/ha)	Seed Yield (kg/ha)**	
DINCER (C)	76	109	87	49	29,2	1524	5220	a
TRE-OA05-02-212110T	78	110	90	37	37,3	1846	4950	ab
TRE-OA05-05-113110T	73	105	77	42	39,4	1915	4860	ab
REMZIBEY-05 (C)	73	106	80	44	32,1	1554	4840	ab
TRE-OA05-02-252110T	76	109	91	40	40,6	1827	4500	abc
TRE-OA05-06-121110T	76	111	78	38	42,6	1891	4440	a-d
TRE-OA05-05-251110T	77	111	89	34	46,1	2019	4380	a-e
BALCI (C)	73	106	78	43	39,7	1731	4360	a-e
TRE-OA05-02-242110T	76	109	85	35	39,6	1719	4340	a-e
TRE-OA05-02-122110T	74	107	79	36	40,5	1737	4290	b-f
TRE-OA05-06-162120T	77	111	84	40	40,4	1729	4280	b-f
TRE-OA05-06-122110T	77	111	88	45	39,7	1695	4270	b-f
TRE-OA05-06-173110T	75	109	73	45	41,7	1747	4190	b-f
TRE-OA05-05-151110T	75	110	85	38	40,6	1547	3810	c-g
TRE-OA05-05-231110T	75	108	86	34	39,5	1454	3680	c-g
TRE-OA05-01-211110T	76	109	86	40	38,0	1391	3660	c-g
TRE-OA05-05-231130T	74	107	85	43	48,7	1748	3590	d-g
TRE-OA05-02-231110T	73	106	77	31	42,5	1500	3530	efg
TRE-OA05-05-231120T	76	109	85	42	41,7	1430	3430	fg
TRE-OA05-04-141110T	73	106	75	39	48,5	1421	2930	g

CV (%) = 12,9 LSD = 891 kg/ha for seed yield.
*- Calculated as days starting from planting date
**- Based on 10 % moisture
***- At dry matter basis (0 % moisture)

Table 3. Performance of New Linoleic Safflower Lines in 2013

LINOLEIC LINES	Flowering Period (day)*	Physiological Maturity Period (day)*	Plant Height (cm)	1000 Seed Weight (g)**	Oil Content (%)***	Oil Yield (kg/ha)	Seed Yield (kg/ha)**	
LINAS (C)	76	109	94	49	39,9	2159	5410	a
DINCER (C)	76	108	88	50	29,2	1577	5400	a
Seledas-162	79	112	92	41	34,0	1717	5050	ab
REMZIBEY- 05 (C)	73	106	85	44	31,9	1544	4840	abc
Seledas-153	78	110	87	41	39,7	1910	4810	abc
TRE-LA05-02-211130T	76	108	81	46	34,0	1612	4740	abc
TRE-LA05-04-221110T	74	107	87	45	37,8	1788	4730	abc
BALCI (C)	75	109	80	45	39,5	1845	4670	bc
TRE-LA05-04-131110T	77	110	89	48	38,4	1747	4550	bcd
TRE-LA05-03-222110T	76	108	87	44	39,4	1690	4290	cde
TRE-LA05-03-111110T	75	107	85	47	36,7	1563	4260	cde
TRE-LA05-07-131110T	76	111	96	47	38,1	1501	3940	def
TRE-LA05-06-141110T	75	108	90	54	36,2	1390	3840	defg
TRE-LA05-08-241210T	75	109	84	43	38,4	1421	3700	efgh
TRE-LA05-01-321110T	76	108	84	39	35,5	1306	3680	efgh
TRE-LA05-05-121110T	76	109	90	50	38,8	1354	3490	fgh
TRE-LA05-04-111110T	76	108	83	49	39,1	1357	3470	fgh
TRE-LA05-05-121120T	74	106	91	50	33,5	1112	3320	fgh
TRE-LA05-01-111210T	74	106	79	55	33,4	1072	3210	gh
Seledas-160	76	108	76	35	48,1	1443	3000	h

CV (%) = 10,3 LSD = 716 kg/ha for seed yield.

*- Calculated as days starting from planting date

**- Based on 10 % moisture

***- At dry matter basis (0 % moisture)

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