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RELATIONSHIPS BETWEEN SURVIVAL IN WINTER COLDS AND SOME MORPHOLOGICAL AND TECHNOLOGICAL CHARACTERISTICS IN SAFFLOWER GENOTYPES

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This study was conducted in the production seasons of 2013-2014 and 2015-2016 on test fields at Bahri Dagdaş International Agricultural Research Institute in the Province of Konya, Turkey, where winters are quite harsh, to determine the relationships between tolerance to winter colds in safflower and some morphological and technological characteristics. Of the 112 genotypes, 11 genotypes which had been selected in previous years on the basis of their tolerance to winter conditions and 4 varieties (Remzibey, Dinçer, Linas, Balcı), which were registered as spring plants in Turkey, were used in the study as materials. Trial sowing was performed in the first week of October in autumn. The survival rates of the genotypes in winter colds were determined at -14.2°C in the 2013-2014 production season and at-17.3°C in the 2015-2016 production season. Root lengths and plant habitus were measured in autumn in the rosette stage (6-8 weeks after emergence). Spring sowing was conducted in the first week of April to determine the stem elongation time of the genotypes and thus their stem elongation times were specified. Oil and seed coat ratios, on the other hand, were determined before sowing for fear that they might be completely destroyed by cold. In standard varieties, survival rates varied between 1.25 % and 40.7 % at -14.2°C without a snow cover in the 2013-2014 production season, whereas in tolerant genotypes this rate was between 94 % and 99.5 %. In the 2015-2016 production season, the survival rate in standard varieties that were sensitive to winter colds varied between 0 % and 2 % at-17.3°C without a snow cover, whereas the survival rates in the most tolerant genotypes varied between 85.9 %, 77.6 % and 54.4 %, respectively. A significant correlation was determined between the survival

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rate and plant habitus and oil content. It was found that the winter-tolerant lines had a more prostrate plant habitus and lower oil contents in the rosette stage. A positive and significant relationship was found between winter survival and root length, seed coat thickness and the length of stem elongation time.

Keywords: safflower, winter survival, cold tolerance, plant habit

INTRODUCTION

Safflower (Carthamus tinctorius L.) is a spring crop planted across the whole world for good quality oil (LI and MÜNDEL, 1996). One of the most fundamental reasons preventing the spread of cultivation of safflower is that the yield of this plant is very low. Sudden heat that sets in during the early growth period of safflower, which is planted as a spring crop in arid zones, and increasing drought reduce its yield**.** The fact that registered varieties are planted in Central Anatolia as a spring crop and that a large part of their growth period in the spring coincides with dry months are major reasons for their low productivity (KOÇ *et al*., 2013).

Cultivation of the safflower plant as a winter crop will cause it to grow more rapidly in the cool and wet months of spring and make better use of rains, which will in turn increase its seed yield (ZAIRE *et al.*, 2011).

Cold tolerance in plants is a complex condition where more than one gene is controlled by more than one gene (GUY, 2003). In addition tolerance and sensitivity to cold in plants is related to complex physiological reactions and parameters. These parameters involve increased sugar and amino acid contents (HAAGENSON *et al*., 2003) and reduced starch and increased proline (PATTON *et al*., 2007). Tolerance to cold is related to prevention of cell dehydration and membrane deterioration caused by freezing (THOMASHOW, 1998). In a study conducted on metabolic adaptation in acclimatization of safflower to cold, it was shown that genotypes with tolerance preserved their cell membrane integrity and had low water content when they were exposed to high concentrations of carbohydrates and proteins as well as to cold (GHORASHY *et al*.,2004).

There is a significant variation among safflower populations in resisting winter. Horizontal development in autumn is important in winter tolerance (JOHNSON *et al*., 2006). It can be said that a procedure of acclimatization to cold is effective in tolerance to winter, in addition to prostrate and low growth in the rosette stage. When plants are exposed to temperatures close to freezing point which are not deadly, they get themselves acclimatized too cold by activating some enzymes (CUNNINGHAM *et al*., 2003; KOSTER, 1992; THOMASHOW, 1999).

There are genotypes that can be tolerated between −15°C and −26°C at the rosette stage (JOHNSON *et al*., 2012). If meristems survive in plants that have suffered from cold damage, they can grow again and can yield adequate output when new leaves replace old damaged leaves that suffered from cold damage. Tolerance to winter decreases after the root elongation phase begins, and even a slight frost may do damage to main apical meristem, which causes the plant to die. Therefore, minimal root elongation is an essential quality for survival in autumn and winter months for safflower genotypes that have a habit of long rosette (JOHNSON *et al*., 2006).

When compared with genotypes whose rosette stages are short, genotypes with longer rosette stages have better tolerance to winter. These genotypes are called winter-type genotypes. An increase in tolerance to freezing can be partially anatomic, that is it may be a result of a large number of young leaves and propyl layer that protect apical meristem, which is the main growth center of the plant. However, not all genotypes that have a vertical plant habit display tolerance to freezing (ALIZADEH *et al*., 2011; JOHNSON *et al*., 2006).

There are tolerant safflower genotypes that can be sowed as winter plants in Turkey, but it has been found that although these genotypes are satisfactory in terms of seed yield, their oil contents are low. Sowing of safflower as a winter plant enabled it to complete a large part of its developmental period in wet spring months, and thus was less affected by drought compared with spring sowing (KOÇ *et al*., 2013). In addition to survival of safflower genotypes in winter colds and some morphological characteristics of them, this study identified the relationships between characteristics like oil content and seed coat ratio.

MATERIALS AND METHODS

This study was planned according to the Randomized Block experimental design in four replications at Konya Bahri Dağdaş International Agricultural Research Institute test fields in the 2013-2014 and 2015-2016 production years**.**

In the study, 11 lines of winter-tolerant materials formed, through single plant selection, from among 112 genotypes obtained from a gene bank in the USA whose pre-selections in terms of winter tolerance had been conducted at -12.8°C in 2008 and at -14.2°C in 2010, and 4 varieties that are registered in Turkey as spring plants (Remzibey, Dinçer, Linas, Balcı). Trial sowing was performed in autumn in the first week of October. In order to better determine the variation in the stem elongation time of the same lines and varieties, planting was performed again in spring in the first week of April. Winter survival rates of the genotypes were determined at -14.2°C in the 2013-2014 production year and at -17.3°C in the 2015-2016 production year. Root length, plant habit was measured in autumn in the rosette stage (6-8 weeks after emergence). In order to determine the genotype's stem elongation time, spring sowing was performed in the first week of April and thus the stem elongation time was determined. The oil and seed coat ratios, on the other hand, were measured after the harvest except for those that were totally destroyed by cold. Oil and coat ratios of the seeds in the genotypes that were completely damaged due to cold were measured before planting.

Table 1. Genotypes and standard varieties whose pre-selection was performed in terms of winter tolerance

Line No	Accession	Origin	Plantid
K-1-a	PI 544017	China	BJ-27
K-1-b	PI 544017	China	BJ-27
K-3-a	PI 405985	Iran	KN-144
K-3-b	PI 405985	Iran	KN-144
K-4	PI 560177	USA, California	Oleic Leed
K-5	PI 253758	ıraq	Qourtum
K-6	W6 23110	China	FQ-4
K-7-a	PI 506426	China	FO-2
K-7-b	PI 506426	China	FO-2
K-9	PI 537692	USA,Arizona	Gila
K-10	PI 537695	USA,Arizona	Ole
Remzibey	GKTAE	Turkey	Remzibey
Dinçer	GKTAE	Turkey	Diçer
Balcı	GKTAE	Turkey	Balcı
Linas	TTAE	Turkey	Linas

It is seen that some lines in Table.1 are of the same origin. The reason for this is that when there is variation in winter tolerant lines within themselves, a single plant is selected there and genotypes are formed.

Years when winter damage did not take place due to absence of snow cover or adequate cold are given in Table. 2.

*Table 2. Minimum temperatures and snow cover in years when winter damage did not occur **

Yaer	**Month**	**Min. Temp. (^{0}C)**	**Snow cower**
2009	January	- 18	With snow cover(+)
2011	February	-11	Without snow cover(-)
2012	January	-19	With snow cover(+)
2013	January	-10	Without snow cover(-)
2015	January	-20	With snow cover(+)
2017	January	-22	With snow cover(+)

**Turkey Konya Bahri Dağdaş International Agricultural Research Institute meteorological station data*

As is seen in Table.2, although the lowest temperatures were -18°C in 2009, -19°C in 2012, -20°C in 2015 and -22°C in 2017, both winter tolerant lines and winter sensitive spring types varieties did not suffer from cold damage due to presence of snow cover; therefore, no selection was performed in terms of winter tolerance.

The lowest temperature was -11°C in 2011 and-10°C in 2013, and again no difference was observed between tolerant lines and sensitive varieties in terms of winter tolerance. The number of genotypes was reduced from 112 to 36 at -12. 8°C (Table 3) in 2008 without a snow cover; likewise, the number of genotypes was reduced to 11 at -14°C (Table.3) in 2010 again without a snow cover.

*Table 3. Minimum temperatures in years when selection could be (without snow cover) performed in terms of survival in winter colds (°C)**

YEARS	MONTHS(Min. Temp.)					
	October	November	December	January	February	March
2007-2008	1.6	- 4.3	- 7.7	**- 12.8**	- 5.7	2.0
2009-2010	4.5	- 3.3	-5.5	**- 14.5**	- 11.4	- 4.8
2013-2014	4.3	- 4.9	- 5.1	**- 14.2**	- 7.2	- 5.5
2015-2016	3.5	- 5.1	- 10.6	**-17.3**	-8.6	-6.5

**Turkey Konya Bahri Dağdaş International Agricultural Research Institute meteorological station data.*

Observations and Measurements Conducted

Winter survival (%): Indicates the rate of plants that survived in the plot at the end of winter.

Plant habit (a): Indicates the length from the point where the plant first emerged out of the soil to the first node (Fig.1)

Root length (b): 9 weeks after planting, the plant was removed from the soil in the rosettes stage without damaging the root and the length from the end of the root to the first node was measured (Fig.1).
Stem elongation time (in days): The length of time that passed from emergence to stem elongation was calculated in days.
Oil content (%): Crude oil analysis was performed at the quality control laboratory of our institute using Soxhlet method.
Seed coat ratio (%): The seeds were first weighed, then the grains were separated from the chaff by soaking the seeds; next, they were dried and weighed and finally they were compared with the whole grains

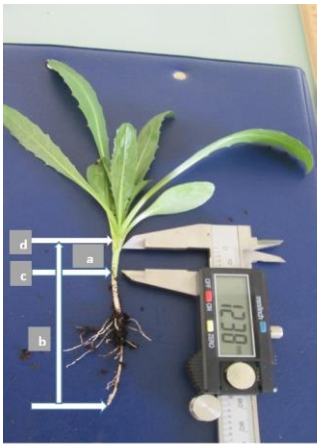

Fig.1. Root parameters of the safflower plant measured in the rosette stage; a=The distance from the soil-shoot interface to the first node was defined as plant habit (Johnson et al.2006), b= Root length, c= soil –shoot interface, d=first node.

The values belonging to the characteristics obtained from the study were combined and subjected to variance analysis and the mean values of the factors determined after conducting an "F" test were grouped according to "LSD" significance test. In addition, correlation analysis was made to determine the relationship between winter survival and the other factors.

RESULTS AND DISCUSSION

Results of combined variance analysis belonging to the periods 2013-2014 and 2015-2016 concerning the morphological and technological characteristics in safflower lines and varieties are shown in Table 4. With regard to the characteristics examined, significant differences at a level of 1 % were found between the genotypes in terms of survival in winter, root length, stem elongation time, oil content and seed coat ratio. The difference between the years, on the other hand, was found to be significant except for oil content and seed coat ratio. This difference between the years in terms of the characteristics that were examined results from differences in climatic conditions. The reason why there was not a difference between the years in terms of oil content and seed coat ratio is that these characteristics are not considerably affected by environmental conditions. The Genotype x Year interaction was found to be significant at the level of 5 % in terms of staying at the rosette form, whereas it was found to be insignificant in terms of oil content and seed coat ratio (Table 4).

Table 4. Combined Variance Analysis for the Morphological and Technological Characteristics Examined in the Study

Source of variance	DF	Winter Survival	Root length	Plant Habit Mean squares	Stem elongation time	Oil content	Seed coat ratio
Total	119	1191**	513**	49**	88**	11.8**	48**
Years	1	28926**	23632**	1719**	1642**	0.3	0.5
Rep.	3	106	1.86	5.2	1.7	0.4	1.9
Genotype	14	7012**	723.5**	232**	621**	96**	396**
Genotype x Year	14	616**	998**	27.5**	3.35*	0.2	0.2
Error	87	65	153	5.5	1.6	0.6	1.2
CV (%)		23	12.5	13.2	1.9	2.5	2.2

** Significant at P<0.01 * Significant at P<0.05 **DF**: Degrees of Freedom, **CV**: coefficient of variation

Table 5. Winter survival rates and some morphological and technological characteristics in safflower genotype

Years	Line No	Accession number	Winter Survival (%)	Root length (mm)	Plant Habit (mm)	Stem elongation time (days)	Oil Content (%)	The ratio of seed coatl (%)
	K-1-a	PI 544017	99.5 a	122.5abcd	15.5 e	83.0 b	24.0 fg	62.0 a
	K-1-b	PI 544017	99.0 a	75 g	14.6 e	85.0 a	25.0 ef	61.0 a
	K-3-a	PI 405985	94.0 a	132.5 abc	15.4 e	81.0 c	26.0 de	57.0 b
	K-6	W6 23110	76.7 b	120abcde	15.5 e	75.5 d	26.5 cd	57.2 b
	K-5	PI 253758	58.3 cd	117.5bcde	19.6 cd	75.7 d	26.9 cd	53.0 de
	K-7-b	PI 506426	63.0 c	110 de	16.5 de	72.0 e	27.3 c	55.0 c
	K-7-a	PI 506426	60.0 cd	105 de	19.1 cd	71.5 e	28.6 b	53.7 cd
	K-3-b	PI 405985	50.5 de	140 a	18.8 cd	68.5 f	26.2cde	52.0 ef
2013-2014	Remzibey	GKTAE	40.7 e	100 ef	18.8 cd	61.2 ı	26.2cde	45.2 h
(-14.2 ^{0}C)	K-9	PI 53769	28.5 f	137.5 ab	20.7 c	65.5g	28.6 b	51.0 f
	Balcı	GKTAE	28.0 f	80 fg	29.6 b	59.7 ı	35.0 a	40.2 ı
	K-4	PI 560177	24.7 f	132.5 abc	21.1 c	63.5 h	23.2 g	45.0 h
	K-10	PI 537695	21.5 f	112.5 cde	21.7 c	66.5 g	29.3 b	48.0 g
	Linas	TTAE	4.0 g	102.5 de	36.3 a	57.7 j	35.2 a	39.0 ı
	Dinçer	GKTAE	1.25 g	105 de	34.7 a	55.5 k	28.8 b	45.0 h
	LSD		**11.9**	**20.5**	**3.3**	**1.7**	**1.2**	**1.7**
	CV(%)		**16.8**	**12.7**	**11.0**	**1.7**	**3.0**	**2.3**

	K-1-b	PI 544017	85.9 a	85 abc	7.7 e	76.9 a	25.0 fg	61.2 a
	K-1-a	PI 544017	77.6 a	74 cd	8.7 de	74.9 b	24.0 gh	61.0 a
	K-3-a	PI 405985	54.4 b	90.5 ab	11.0cde	72.9 c	26.0def	56.7 b
	K-6	W6 23110	20.0 c	86 abc	12.2 bc	67.9 d	26.2 de	57.2 b
	K-5	PI 253758	17.9 cd	86.5 abc	12.0bcd	66.8 d	26.4 d	53.0 de
	K-7-a	PI 506426	8.7 d	90 ab	13.7 bc	64.5 e	28.7 bc	53.7 cd
	K-7-b	PI 506426	7.1 d	86 abc	13.0 bc	64.3 e	27.6 c	55.0 c
2015-2016	K-3-b	PI 405985	5.6 e	92 ab	14 bc	61.4f	25.2 ef	52.0 ef
(-17.3 ^{0}C)	Remzibey	GKTAE	2.0 e	92 ab	12.0bcd	59.8 fg	26.2 de	44.5 h
	K-9	PI 53769	2.0 e	67.5 d	14 bc	58.9 g	28.6 bc	51.0 f
	K-10	PI 537695	1.5 e	84 abc	14.5 b	59.8 fg	29.1 b	48.0 g
	Balcı	GKTAE	0.4 e	80 bcd	13.5 bc	53.7 ı	35.2 a	40.2 ı
	K-4	PI 560177	0.4 e	76.5 cd	12.5 bc	56.9 h	23.2 h	45.0 h
	Linas	TTAE	0 e	97 a	22.2 a	51.3 j	35.0 a	39.0 ı
	Dinçer	GKTAE	0 e	84.5 abc	23.2 a	49.9j	29.0 b	44.7 h
	LSD		**11.0**	**13.0**	**3.4**	**1.7**	**1.0**	**1.5**
	CV(%)		**41.2**	**10.8**	**17.6**	**1.9**	**2.7**	**2.1**
	K-1-b	PI 544017	92.4 a	80.0 d	11.1 ı	81.0 a	25.0 f	61.1 a
	K-1-a	PI 544017	88.5 a	98.2 c	12.1 hı	78.7 b	24.0g	61.5 a
	K-3-a	PI 405985	74.2 b	111.5 ab	13.2ghı	77.0 c	26.0 de	56.9 b
	K-6	W6 23110	48.4 c	103 bc	13.8fgh	71.7 d	26.3 de	57.2 b
	K-5	PI 253758	38.0 d	102 bc	15.8c-f	71.1 d	26.6 d	53.0 de
	K-7-b	PI 506426	35.0 de	98 c	14.7efg	68.0 e	27.5 c	55.0 c
	K-7-a	PI 506426	34.3 de	97.5 c	16.4cde	67.7 e	28.7 b	53.7 d
Means	K-3-b	PI 405985	28.0 ef	116 a	16.4cde	64.8 f	25.7 ef	52.0 ef
	Remzibey	GKTAE	21.3 fg	96 c	15.4d-g	57.5 ı	26.2 de	44.9 h
	K-9	PI 53769	15.2 gh	102.5 bc	17.3 cd	62.0 g	28.6 b	51.0 f
	Balcı	GKTAE	14.2 gh	80 d	21.5 b	56.7 ı	35.1 a	40.2 ı
	K-4	PI 560177	12.6 h	104.5 abc	16.8cde	59.8 h	23.2 g	45.0 h
	K-10	PI 537695	11.5 h	98.2 c	18.1 c	63.0 g	29.2 b	48.0 g
	Linas	TTAE	2.0 ı	99.7 bc	29.2 a	54.3 j	35.1 a	39.0 j
	Dinçer	GKTAE	0.6 ı	94.7 c	28.9 a	53.5 j	28.9 b	44.9 h
	LSD		**7.9**	**12**	**2.3**	**1.2**	**0.8**	**1.1**
	CV(%)		**23**	**12.5**	**13.2**	**1.9**	**2.5**	**2.2**

Mean values of the investigated characteristics of the safflower varieties and lines belonging to the 2013-2014 and 2015-2016 production years and the LSD (5 %) groups that were formed are given in Table 5.

Winter survival

When the 2013- 2014 production year is examined, it is seen that there are significant differences between winter tolerant varieties and lines in terms of survival in winter at -14.2°C. In terms of the survival rates, the Dinçer variety was found to be the most sensitive variety to winter colds among the registered varieties with a survival rate of 1.25 %.

Among the standard varieties, on the other hand, the Remzibey variety became the most tolerant variety to winter colds with a survival rate of 40.7 %. Of the lines developed to be winter tolerant through selection, the K-1-a and K-1-b lines obtained from material numbered PI 544017 of Chinese origin ranked first and second with survival rates of 99.5% and 99%, respectively. They were followed by K-3-a line obtained from material number PI 405985 of Iranian origin with a survival rate of 94%. In a study they conducted on winter survival rates of various safflower genotypes, JOHNSON *et al*. (2006) obtained the highest survival rate with the BJ-27 genotype of Chinese origin. K-1-a and K-1-b genotypes, which had the highest survival rates in this study, were also selected from the same material (Table 1). Winter survival rates of the lines varied between 21.5% and 99.5%. Spring type safflower genotypes can be sown in autumn only in areas where winter colds drop to a minimum of -11°C and they can pass winter without suffering any damage when it enters winter in the rosette stage (Table 2).Damage from cold is inevitable at temperatures lower than this when there is no snow cover. When there was snow cover, however, even spring type safflower genotypes did not sustain any damage from cold at -22°C (Table.2).

Of the standard varieties, Linas and Dinçer varieties were completely damaged by winter cold in the 2015-2016 production season at the minimum temperature of -17.3°C without a snow cover (Winter survival rate is 0%). As for the other varieties, the survival rate was 0.4% in the Balcı variety, whereas it was 2% in the Remzibey variety. Here, while almost all of the standard varieties sustained significant damage from winter colds, winter tolerant genotypes of K-1-a, K-1-b and K-3-a survived at rates of 85.9%, 77.6% and 54.4%, respectively. When averages of two years are taken into consideration, it is seen that the same genotypes again tolerated winter colds with survival levels varying between 74.2% and 92.4%.

Coefficient of Variation (CV) was quite high especially in the 2015-2016 production season when temperatures dropped to as low as -17.3°C (41.2 %). The reason for this is probably that various factors such as direction of wind have different effects on blocks in the occurrence of winter damage. Similar to this study, JOHNSON and LI (2008) reported that the BJ-27 genotype had a survival rate of 38% at -19.5°C and that physiological adaptation to low temperatures was necessary for high winter survival rates in safflower. ALIZADEH *et al*., (2011) found that the survival rate of pre-selection genotypes under controlled conditions at -19°C ranged from 2-88% in field conditions. PASCUAL-VILLOBOUS and ALBURQUERQUE (1995) found that the winter tolerance of the BJ-27 Chinese genotype with a long rosette circuit in 23 Aspir genotypes planted as winter in southern Spain was quite good.

Minimum temperatures in the years when selection was performed (4 years) in terms of survival in winter colds are given in Table 3. It is seen that temperatures gradually dropped in all the years beginning with October and finally minimum temperature was measured in January.

Winter damage occurred in January in all of the 4 years. Here, it is extremely important, in terms of winter tolerance, for plants to adapt themselves to cold as temperatures fall gradually.

Plant habit

The distance between the places where the plant root emerged from the soil and the first node (a) was measured as suggested by (JOHNSON *et al*., 2006) to determine whether the plant had prostrate or vertical growth habit in the rosette stage. When Table 5 is examined, it is seen that this distance (a) is short in winter tolerant lines (11.1-13.2 mm), whereas they it is (15.4-29.2 mm) in Spring type winter sensitive standard varieties.

As can be seen in Table 6 with regard to the correlation analysis between survival in winter and some morphological and technological characteristics in safflower genotypes, there is a negative and significant correlation between survival in winter and plant habit (a) (r = -0,2783**). Lines with low plant habit and prostrate growth better tolerate winter colds.

Similar to the present study, JOHNSON and LI (2008); JOHNSON *et al*., (2006) reported that for tolerance to winter colds, low plant habit is absolutely necessary in Autumn. They found a significant negative correlation between winter survival rates and plant habit (r= -0.41).

Table 6. Correlation coefficients between winter survival rates and some morphological and technological characteristics in safflower genotypes (2013-2014 and 2015-2016).

	Winter Survival	Plant habit	Root length)	Stem elongation time	Oil Content(%)	The ratio of seed coat
Winter Survival(%)	1,0000	-0,2783**	0,2725**	0,9076**	-0,4438**	0,7246**
Plant habit		1,0000	0,2642**	-0,3549**	0,5373**	-0,5809**
Root length			1,0000	0,2684**	-0,1281 NS	0,0667 NS
Stem elongation				1,0000	-0,5210 **	0,8514**
Oil Content					1,0000	-0,6582 **
The ratio of seed coat						1,0000

***Significant at P< 0.01 and NS, not significant*

Root length (b)

In the rosette stage**,** root length (a) was 98.2 mm in the K-1-a genotype in the winter tolerant lines according to the averages of two years, whereas it was 111.5 mm in K-3-a and 103 mm in K-6. On the other hand, in Spring type standard lines that are sensitive to winter, it was 80 mm in the Balcı variety, 94.7 mm in the Dinçer variety, 96 mm in the Remzibey variety and 99.7 mm in the Linas variety (Table 5). When Table 6 is examined, it is seen that there is a positive correlation between winter tolerance and root length (r=0,2725**). Short root length (80 mm) was measured only in the winter tolerant K-1-b genotype. The reason for this could be that in addition to genetic factors, various environmental conditions like soil humidity might have an effect on root length.

Varieties whose roots grow faster and better in the early developmental period are more tolerant to unfavorable conditions (GEÇIT *et al*., 1987). It can be said that genotypes in this study with long roots had higher tolerance towards winter colds.

Stem elongation time

According to the two-year averages, the longest stem elongation time occurred in the winter-tolerant K-1-a, K-1-b and K-3-a genotypes with 81, 78.7 and 77 days, respectively, whereas in winter-sensitive varieties, it was measured as 53.5 days in the Dinçer variety, 54.3 days in Linas, 56.7 days in Balcı and 57.5 days in Remzibey (Table 5). On average, there is a difference of 27.5 days between the most winter tolerant genotype and the most winter sensitive genotype. Late stem elongation is an important selection criterion in winter tolerant type due to long rosette stage. This slow plant habit on the part of winter type genotypes provides an advantage in avoiding winter colds, thereby preventing them from being damaged by winter. As can be seen in Table 6, there is a positive and significant correlation between survival in winter colds and stem elongation time (r= 0,9076**).

Safflower is more tolerant to low temperatures during the rosette stage (YAZDI-SAMADI and ZALI, 1979). GHANAVATI and KNOWLES (1977) found that safflower genotypes that had a long rosette stage were more tolerant to cold. The length of the rosettes stage depends not only on the environment but also hereditary genetic characteristics (ZIMMERMAN and BUCK, 1977). The long stay in the rosette stage in safflowers has a dominant effect on long rosette period (CARAPETION, 2001).

Oil Content

According to the two-year oil content values, 24% oil content was found in the K-1-a genotype, 25% oil content in K-1-b genotype and 26% oil content in K-3-a genotype among the most winter tolerant genotypes. On the other hand, of the winter sensitive genotypes, oil content was 35.1% in Linas variety, 35.1% in Balcı variety, 26.2% in Remzibey variety and 28.9% in Dinçer variety. Oil content was generally found to be low in winter tolerant types (Table 5). Indeed, as can be seen in Table 6, there is a negative and significant correlation between survival in winter and oil contents of genotypes (r=-0,4438**). Likewise, CARAPETION (2001), winter type safflower genotypes oil contents, compared to summer types are lower and it should be used to increase repetitive back-hybridization stated. In this study, oil contents of winter tolerant lines remained low.

The ratio of seed coat

The average ratio of seed coat varies between 51% and 61.2% in winter tolerant genotypes, whereas this ratio varies between 39% and 44.9% in winter-sensitive spring type varieties (Table 5). There is a positive and significant correlation between survival rate and seed coat ratio r (r=0,7246**). The fact that seed coat ratios of winter-tolerant genotypes are high and therefore oil contents are low is an important problem and this situation needs to be corrected through improvement efforts.

CONCLUSION

This study aimed to determine the relationships between winter tolerance in safflower plant in field conditions and some morphological and technological characteristics.

1. A negative and significant correlation was found between survival in winter and vertical and rapid growth in autumn. It was discovered that winter-tolerant genotypes had a prostate and low plant habit in autumn.

2. Genotypes with long roots are more tolerant to winter and there is a positive correlation between root length and survival. The part of the root above the soil needs to be shorter in terms of tolerance to winter whereas the part below the soil needs to be shorter

3. Winter tolerant genotypes have longer stem elongation time. Thus, the possibility of their growing rapidly and being exposed to cold decreases. There is a positive correlation between stem elongation time being long and winter survival.

4. Technologically, however, winter tolerant genotypes have low oil contents but high seed coat ratios.

5. Critical temperature for winter tolerance studies in safflower is –12°C. For an effective selection to be conducted, temperatures need to be lower than this and there must not be a snow cover.

6. Planting of safflower as a winter crop especially in areas where there is serious spring drought will provide significant advantages in terms of tolerance to drought. Tolerance to winter colds in safflower is an important characteristic influenced by various environmental and genetic factors. In this study, some of these factors were investigated.

This study is important in that it has reduced the time in winter tolerance studies in safflower. These studies can be replicated in conditioning chambers in controlled circumstances.

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ODNOSI IZMEĐU PREŽIVLJAVANJA U TOKU ZIME I NEKIH MORFOLOŠKIH I TEHNOLOŠKIH OSOBINA KOD GENOTIPOVA ŠAFRANIKE

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Izvod

Ova studija je sprovedena u proizvodnim sezonama 2013-2014 i 2015-2016 na eksperimentalnim poljima u Međunarodnom institutu za istraživanja u poljoprivredi Bahrije u provinciji Konja u Turskoj, gdje su zime prilično oštre, kako bi se utvrdile veze između tolerancije na zimske hladnoće i nekih morfoloških i tehnoloških karakteristika kod šafranike. Od 112 genotipova, u studiji je korišćeno 11, koji su izabrani u prethodnim godinama na osnovu njihove tolerancije na zimske uslove i 4 varijeteta (Remzibei, Dincer, Linas, Balcı), koji su registrovani kao jari usevi u Turskoj. Setva je izvršena u prvoj nedelji oktobra. Stopa preživljavanja genotipova u toku zime utvrđena je na -14.2°C u proizvodnoj sezoni 2013-2014 i na -17.3°C u proizvodnoj sezoni 2015-2016. Dužine korena i habitus biljke su mereni na jesen u fazi rozete (6-8 nedelja nakon pojave). U standardnim varijetetima, stopa preživljavanja varirala je između 1.25% i 40.7% na -14.2°C bez snežnog pokrivača u proizvodnoj sezoni 2013-2014, dok je kod tolerantnih genotipova ta stopa bila između 94% i 99.5%. U proizvodnoj sezoni 2015-2016, stepen opstanka u standardnim sortama, koje su bile osetljive na zimske uslove varirao je između 0% i 2% na-17.3°C bez snežnog pokrivača, dok su stope preživljavanja kod najtolerentnijih genotipova varirale između 85.9%, 77.6% i 54.4%, respektivno. Određena je korelacija između stepena preživljavanja i odnosa habitusa biljke i ulja. Utvrđeno je da su zimske tolerantne linije imale veći habitus biljke i niži sadržaj ulja u fazi rozete. Pozitivan i značajan odnos je pronađen između zimskog preživljavanja i dužine korena, debljine omotača semena i dužine vremena elongacije stabljike.

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