

EFFECTS OF TEMPERATURE AND MOISTURE STRESS DURING ELONGATION AND BRANCHING ON DEVELOPMENT AND YIELD OF SAFFLOWER

Uslu, N., I. Tutluer, Y. Taner, B. Kunter, Z. Sagel and H. Peskircioglu

Turkish Atomic Energy Authority,
Ankara Nuclear Research Center
in Agriculture and Animal Science
06983 Saray, Ankara, Turkey

ABSTRACT

Although safflower is considered a drought resistant crop, irregular distribution of precipitation and limited rain are the main risk factors for growing this crop in fields under dryland agriculture. This study presents the effects of water shortage and high temperature during stem elongation and branching on development and yield of safflower under non-irrigated conditions in Ankara (Turkey). Three years of results showed that plant height, number of heads per plant, head diameter, and yield were reduced drastically (from 74.4 to 48.2 cm; from 10.2 to 4.1 heads/plant; from 2.3 to 1.9 cm and from 218.9 to 48.4 kg/da, respectively) when the crop was subjected to limited rains. Consequently, supplementary irrigation must be applied during the specific stages of plant i.e. elongation and/or preflowering for ensuring the development of safflower under Ankara conditions.

INTRODUCTION

Although safflower is considered to be a drought resistant crop, it needs suitable soil moisture levels to ensure a high yield. In general, 600 mm of rainfall during the growing season (the major portion falling before flowering) seems to be sufficient in obtaining high yields. Water shortage during the normal period of maximum growth, i.e. from rosetting until flowering, will cause a marked reduction in growth and delay maturity (Weiss, 1983).

An economical crop can be raised without supplementary irrigation when the rain in the months of spring are sufficient. When there is a drought, supplementary irrigation in the dry months at elongation and/or flowering is needed (Agasimani et al., 1997). Haby et al. (1982) applied irrigation treatments at specific plant growth stages at the Northern Great Plains, and they found that a single irrigation at the early bud growth stage produced maximum seed yields. Zimmerman (1978) noted that there can also be an interaction between high temperature and high humidity, which can severely reduce seed yield. Cosentino et al. (1997) found that the seed yield was positively related to rainfall and minimum temperature in the period between emergence and flowering and negatively related to maximum temperature in the same periods.

Studies have been carried out on safflower at the experimental field of the Ankara Nuclear Research Center in Agriculture and Animal Science in Ankara since 1994. However, the development and yields of safflower show differences depending on the temperatures and variations in the distribution of the precipitation during the growing period. The 2001 results, specially, exhibited the lowest seed yields.

The aim of this research was to verify the effect of water shortage during stem elongation and branching on development and yield of safflower under non-irrigated condition in Ankara.

MATERIALS AND METHODS

Safflower field experiments were conducted at the Ankara Nuclear Research Center in Agriculture and Animal Science in Ankara (Turkey) under non-irrigated conditions. The soil of the site was heavy textured, slightly alkaline, low in organic matter and total nitrogen and also low in extractable phosphorous. In the experiments, local safflower varieties and their mutants were used. Mutants were developed by using gamma irradiation by Uslu (1977). The experiments were laid out in randomized block design with three replications. Seeds were sown on 6 May, 16 May and 13 April in 1998, 2000 and 2001, respectively. Each plot consisted of three rows with 40 cm inter-row spacing and 4 m long. Plots were harvested on 20 August 1998, on 17 August 2000 and on 30 July 2001 after physiological maturity.

The total precipitation during crop growing periods was 113.8 mm, 61.7 mm and 104.8 mm, in 1998, 2000 and 2001, respectively (Table 1). A great amount of precipitation was observed in May/June 1998 (total 110 mm), June 2000 (total 41 mm) and April/May 2001 (total 105.2 mm). In the site that the distribution of the precipitation was irregular, no rain was observed in June of 2001. This drought period in 2001 had began from the mid-May (5.2 mm only recorded after 15 May) that was very critic period for the stem elongating plants. Monthly mean temperatures ranged from 12°C (in April) to 26°C (in July) for three years. The highest maximum monthly temperature was recorded in June of 2000 (42°C).

Table 1. Monthly weather data for the safflower growing periods in experiment site in 1998, 2000 and 2001.

Month	1998			2000			2001		
	P (mm)	MinT (°C)	MaxT (°C)	P (mm)	MinT (°C)	MaxT (°C)	P (mm)	MinT (°C)	MaxT (°C)
April	-	-	-	-	-	-	38.9	1.6	29.0
May	64.8	6.6	28.8	16.3	0.7	27.2	66.3	4.0	29.9
June	45.8	7.6	32.7	41.0	4.0	33.7	0.0	4.6	35.0
July	8.5	8.8	38.0	0.4	12.7	42.0	4.0	12.0	39.0
August	0.0	0.0	36.0	24.1	7.2	36.5	-	-	-

P: precipitation; T: temperature

Measured parameters were plant height, number of branches per plant, number of heads per plant, head diameter, 100 seed weight, oil percentage and seed yield. Seed oil content was determined by NMR. All data were subjected to ANOVA analyses by using year x variety (evaluated 5 genotypes) combination. In addition, the data of 2001 based on varieties (evaluated 13 genotypes) were analyzed according to randomized block design. The means of characters were compared by Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Plant Development

The length of the growing period decreased from 108 to 93 days when seeding was delayed from 13 April (2001) to 16 May (2000), respectively (Table 2). Flowering took place 70-83 days after planting and the duration for 50 % flowering to maturity was 23-25 days. Date of 50 % flowering were 20 July, 25 July and 5 July for 1998, 2000 and 2001, respectively. Although the seeding was performed on 13 April in 2001 (about one month earlier than the seeding of 2000 and three weeks earlier than the seeding of 1998), all plants had flowered in the first week of July. In previous experiments, the autumn seedings had reached 50% flowering

after mid-July (Uslu, 2001). This depended on the drought season with high temperatures after mid-May (Mean temperature 21.6°C, maximum temperature 35°C and 0.0 mm rain in June). The absence of adequate soil moisture increased the adverse effect of the high temperature, so that plants had completed stem elongation and started head formation in a short period of time (elongation started after mid-May).

Table 2. Days to flowering and maturity of safflower at three years (based on means of genotypes).

	1998	2000	2001
Flowering	75	70	83
Maturity	100	93	108
PBFM	25	23	25

PBFM: Period between maturity and 50% flowering

Seed Yield and Plant Characters

In some years, the seed yield and plant characters were affected significantly. The highest seed yield (218.9 kg/da) was obtained from 1998 seeding. In this growing period, plants reached 74.4 cm in height and they had 6.1 branches per plant and 10.2 heads per plant. They also had the biggest head diameter (2.3 cm). Contrarily, 2001 seeding resulted in the lowest seed yield (48.4 kg/da) that was a quarter of the amount of 1998 due to shorter plants with few branches and a smaller head. The main reason was the unpredictable lack of precipitation and increasing daily maximum temperatures during the stem elongation and branching. In the year 2000, 100 seed weight and percentage of oil showed a decrease when compared with 1998 and 2001. The major factor that effected these characters was the highest maximum temperatures during flowering stage (42 °C in July). A report from Knowles (1972) provides support for this thought as he stated that yields are generally higher when the day temperature at flowering is in the 24-32 °C range. A high temperature tends to decrease the seed weight and oil percentage.

The investigated characters also showed differences according to genotypes. However, these differences were not statistically significant for number of branches per plant and seed yield. Mutant M-7 outyielded (160.6 kg/da) all other genotypes based on means of year. This mutant had the greatest number of heads per plant (8.9 heads/plant) (Table 3).

Table 3. Effects of year and cultivar on plant characters and seed yields of safflower.

	Plant height (cm)	No. of branches/plant	No. of heads/plant	Head diameter (cm)	100-seed weight (g)	Seed yield kg/da
Year						
1998	74.4 a	6.1 ab	10.2 a	2.3 a	3.76 a	218.9 a
2000	50.6 b	6.7 a	8.1 ab	2.1 ab	2.97 b	153.3 a
2001	48.2 b	3.0 b	4.1 b	1.9 b	3.26 ab	48.4 b
Genotype						
5-118	59.2 ab	5.1 a	6.9 ab	2.4 a	3.60 a	138.6 a
5-154	53.0 b	5.8 a	8.2 ab	2.1 bc	3.58 a	111.8 a
M-7	56.7 ab	5.8 a	8.9 a	1.9 cd	2.85 b	160.6 a
M-9	56.1 b	4.9 a	7.2 ab	1.9 cd	3.01 b	160.2 a
M-15	63.5 a	4.8 a	6.1 b	2.3 ab	3.61 a	129.8 a

In a column, means followed by a common letter are not significantly different at the 0.05 by DMRT.

Drought Effects on Safflower in 2001

When the data for the year 2001 were evaluated, it was seen that the seed yields ranged between 19.0 kg/da (M-20) and 54.6 kg/da (M-15). The mean of seed yields was 38.7 kg/da and this value was the second lowest within the experiments conducted in Ankara since 1994. Similarly, plants that had an average 48 cm in height, produced fewer branches (2.7 branches/plant) and heads (3.8 heads/plant). Also, their head diameter was below 2.0 cm on averages of genotypes. Although the highest seed weight was recorded from M-17 as 4.37 g, mutant M-12 produced the highest seed oil (30.2 %), but the seed yield of M-12 was only 40 kg/da.

Table 4. Agronomic character and seed yields of genotypes in 2001.

	Plant height (cm)	No. of branches/plant	No. of heads/plant	Head diameter (cm)	100-seed weight (g)	Seed yield kg/da	Seed oil (%)*
5-38	55.1 a	2.0 c	3.0 a	22.0 a	25.2 de	28.8 ce	17.3
5-118	46.9 ab	2.7 ac	3.7 a	21.3 ab	36.0 ac	50.0 ac	28.8
5-154	45.5 ab	2.8 ac	3.8 a	18.7 bd	36.2 ac	42.6 ad	24.5
M-3	45.3 ab	3.1 ac	4.1 a	22.0 a	26.3 de	44.6 ad	27.4
M-7	45.3 ab	3.6 a	4.7 a	17.0 ce	27.7 de	51.7 ab	25.9
M-8	46.9 ab	3.4 ab	4.5 a	16.0 de	27.5 de	33.4 ae	27.4
M-9	47.7 ab	3.3 ac	4.4 a	17.0 ce	27.7 de	43.0 ad	27.4
M-11	44.4 ab	2.2 bc	3.3 a	16.7 de	29.3 cd	31.1 be	28.8
M-12	51.4 a	2.1 bc	3.1 a	16.7 de	26.3 de	38.8 ae	30.2
M-15	55.3 a	2.6 ac	3.9 a	21.0 ab	35.4 bc	54.6 a	24.5
M-17	52.2 a	2.3 ac	3.4 a	19.7 ac	43.7 a	37.5 ae	25.9
M-19	54.4 a	2.3 ac	3.3 a	20.3 ab	41.4 ab	28.4 de	27.4
M-20	36.6 b	3.1 ac	4.1 a	15.7 c	21.5 e	19.0 e	21.6

In a column, means followed by a common letter are not significantly different at the 0.05 P by DMRT.

*Statistical analyses for seed oil could not performed because of low seeds.

CONCLUSIONS

The combination of temperature and moisture stress in 2001 seeding critically affected plant development and seed production. A dry regime during stem elongation and branching resulted in a relative reduction in the number of days required to reach flowering. As a result, the growth period became compressed and plant heights, head production, head scales and yields were reduced drastically.

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