Turk J
Field Crops
2017, 22(2), 178-186
DOI: 10.17557/tjfc.356210

THE EFFECTS OF HIGH TEMPERATURE AT THE GROWING PERIOD ON YIELD AND YIELD COMPONENTS OF SOYBEAN [*Glycine max* (L.) Merr] VARIETIES

Bihter ONAT[1], Halil BAKAL[2], Leyla GULLUOGLU[2], Halis ARIOGLU[2]*

[1]Cukurova University, Vocational School of Kozan, Adana, TURKEY
[2]Cukurova University, Faculty of Agriculture, Dep. of Field Crop, Adana, TURKEY
**Corresponding author: halis@cu.edu.tr*

Received: 07.06.2017

ABSTRACT

This study was conducted at the Experimental Area of Cukurova University in 2015 and 2016 as a double crop growing season. The objective of this study was to determine the effect of high temperature on seed yield and some yield component of soybean [*Glycine max* (L.) Merr] varieties in double crop growing season in Mediterranean region in Turkey. The experimental design was a Randomized Complete Block with three replications. The Arısoy, Atakisi, Ataem-7, Umut-2002, Turksoy, Adasoy, Cinsoy, Ilksoy, Bravo, Sa-88, S.4240, Blaze, Nova, May-5312, Cetinbey, May-5414 and 34A7 varieties (belonging to maturity groups II, III, IV and V) were used as a plant material in this research. The maximum air temperature data was recorded day by day during the growing period in both years and daily maximum air temperatures were higher in 2016 than in 2015. When the seed yield compared in 2015 and 2016, it is found that the seed yield was lower (29.5%) in 2016 than in 2015. The high temperature was negatively affected the seed yield of soybean varieties. It was found that the soybean varieties differ in their sensitivity to high temperatures.

Key words: air temperature, double crop, seed yield, soybean, yield reduction

INTRODUCTION

Soybean is one of the important oil and protein crop of the world and is grown under a wide range of environmental conditions, where climate factors such as temperature, photoperiod and moisture stress, exerts a detrimental effect on plant growth and metabolism (Khan et al., 2007). Patel and Franklin (2009) reported that temperature is a critical factor that controls plant growth and development. The suitable temperature for soybean is 15-22ºC at emergence, 20-25ºC at flowering and 15-22ºC at maturity (Liu et al., 2008). Hicks (1978) and Whigham and Minor (1978) reported that high air temperature may also have detrimental effects on soybean development. Maximum temperature above 35ºC cause heat stress, which has harmful effect on flowering and pod set of soybean. Heat stress is considered one of the main factors that negatively affect crop production. The high temperatures reduce plant growth, as well as the number of flowers and seeds per pod (Tubiello et al., 2007, Canci and Toker 2009a,b and Wheeler and von Braun, 2013)

Heat stress during flowering can result in pollen sterility and reduced seed set. Temperature exceeding 29.4ºC can result in a decreased number of pods while temperature above 37.2ºC severely limited pod formation. Heat stress at the R5 growth stage, has the greatest impact on soybean yield. During the seed fill, daytime temperature of 32.8-35.6ºC result in fewer seeds per plant, day time temperatures greater than 29.4ºC during seed fill can result in decreased soybean weight. High nighttime temperatures can result in wasteful respiration and a lower net amount of dry matter accumulation in plants. The rate of respiration of plants increases rapidly as the temperature increases, approximately doubling for each 10.6ºC increase. During the day, soybean plants accumulate starch in their leaves. At night, the starch is broken down and exported from their leaves. When nights are cool, the amount of starch exported is reduced resulting in high leaf starch the following day, which can disrupt photosynthesis. Nighttime temperatures have to exceed 29.4ºC before any noticeable reduction in soybean yield is experienced (10%) (Anonymous, 2012a).

Whigham and Minor (1978) indicated that the optimum air temperature for photosynthesis is 25º-30ºC. The CO_2 assimilation by soybean canopies is reduced 20% when the canopy temperature is increased from 30º to 40ºC. The respiration rate increases at higher temperatures causing a greater loss in seed weight. Gulluoglu et al. (2006) reported that soybean cannot synthesize some of the necessary hormones in a sufficient level to control its growth and development under high temperature and low humidity, consequently, the plant cannot show its real yield potential. Marking (1986) indicated that high temperature pollen viability and accelerates ethylene production that increase flower abortion and plant senescence. Yield decrease due to high temperature and (CO_2) could be due to the effect of on reproductive at both organ and process levels. High temperature inhibits pollen germination and pollen tube growth and genotypes differ in their sensitivity (Huan et al., 2000 and Kakani et al., 2002).

Hicks (1978) reported that temperature throughout the 16-32ºC ranges increase the percentage of flower and pod shedding. Yield is reduced when July and August temperature are above average. Seed-filling rate is enhanced by temperature in the 26-30ºC range compared with the 16-18ºC range. Mishra and Cherkauer (2010) indicated that soybean crop yields were strongly correlated with maximum daily temperature during seed filling (R5-R7) stages. Djanaguiraman and Prasad (2010) showed that heat stress decreased photochemical efficiency by 5.8%, photosynthetic rate by 12.7% and increased ethylene production rate, which triggered premature leaf senescence.

Soybean seed yield components are also influenced by temperature. Soybean seed yield increased as temperature increased between 18/12 (day/night) and 26/20ºC, but yield decrease greater than 26/20ºC (Huxley et al., 1976 and Sionit et al., 1987). Raising temperature from 29/20 to 34/20ºC during seed fill decreased soybean seed yield (Dornobos and Mullen, 1991). Sapra and Anaele (1991) reported that soybean cultivars differ in their sensitivity to high temperatures. Arioglu and Ersoy (1987) found that 19.9% yield decrease was estimated due to high temperature in soybean varieties and the response against to high temperature of the soybean varieties were different. When soybean plants were exposed to temperature of 35ºC for 10 hour during the day, yield reduction of about 27% were measured (Gibson and Mullen, 1996). Prasad et al. (2000) investigated the effect of daytime soil and air temperature of 20º and 38ºC, from start of flowering to maturity, and reported 50% reduction in pod yield at high temperatures.

The Intergovernmental Panel on Climate Change (IPCC) has forecasted that global temperatures will increase between 2º and 5ºC by the end of this century. In most regions this global warming will negatively impact plant growth and development. As a consequence, the yields of a variety of important crops, such as corn, wheat and soybean will be compromised. Thus, it is imperative to understand the physiological and molecular processes that plants use to cope with heat stress as a first step to breed for plants more tolerant to the negative effects of climate change (Anonymous, 2012b). Breeding of soybean varieties tolerant to heat stress is getting more important to obtain high yield in soybean farming.

Soybean mainly is grown as a double crop after small grain harvest in the Cukurova region (Mediterranean region) in Turkey. The air temperature can be varied during the growing season year by year in this region. The air temperature and seed yield of varieties were found different in 2015 and 2016 growing seasons. The air temperature was higher in 2016 than in 2015. The high temperature negatively effects on seed yield and soybean varieties differ in their sensitivity to high temperatures. The objective of this study was to determine the effect of high temperature on seed yield and some yield component of soybean varieties in double crop growing season in Mediterranean region in Turkey.

MATERIALS AND METHODS

Experimental site and plant materials

The trials were conducted during the 2015 and 2016 two consecutive cropping seasons as a double crop at the Experimental Area of Cukurova University in Adana, Turkey (Southern Turkey, 36º59ˡ N, 35º18¹ E; 23 elevation). 17 different soybean varieties (belonging to maturity groups II, III, IV and V) were used a plant material in this research (Table 1). It can be seen in Table 1, growing period of the soybean varieties varied between 105-125 days in 2015 and 100-120 days in 2016. Soybean varieties were matured five days earlier in 2016 than in 2015 due to high temperature. The flowering and pod formation periods of soybean varieties were in July and in August, respectively in both years.

The soil in the experimental site is classified as clay loam texture. The soil tests in both years indicated a pH of 7.6 with high concentrations of K_2O and low concentrations of P_2O_5. In addition, the organic matter and nitrogen content of the soil was very low. The lime content was 20.5% in the upper layers of the soil.

The climate data during the 2015-2016 growing period in experimental area were given in Table 2.

In Adana, winters are warm and rainy, whereas summers are dry and hot, which is a typical of a Mediterranean climate. The differences between the 2015 and 2016 years were significant for the air temperature. The air temperature was higher in 2016 than in 2015 during the growing period. The total rainfall was 146 mm and 93.8 mm during the growing periods in 2015 and 2016, respectively. The average relative humidity was ranged from 54.0% to 69.8% in 2015 and 59.9% to 67.5% in 2016 (Table 2).

The average maximum temperature data during the growing period (July, August and September months) in 2015 and 2016 as a five days interval were given in Table 3 and Figure 1. The maximum air temperature was higher in 2016 than 2015 during the flowering and pod formation stages of the soybean varieties.

Table 1. Soybean varieties

Varieties	Originate	Maturity group	Growing period	
			2015	2016
Arısoy	Turkey	III	110	105
Atakisi	Turkey	III	110	105
Ataem-7	Turkey	III-IV	115	110
Umut-2002	Turkey	III	110	105
Turksoy	Turkey	IV	120	115
Adasoy	Turkey	IV	120	115
Cinsoy	Turkey	IV	120	115
Ilksoy	Turkey	IV	120	115
Bravo	USA	II	105	100
Sa-88	Turkey	III	110	105
S.4240	USA	IV	120	115
Blaze	USA	IV	120	115
Nova	USA	III	110	105
May-5312	USA	III	110	105
Cetinbey	Turkey	IV	120	115
May-5414	USA	V	125	120
34A7	USA	III	110	105

Table 2. The climate data during the 2015-2016 growing period in experimental area (Anonymous, 2016)

Months	Min. temp. (ºC)		Max. temp. (ºC)		Average temp. (ºC)		Relative humidity (%)		Precipitation (mm)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
June	17.8	20.5	29.5	33.3	24.1	26.9	69.1	63.8	4.8	45.6
July	22.3	23.2	33.0	35.7	27.6	29.5	69.8	67.5	0.4	0.2
August	22.9	23.7	35.9	37.5	29.4	30.6	62.3	67.4	10.9	8.2
September	20.0	19.8	34.1	34.7	27.8	27.4	54	59.9	130	39.8

Table 3. The average maximum air temperature data (five days interval) during the 2015-2016 growing period in experimental area (Anonymous, 2016)

Five days interval	July		August		September	
	2015	2016	2015	2016	2015	2016
1-5	30.8	33.8	36.8	38.6	36.4	37.0
6-10	32.4	35.6	38.0	38.0	36.8	37.0
11-15	32.4	37.0	35.2	36.8	37.0	36.0
16-20	34.0	35.4	35.6	38.0	34.4	34.6
21-25	34.2	35.4	34.0	38.4	33.8	34.0
26-31	34.2	37.0	35.9	35.5	33.0	30.6
Average	33.0	35.7	35.9	37.6	34.1	34.7

The experiment treatments

The study design was a Randomized Complete Block with three replications. Before sowing, 200 kg ha^{-1} of DAP (36 kg ha^{-1} N, 92 kg ha^{-1} P) was applied. Fertilizer requirements were determined based on the nutritional requirements of soybean and soil nutrient availability. Additional nitrogen fertilizer was applied (side-dressing) as a rate of 66 kg ha^{-1} in the form of Ammonium nitrate (33%N) before first irrigation (R1 stage). Weed control was done using pre-plant application of Traflen (Trifuralin) at amount of 1.5 l ha^{-1}. The plot size was 14.0 m^2 (2.8 m x 5.0 m) consisting of four rows, five meter long and 70 cm apart. The soybean seeds were planted as a high density at planting and then plant distance (plant density) was regulated (4 cm) by pulling out plants (thinning) at the V2 growth stage. Before planting, all seeds were inoculated with *Rhizobium bradyrhijaponicum* bacteria**.** The planting and harvesting dates were June 15 and October 10 in 2015 and June 15 and October 5 in 2016. During the growing period, recommended pesticides and fungicides were applied to control insects and diseases. During the growing period, other standard cultural practices were applied at proper time intervals. The plants harvested by hand when the pods and plants are matured in both years.

Pod number per plant data were collected from 20 plants randomly selected from each plot at the harvesting time. Yield data per plot was measured in a similar way from all remaining plants excluding the very end on each side of the four rows. 100-seed weight (g) data was obtained after harvesting (Gulluoglu et al., 2016).

The data were statistically analyzed by JUMP 8.1.0 statistical software with Randomized Complete Block design and Least Significant Differences (LSD) test was used to compare the treatments at probability level of 0.05.

RESULTS AND DISCUSSION

Pod number

Pod number per plant and 100-seed weight characteristics are the most important seed yield components in soybean. For this reason only these two characteristics were investigated as a seed yield component in this research.

The average data belonging to pod number per plant and 100-seed weight of soybean varieties has been presented in Table 4. The average pod number of the soybean varieties was 48.23 pods plant^{-1} in 2015 and 36.0 pods plant^{-1} in 2016. The differences between the years were statistically significant for pod number. The number of pods per plant in 2016 was higher when compared to 2015 (Table 4). The pod number per plant was affected significantly by air temperature during the growing seasons. The maximum air temperature was higher in 2016 than in 2015. Maximum temperature above 35^{o}C cause heat stress, which has harmful effects on flowering and pod set of soybean (Whigham and Minor, 1978).

Table 4. The pod number and 100-seed weight data belonging to soybean varieties in 2015 and 2016

Varieties (A)	Pod number (pods plant^{-1}) Years (B)		100-seed weight (g) Years (B)	
	2015	2016	2015	2016
Arısoy	45.0	31.0	17.7	16.7
Atakisi	46.1	37.3	17.5	16.0
Ataem-7	44.8	32.7	16.5	18.2
Umut-2002	45.2	34.9	18.6	17.3
Turksoy	46.8	36.1	21.1	16.4
Adasoy	53.3	40.2	15.3	15.4
Cinsoy	42.1	32.9	17.3	17.9
Ilksoy	44.5	38.9	16.4	16.7
Bravo	40.7	36.6	17.4	17.3
Sa-88	59.9	40.7	14.2	16.0
S.4240	46.9	35.5	17.2	17.0
Blaze	54.4	34.0	16.6	15.9
Nova	55.5	40.6	17.7	16.8
May-5312	54.5	41.3	17.1	16.4
Cetinbey	42.9	32.5	18.4	22.2
May-5414	42.9	33.9	19.1	19.9
34A7	54.6	33.7	20.6	19.5
Average	48.2	36.0	17.6	17.4
LSD ($5\%_A$)	12.04	2.65	0.50	1.47
LSD ($5\%_B$)	5.03		NS	
LSD ($5\%_{AxB}$)	NS		1.07	

The high temperature affects pod production efficiency in soybean plant. Marking (1986) reported that high temperature effects on pollen viability and accelerates ethylene production that increase flower abortion. Hicks (1978) reported that temperature throughout the 16-32 ^{o}C ranges increase the percentage of flower and pod shedding. The number of pods per plant generally increased as temperatures increased to near 26/20^{o}C. Plants grown at temperature exceeding 26/20^{o}C had decreased pod numbers (Huxley et al., 1976; Thomas and Raper, 1978 and Sionite et al., 1987). Physiologically, the high temperature stress during reproductive development may have affect flower abortion sequent sink site and later pod abscission resulting a decreased number of seeds per plant (Duthion and Pigeaire, 1991). Prasad et al. (2000) investigated the effect of daytime soil and air temperature of 20^o and 38^{o}C, from start of flowering to maturity, and reported 50% reduction in pod yield at high temperatures. Tubiello et al. (2007) and Wheeler and von Braun (2013) indicated that heat stress is considered one of the main factors that negatively affect crop production. The high temperatures reduce plant growth, as well as the number of flowers and seeds per pod. Heat stress during flowering can result in pollen sterility and reduced seed set. Temperature exceeding 29.4^{o}C can result in a decreased number of pods while temperature above 37.2^{o}C severely limited pod formation (Anonymous, 2012a).

The differences between the varieties were statistically significant for the pod number per plant in both years. The pod number of soybean varieties varied between 40.7-59.9 pods plant^{-1} in 2015 and 31.0-41.3 pods plant^{-1} in 2016. In this research, the number of pods per plant of soybean varieties was found higher in 2015 than in 2016. The pods number per plant was affected by the environment condition such as air temperature. Sapra and Anaele (1991) reported that soybean cultivars differ in their sensitivity to high temperatures. For this reason, the pod number per plant was different. Puteh et al. (2013) indicated that soybean seed yield components are influenced by temperature. Huxley et al. (1976), Dornbos and Mullen (1991) and Gibson and Mullen (1996) reported that the air temperature during the reproductive periods reduce seed yield components of soybean in high temperature of 32-38ºC. The interaction between the year and variety for the pod number per plant was not found statistically significant. The results are corresponded well with the findings of Puteh et al. (2013), Tacarindua et al. (2013), Sadeghi et al. (2014) and Kumagai and Sameshima (2014).

100-Seed weight

The average 100-seed weight of soybean varieties was 17.6 g in 2015 and 17.4 g in 2016 (Table 4). The 100-seed weight was found higher in 2015 than in 2016. 2015 and 2016 years compared for the average 100-seed weight of soybean varieties was not found significant The air temperature during the seed filling period (in September) was similar in each year. For this reason, it has not found significant between the years. Munier-Jolain and Ney (1998) indicated that the high temperature stress during reproductive development may have negatively affected cell expansion, cotyledon cell number and seed filling rate, resulting in the lowered weight per seed. Sionite et al. (1987) and Baker et al. (1989) reported that weight per seed in soybean was increase in season-long temperatures from 18/12 to 26/20ºC, but as temperature increased above 26/20ºC, weight per seed decreased. Temperature above 30/25ºC during flowering and pod development reduced weight per seed, regardless of the temperature during seed fill (Egli and Wardlaw,1980).Temperature above 29/20ºC during seed fill decreased soybean seed weight (Dornbos and Mullen,1991). During the seed fill, daytime temperature of 32.8-35.6ºC result in fewer seeds per plant, day time temperatures greater than 29.4ºC during seed fill can result in decreased soybean seed weight (Anonymous, 2012a).

The 100-seed weight of soybean varieties varied between 14.2-21.1 g in 2015 and between 15.4-22.2 g in 2016 (Table 4). The differences between the varieties were significant for the 100-seed weight in both years. Sadeghi and Niyaki (2013) reported that different soybean varieties are sensitive to change to environment conditions where the crop is being grown. Early maturing varieties are more sensitive to high temperature than late varieties. For this reason, the differences between the varieties for the 100-seed weight were found significant. Year x variety interaction on 100-seed weight of soybean was statistically significant. The highest 100-seed weight was obtained from Turksoy (21.1 g) in 2015 and Cetinbey (22.2 g) in 2016, and the lowest from Sa.88 (14.2 g) in 2015 and Adasoy (15.4 g) in 2016, respectively (Table 4). Similar results were reported by Gulluoglu et al. (2006), Sadeghi et al. (2013), Puteh et al. (2013), Tacarindua et al. (2013), Kumagai and sameshima (2014) and Choi et al. (2016).

Seed yield

The seed yield data belonging to soybean varieties in 2015 and 2016 and the comparison of the years for yield potential were given in Table 5.

Table 5. The seed yield data belonging to soybean varieties in 2015 and 2016 and the comparison of the years for yield potential

Varieties (A)	Seed yield (kg ha^{-1}) Years (B)		Yield reduction (kg ha^{-1})	Yield reduction (%)
	2015	2016		
Arısoy	5121.4	3547.2	1574.2	30.7
Atakisi	4830.9	3340.5	1490.4	30.9
Ataem-7	4840.5	3304.3	1536.2	31.7
Umut-2002	4769.0	3348.1	1420.9	29.8
Turksoy	4435.7	2930.0	1505.7	33.9
Adasoy	4883.4	3646.0	1237.4	25.3
Cinsoy	4897.6	3374.3	1523.3	31.1
Ilksoy	4664.3	4196.7	467.6	10.0
Bravo	4673.8	3338.1	1335.7	28.6
Sa-88	4831.0	3523.4	1307.6	27.1
S.4240	4797.6	3490.5	1307.1	27.2
Blaze	4719.1	3038.1	1681.0	35.6
Nova	4581.0	3409.5	1171.5	25.6
May 53-12	4545.2	3082.8	1462.4	32.2
Cetinbey	4338.1	2984.3	1353.8	31.2
May 54-14	4683.3	3180.5	1502.8	32.1
34A7	5275.4	3267.2	2008.2	38.1
Average	4758.1	3353.0	1405.0	29.5
LSD ($5\%_A$)	407.0	360.2		
LSD ($5\%_B$)	198.1			
LSD ($5\%_{AxB}$)	376.9			

There was a statistically significant difference between the years for the seed yield. The average seed yield values was found 4758.1 kg ha^{-1} in 2015 and 3353.0 kg ha^{-1} in 2016. The seed yield in 2015 was higher when compared to 2016. The seed yield per hectare was reduced 1405 kg ha^{-1} (29.5%) in 2016 when compared to 2015 (Table 5). The daytime maximum air temperature was 2.7^{o} and 1.6^{o}C higher in July and August (during the flowering and pod formation period), respectively in 2016 than in 2015 (Table 3 and Figure 1). The growth and development of soybean plant is affected by the environmental factors such as temperature and photoperiod. Hu and Wiatrak (2012) reported that unfavorable environmental conditions such as high temperature have a negative effect on soybean growth, development and yield.

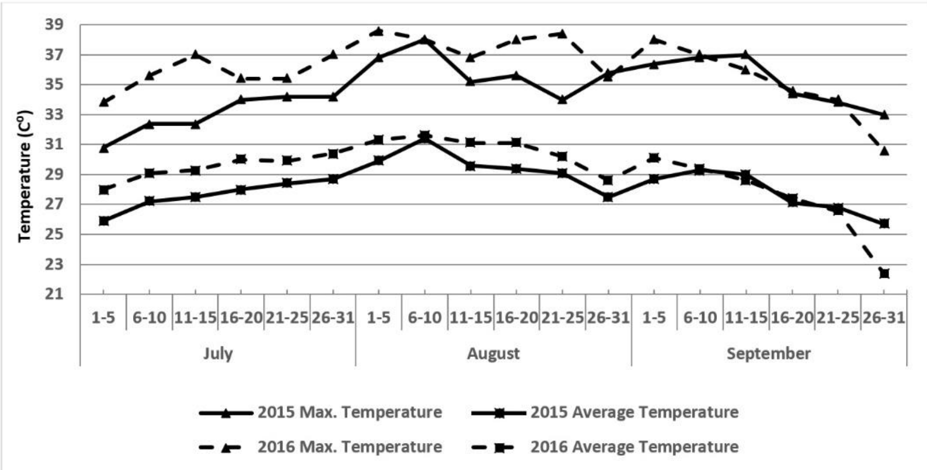

Figure 1. The average and maximum air temperature data (five days interval) during the 2015 2016 growing period in experimental area (Anonymous, 2016)

Soybean seed yield is calculated by multiplying the plant number per unit area x pod number per plant x seed number per pod x average seed weight. Generally, soybean seed yield depends mostly on pod number per unit area and seed weight (Ohyama et al., 2013). These two factors are chances by the environment factories such as temperature which are grown. The high temperature affects pod production efficiency in soybean plant. Plants grown at temperature exceeding 26/20^{o}C had decreased pod numbers (Huxley et al., 1976; Thomas and Raper, 1978 and Sionite et al., 1987). The high temperatures reduce plant growth, as well as the number of flowers and seeds per pod. Heat stress during flowering can result in pollen sterility and reduced seed set. Temperature exceeding 29.4^{o}C can result in a decreased number of pods while temperature above 37.2^{o}C severely limited pod formation (Anonymous, 2012a). It can be seen in Table 4, the average pod number per plant of soybean varieties were negatively affected by the high temperature and it was found higher in 2015 than in 2016. Choi et al. (2016) was found high positive correlation between the pod number per plant and seed yield. For this reason, the seed yield of soybean varieties was found lower in 2016 than in 2015.

Whigham and Minor (1978) reported that high air temperature may also have detrimental effects on soybean development. Maximum temperature above 35^{o}C cause heat stress, which has harmful effects on flowering and pod set of soybean. Tubiello et al. (2007) and Wheeler and von Braun (2013) indicated that heat stress is considered one of the main factors that negatively affect crop production. The high temperatures reduce plant growth, as well as the number of flowers and seeds per pod. Soybean crop yields were strongly correlated with maximum daily temperature during seed filling (R5-R7) stages (Mishra and Cherkauer, 2010). Djanaguiraman and Prasad (2010) showed that heat stress decreased photochemical efficiency by 5.8%, photosynthetic rate by 12.7% and increased ethylene production rate, which triggered premature leaf senescence. Sapra and Anaele (1991) reported that soybean cultivars differ in their sensitivity to high temperatures. When soybean plants were exposed to temperature of 35^{o}C for 10 hour during the day, yield reduction of about 27% were measured (Gibson and Mullen, 1996). Prasad et al. (2000) investigated the effect of daytime soil and air temperature of 20^{o} and 38^{o}C, from start of flowering to maturity, and reported 50% reduction in pod yield at high temperatures. As mentioned above by some researchers, the seed yield of soybean varieties were negatively affected by the high temperature during the growing period.

As it can be seen in Table 5 and Figure 2, the average seed yield values of soybean varieties varied between 5275.4-4338.1 kg ha^{-1} in 2015 and 2930-4196.7 kg ha^{-1} in 2016. The differences between the soybean varieties for the seed yield were found significant in both years. The seed yield of tested varieties was found higher in 2015 than in 2016. The effect of air temperature on seed yield of soybean varieties was markedly different. The yield reduction of soybean varieties varied between 10.0-38.1%. The highest seed reduction was found from 34A7 (38.1%) and the lowest from Ilksoy (10.0%) varieties. Different soybean varieties are sensitive to change to environment conditions such as air temperature where the crop is being grown. Early maturing varieties are more sensitive to high temperature than late varieties (Sadeghi and Niyaki, 2013). For this reason, the differences between the varieties for the seed yield were found significant.

The growing period of soybean varieties is shorter and dry matter accumulation is lower in high temperature conditions. The dry matter accumulation in soybean seed depends on the length of seed filling period, vegetative growth and the rate of the dry matter production (Brun, 1978). Soybean plant has shorter vegetative growth in short photoperiod with high temperature and longer vegetative growth in long photoperiod with low temperature. High temperature was accelerated to maturity of soybean variety. The growing period was shorter in 2016 (100-120 days) than in 2015 (105-125 days).

Sapra and Anaele (1991) reported that soybean cultivars differ in their sensitivity to high temperatures. Arioglu and Ersoy (1987) found that 19.9% yield decrease was estimated due to high temperature in soybean varieties and the response against to high temperature of the soybean varieties were different. When soybean plants were exposed to temperature of 35ºC for 10 hour during the day, yield reduction of about 27% were measured (Gibson and Mullen, 1996). Stress that reduce crop growth rate between growth stage R1 and R5 result in the greatest seed-yield decrease (Board and Harville, 1998). Prasad et al. (2000) investigated the effect of daytime soil and air temperature of 20º and 38ºC, from start of flowering to maturity, and reported 50% reduction in pod yield at high temperatures.

Year x variety interaction on seed yield of soybean was statistically significant (Figure 2). The seed yield of soybean varieties varied in 2015 and 2016. The effect of high temperature on seed yield of soybean varieties was different. The highest seed yield was obtained from 34A7 (5275.4 kg ha^{-1}) and Ilksoy (4196.7 kg ha^{-1}) and the lowest from Cetinbey (4338.1 kg ha^{-1}) and Turksoy (2930.0 kg ha^{-1}) in 2015 and 2016, respectively (Table 5). These results are matched with the findings of Arıoglu and Ersoy (1987), Dornobos and Mullen (1991), Gibson and Mullen (1996), Gulluoglu et al. (2006), Puteh et al. (2013), Tacarindua et al. (2013), Kumagai and Sameshima (2014), Sadeghi et al. (2014) and Choi et al. (2016).

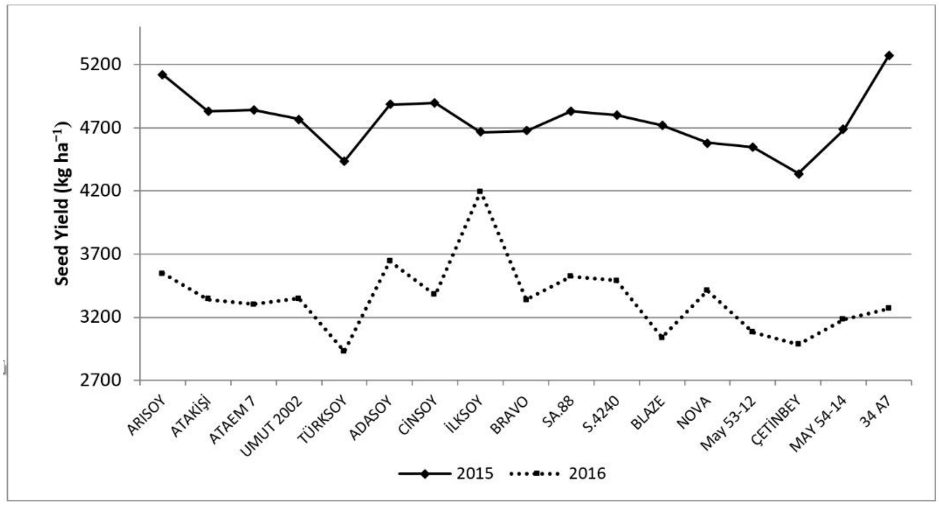

Figure 2. The seed yield data belonging to soybean varieties in 2015 and 2016

CONCLUSIONS AND SUGGESTIONS

The growth and development of soybean plant is affected by the environmental factors such as temperature and photoperiod. The temperature is a critical factor that controls plant growth and development. The suitable temperature for soybean is 15-22ºC at emergence, 20-25ºC at flowering and 15-22ºC at maturity. High air temperature during the flowering and pod formation may also have detrimental effects on soybean growth, development and seed yield. Maximum temperature above 35ºC cause heat stress, which has harmful effect on flowering and pod set of soybean. The high temperatures reduce plant growth, as well as the number of flowers and seeds per pod.

In this research; the average seed yield values was found 4758.1 kg ha^{-1} in 2015 and 3353.0 kg ha^{-1} in 2016. The seed yield in 2015 was higher when compared to 2016. The seed yield per hectare was reduced 1405 kg ha-1 (29.5%) in 2016 when compared to 2015 (Table 5). The daytime maximum air temperature during the flowering and pod formation period (July and August) was higher in 2016 than in 2015 (Table 3 and Figure 1). High temperature was negatively affected on soybean seed yield.

The average seed yield values of soybean varieties varied between 5275.4-4338.1 kg ha^{-1} in 2015 and 2930-4196.7 kg ha^{-1} in 2016. The differences between the soybean varieties for the seed yield were found significant in both years. The seed yield of tested varieties was found higher in 2015 than in 2016. The effect of air temperature on seed yield of soybean varieties was markedly different. Soybean varieties are sensitive to change to environment conditions such as air temperature where the crop is being grown. The yield reduction of soybean varieties varied between 10.0-38.1%. The highest seed reduction was found from 34A7 (38.1%) and the lowest from Ilksoy (10.0%) varieties. As a result, soybean varieties have to tolerant to high temperature grown as a double crop in Mediterranean region in Turkey.

LITARATURE CITED

Anonymous, 2012a. http://www.cornandsoybeandigest.com/corn/high-temperature-effects-corn-soybeans

Anonymous, 2012b. http://www.ipcc.ch. 2012. The Intergovernmental Panel on Climate Change (IPCC), Czechoslovakia

Anonymous, 2016. The Meteorological Data for Adana. Faculty of Agriculture Meteorological Station.

Arioglu,H.H. and T. Ersoy. 1987. The effect of high temperature at growing period on soybean [*Glycine max* (L.) Merr] yield. J. of Natural Science, 11 (2) : 262-268

Baker, J.T., L.H. Allen and K.J. Boote. 1989. Response of soybean to air temperature and carbon dioxide concentration. Crop Science, 29:98-105

Board, J.E and B.G. Harville. 1998. Late-planted soybean yield response to reproductive source/sink stress. Crop Science, 38:763-771

Brun, W.A. 1978. Assimilation. Soybean Agronomy, Physiology and Utilization. Geoffrey Norman, A. (Ed.), Academic Press, London. pp. 45-73 & 249.

Canci, H and Toker, C. 2009a. Evaluation of yield criteria for drought and heat resistance in Chickpea (Cicer arietinum L.).J.Agronomy and Crop Science, 195:47-54.

Canci, H and Toker, C. 2009b. Evelaution of annual wild Cicer species for drought and heat resistance under field conditions. Genetic Resources and Crop Evolution, 56:1-6.

Choi, D.W., H.Y. Ban, B.S. Seo, K.J. Lee and B.W. Lee. 2016. Phenology and seed yield performance of determinant soybean cultivars grown at elevated temperatures in a temperate region. Plos One, 11(11): e0165977. DOI:10.1371/journal.pone.0165977

Djanaguiraman, M and P.V.V.Prasad. 2010. Ethylene production under high temperature stress causes premature leaf senescence in soybean. Functional Plant Biology, 37:1071-1084

Dornbos, D.L and R.E. Mullen. 1991. Soybean Seed Protein and Oil Contents and Fatty Acid Composition Adjustments by Drought and Temperature. J. American Oil Chem. Soc. (JAOCS). **69**(3): 228-231.

Duthion, C and A. Pigeaire. 1991. Seed lengths corresponding to the final stage in seed abortion of three grain legumes. Crop Science, 31:1579-1583

Egli, D.B and I.F. Wardlaw. 1980. Temperature response of seed growth characteristics of soybeans. Agronomy Journal, 72(3):560-564

Gibson, L.R and R.E. Mullen. 1996. Influence of day and night temperature on soybean seed yield. Crop Science, 36(1):98-104

Gulluoglu, L., H. Arioglu and M. Arslan. 2006. Effect of some plant growth regulators and nutrient complexes on above-ground biomass and seed yield of some soybean grown under heat-stressed environment. Journal of Agronomy, 5(2):126-130

Gulluoglu, L., H. Bakal and H. Arioglu. 2016. The Effects of Twin-row Planting Pattern and Plant Population on Seed Yield and Yield Components of Soybean at Late Double-Cropped Planting in Cukurova Region. Turkish Journal of Field Crops, 21(1):59-65

Hicks, D.R. 1978. Growth and development. Soybean Agronomy, Physiology and Utilization. Geoffrey Norman, A. (Ed.), Academic Press, London. pp. 17-41 & 249.

Huan,F., A.Lizhe, T. Ling Ling, H. Zonf Dong and W. Xunling. 2000. Effect of enhanced ultraviolet-B radiation on pollen germination and tube growth of 19 taxa in vitro. Environment an Experimental Botany, 43:45-53

Hu, M and P. Wiatrak. 2012. Effect of Planting Date on Soybean Growth Yield and Grain Quality: Review. Agronomy Journal, **104**(3):785-790

Huxley, P.A., R.J. Summerfield and P. Hughes. 1976. Growth and development of soybean CV-TK5 as affected by tropical day lengths, day/night temperatures and nitrogen nutrition. Ann. Apply. Biol.82:117-133

Kakani, V.G., P.V.V. Parasad, P.Q. Craufurd and T.R. Wheeler. 2002. Response of in vitro pollen germination and pollen tube growth of Groundnut (*Arachis hypogaea* L.) genotype to temperature. Plant Cell and Environment, 25:1651-1661

Khan, A.Z., H. Khan, A. Ghoneim, R. Khan and A. Ebid. 2007. Seed quality and vigor of soybean as influenced by planting date, density and cultivar under temperature environment. Int. Journal of Agriculture Research, 2(4): 368-376

Kumagai, E and R. Sameshima. 2014. Genotypic differences in soybean yield response to increasing temperature in a cool climate are related to maturity group. Agricultural and Forest Meteorology, 198-199:265-272

Liuet, X., J. Jian, Wguanghua and S.J. Herbert. 2008. Soybean yield physiology and development of high-yielding practices in Northeast China. Field Crops Research, 105:157-171

Marking, S. 1986. Heat stress shrivels bean bushels. Soybean Digest; May-June 44-45pp, USA

Mishra,V and K.A. Cherkauer. 2010. Retrospective droughts in the crop growing season: Implications to corn and soybean yield in the Midwestern United States. Agricultural and Forest Meteorology, 150:1030-1045

Munier-Jolain, N.G and B. Ney. 1998. Seed growth rate in grain legumes II. Seed growth rate depends on cotyledon cell number. J. Exp. Bot. 49:1971-1976

Ohyama, T., R. Minagawa, S. Ishikawa, M. Yamamoto, N. Van Phi Hung, N. Ohtake, K. Sueyoshi, T. Sato, Y. Nagumo, and Y. Takahasi. 2013. Soybean seed production and nitrogen nutrition. http:/dx.doi.org/10.5772/45867

Patel, D. and K.A. Franklin. 2009. Temperature-regulation of plant architecture. Plant Signaling and Behavior Journal, 4: 577-579

Prasad, P.V.V., P.Q. Craufurd and R.J. Summerfield. 2000. Effect of high air and soil temperature on dry matter production, pod yield and yield components of Groundnut. Plant and Soil, 222:231-239

Puteh, A.B., M. ThuZar, M.M.S. Mondal, N.A.P.B. Abdullah and M.R.A. Halim. 2013. Soybean [*Glycine max* (L.)Merrill] seed yield response to high temperature stress during reproductive growth stages. Australian J. of Crop Science, **7**(10):1472-1479

Sadeghi, H., H.H.S. Abad, A. Hamidi, G.N. Mohammadi and H. Madani. 2014. Effect of planting management on soybean agronomic traits. Int. Journal of Biosciences, 4(5):85-91

Sadeghi, S.M and S.A. Niyaki. 2013. Effects of planting date and cultivar on the yield and yield components of soybean in North of Iran. ARPN journal of Agricultural and Biological Science, **8**(1):81-85

Sapra, V.T and A.O. Anaele. 1991. Screening of soybean genotypes for drought and heat tolerance. J. Agron. Crop Sci.167:96-102

Sionite, N., B.R and E.P. Flint. 1987. Interaction of temperature and CO_2 enrichment on soybean: growth and dry matter partitioning. Can. Journal Plant Science 67:59-67

Tacarindua, C.R.P., T. Shiraiwa, K. Homma and E. Kumagai. 2013. The effects of increased temperature on crop growth and yield of soybean grown in a temperature gradient chamber. Field Crops Research, 154:74-81

Thomas, J.F and C.D. Raper. 1978. Effect of day and night temperatures during floral induction on morphology of soybeans. Agronomy Journal, 70:893-898

Tubiello, F.N., J.F. Soussans and S.M. Howden. 2007. Crop and pasture response to climate change. Proc. Natl. Acad. Sci. 104: 19686-19690

Wheeler, T. and J. von Braun. 2013. Climate change impacts on global food security. Science 341: 508-513

Whigham, D.K and H.C. Minor. 1978. Agronomic characteristics and environmental stress. Soybean Agronomy, Physiology and Utilization. Geoffrey Norman, A. (Ed.), Academic Press, London. pp. 78-116, 247p.