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EFFECT OF HIGH AIR AND SOIL TEMPERATURE ON YIELD AND SOME YIELD COMPONENTS OF PEANUT (*Arachis hypogaea* L.)

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

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

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ABSTRACT

This research was conducted as a main crop in University of Cukurova, Faculty of Agriculture Field Crops Department in 2016 and 2017 growing seasons. The objective of this study was to determine the effect of high air and soil temperature on pod yield and some yield component of peanut (*Arachis hypogaea* L.) breeding lines in main crop growing season in Mediterranean region in Turkey. In this study, 22 peanut lines (F6 and F7) belonging to Brantley x Halisbey crossing and NC-7 variety (st) were used as a plant material. The experimental design was a Randomized Complete Block with three replications. The main yield component such as pod number, pod weight, 100-seed weight, and pod yield per hectare values of lines were investigated. The maximum air temperature data was recorded day by day during the growing period in both years and average daily maximum air temperatures were higher in 2017 than in 2016. When the pod yield compared in 2016 and 2017, it is found that the pod yield was lower (21.5%) in 2017 than in 2016. The high air and soil temperature was negatively affected the pod yield of peanut breeding lines. It was found that the breeding lines differ in their sensitivity to high temperatures.

Key words: Breeding lines, high temperature, peanut and pod yield

INTRODUCTION

The temperature is a critical factor that controls plant growth and development (Patel and Franklin, 2009). Heat stress is considered one of the main factors that negatively affect crop production. Rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum (IPCC, 2007). Cox (1979) and Hatfield and Prueger (2015) indicated that temperature is a primary factor determining the growth and development of plants. Warmer temperatures expected with climate change and the potential for more extreme temperature events will impact plant productivity. Pressman et al. (2002), McKeown et al. (2005), Sønsteby and Heide (2008) and Dufault et al. (2009) suggested that in annual specialty crops in which temperature is the major environmental factor affecting production with specific stresses, such as periods of hot days, overall growing season climate, minimum and maximum daily temperatures, and timing of stress in relationship to developmental stages having the greatest effect. Marshall (1982) and Paulsen (1994) indicated that high temperature stress is one of the least well understood of all the abiotic adversities that affects crops and is one of the major uncontrollable factors affecting plant growth, development and productivity.

Ishag (2000) and Kaba et al. (2014) reported that peanut plant has indeterminate growth habit. For this reason, flowering and pod formation continue long time during the growing period. The peanut plants produced many flowers but, only 15-20% of flowers produce mature pods (Lim and Hamdan, 1984). Ketring et al. (1982) indicated that temperature plays a critical role in the growth and development of peanut plants and it appears that optima are different depending on the phase (reproductive or vegetative) of development.

Prasad et al. (2000) reported that peanut plants are susceptible to both high air and soil temperature due to their aerial flowering and subterranean fruiting habit, respectively. Peanut plants produce their pods under the soil. For the peanut crop with its subterranean fruiting habit, soil temperature could have a major influence on reproductive growth and development. It is evident that extremes of soil temperature limit reproductive growth and yield of peanut (Ono, 1979 and Ong, 1986). Awal and Ikeda (2002) and Prasad et al. (2006) reported that base temperature for germination of peanut is approximately 10ºC and the optimum temperature for emergence is between 25-30ºC. Ono et al. (1974), Ono (1979) and Dreyer et al. (1981) reported that air and soil temperature both are important factors to determine the yield of peanut as peanut flowers develop aerially and pods in the soil.

The optimum soil temperature range for pod formation and development is between 31ºC and 33ºC and soil temperatures above 33ºC significantly reduced the number of mature pod and seed yields.

Ketring (1984) and Prasad et al. (1999a) indicated that the optimum mean air temperature for vegetative growth of peanut seemed to range between 25 and 30ºC while that for reproductive processes ranged between 20 and 25ºC. Day temperatures above 35ºC during the reproductive phase reduce fruit-set and consequently the number of pod and ultimately seed yields. Cox (1979), Ketring (1984) and Ong (1984) reported that increasing daytime temperature from 26-30ºC to 34-36ºC significantly reduced the number of subterranean pegs and pods, seed size on seed yield by 30-50%. Prasad et al. (2000) investigated that the effects of daytime soil and air temperature of 28ºC and 38ºC, from start of flowering to maturity and reported 50% reduction in pod yield at high temperatures. Tai and Hammons (1978) and Wynne and Isleib (1978) reported that the evaluation of peanut cultivars for genotype x environment interaction on yield and yield components seems to indicate only minor effects of genotype x location and genotype x year interactions, but there were relatively large genotype and genotype x location x year interactions. Arioglu and Ersoy (1987) and Onat et al. (2017) findings showed that the average yield reduction was 19.9% and 29.5%, respectively in soybean varieties due to high temperature and the response against to high temperature of the soybean varieties were different.

The expected changes in temperature over the next 30-50 years are predicted to be in the range of 2-3°C. In most regions this global warming will negatively impact plant growth and development. As a consequence, the yields of a variety of important crops 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 (IPCC, 2007 and Anonymous, 2012). Breeding of peanut varieties tolerant to heat stress is getting more important to obtain high yield in peanut farming.

The air temperature can be varied during the growing season year by year in this region. The agronomic characteristic and pod yield of peanut varies depending on growing conditions and varieties. The yield components of peanut are influenced by air temperature and the high air and soil temperature negatively effects on pod yield. Peanut varieties differ in their sensitivity to high temperatures. The objective of this study was to determine the effect of high air and soil temperature on pod yield and some yield component of peanut breeding lines in main crop growing season in Mediterranean region in Turkey.

MATERIALS AND METHODS

Experimental site and plant materials

This experiment was conducted in 2016 and 2017 at Research Farm of Cukurova University (Southern Turkey, 36º59ˡ N, 35º18¹ E; 23 elevation) as a main crop. 22 advanced (F6 and F7) peanut breeding lines (Brantley x Halisbey) and NC-7 variety (st) were used as a plant material in this research.

The soil texture was clay loam. The soil tests indicated that pH of 7.5 with high concentrations of K_2O and low concentrations of P_2O_5. In addition, the organic matter and nitrogen content of the soil were very low. The lime content was 20.5% in the upper layers with increased levels in lower layers in both years.

The climate data during the 2016 and 2017 growing period in experimental sites were given in Table 1.

Table 1. Temperatures, relative humidity, precipitation and 10 cm top soil temperature of the experimental site during the 2016-2017 growing period (Anonymous, 2017a)

Months	Min. temp. (ºC)		Max. temp. (ºC)		Average temp. (ºC)		*Relative humidity (%)		*Precipitation (mm)		*10 cm Soil temp. (ºC)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
April	11.6	10.6	27.4	26.1	20.0	15.4	59.2	60.7	1.8	65.9	20.5	19.7
May	14.2	14.7	28.4	29.5	21.3	22.5	69.3	68.8	87.9	45.9	23.9	23.7
June	20.5	21.3	33.3	34.9	26.9	27.2	63.8	69.1	45.6	17.3	29.8	29.8
July	23.2	24.4	35.7	37.9	29.5	31.4	67.5	64.4	0.2	-	34.8	36.5
August	23.7	24.9	37.5	38.4	30.6	31.9	67.4	67.5	-	-	34.8	36.5
September	19.8	20.6	34.7	34.9	27.4	27.8	59.9	66.1	34.8	11.2	29.0	32.3

*These values belongs to Adana province

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 2016 and 2017 years were significant for the air temperature. The air temperature was higher in 2017 than in 2016 during the growing period. The total rainfall was 170.3 mm and 140.3 mm during the growing periods in 2016 and 2017, respectively. The average relative humidity was ranged from 59.2% to 69.3% in 2016 and 60.7% to 69.1% in 2017 (Table 1). 10 cm soil temperature is very important climate data for the peanut production. The peanut pods form in the level of the soil and the temperature effects on pod formation and growth. The soil temperature was higher in 2017 than in 2016.

The average maximum temperature data during the growing period (June, July and August months) in 2016 and 2017 as a five days interval were given in Table 2 and Figure 1. As it can be seen in Table 2, the maximum air temperature was higher in 2017 than 2016 during the flowering, pod formation and pod filling stages of the peanut lines. In these stages, the maximum air temperature above 42-43ºC was observed during daytime at the experimental site and the growth and development of peanut plants were negatively affected.

Table 2. The average maximum air temperature data (five days interval) during the 2016-2017 growing period at the experimental area (Anonymous, 2017b)

Five days interval	June (ºC)		July (ºC)		August (ºC)	
	2016	2017	2016	2017	2016	2017
1-5	30.2	32.2	33.8	42.4	38.6	38.8
6-10	30.2	33.6	35.6	35.2	38.0	38.8
11-15	31.2	34.2	37.0	37.6	36.8	38.2
16-20	36.5	34.8	35.4	37.2	38.0	38.2
21-25	38.0	38.8	35.4	37.8	38.4	38.2
26-31	33.5	35.8	37.0	37.3	35.5	38.0
Average	33.3	34.9	35.7	37.9	37.5	38.4
Difference 2016-2017	1.6		2.2		0.9	

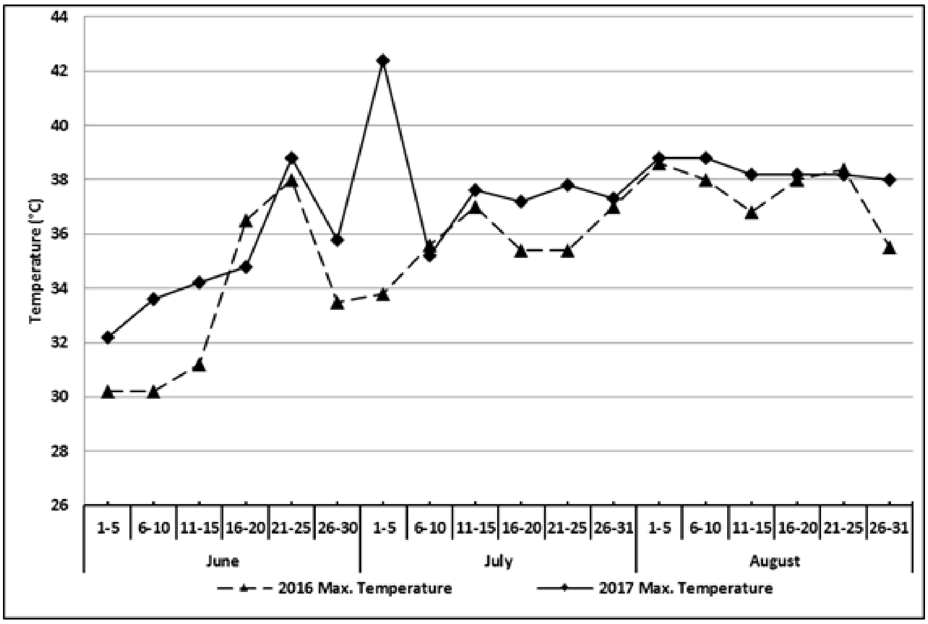

Figure 1.The maximum air temperature (five days interval) during the 2016 and 2017 growing period at the experimental area (Anonymous, 2017)

Method

The experiment was designed at Randomized Complete Block with three replications. Each plot consisted of 4 rows 5.0 m long and 70 cm apart. The seeds were sown by hand on 11 April 2016 and 10 April 2017 with 70 x 15 cm distance. A composed fertilizer of Di-ammonium phosphate (18% N and 46% P_2O_5) at 250 kgha^{-1} level was applied and incorporated to soil before planting. Ammonium nitrate (33%N) at the rates of 200 kgha^{-1} was applied two times; before first (beginning of flowering) and second (pod formation) irrigation. During the growing period, recommended pesticides and fungicides were applied to control insects and diseases. During the growing period, other standard cultural practices were done. The plants were harvested by hand at the 20th of September 2016 and 15th of September 2017.

Per plant data were measured from the 20 plants that were randomly selected from the central rows of each plot and then harvested by hand. Pod number and pod weight per plant, 100-seed weight and pod yield per hectare values of lines were investigated (Gulluoglu, 2011). The pod yield reduction percentage (%) was calculated by (2016 year data - 2017 year data/2016 year data) x 100.

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

RESULTS AND DISCUSSION

Pod number per plant

Some agronomic characteristics and pod yield of peanut varies depending on growing conditions and varieties. These characteristic (yield components) of peanut varieties are influenced by air and soil temperature during the growing season and the high temperature negatively effects on pod yield. Peanut varieties differ in their sensitivity to high temperatures.

The data belonging to yield components such as pod number and pod weight per plant and 100-seed weight of peanut breeding lines in 2016 and 2017 has been presented in Table 3.

Table 3. The pod number and pod weight per plant and 100-seed weight of peanut breeding lines in 2016 and 2017

Breeding Lines (A)	Pod number (pods plant^{-1})		Pod weight per plant (g plant^{-1})		100-seed weight (g)	
	Years (B)		Years (B)		Years (B)	
	2016	2017	2016	2017	2016	2017
YF-1	31.1	28.6	73.3	69.5	124.8	121.1
YF-2	30.0	30.2	77.8	68.2	130.8	118.3
YF-3	27.4	27.8	80.3	63.2	147.2	133.8
YF-4	31.6	28.6	79.8	67.9	118.4	113.1
YF-5	28.5	27.5	81.5	66.9	141.7	122.8
YF-6	31.3	27.6	91.2	60.6	130.5	119.6
YF-7	31.0	30.4	81.8	78.1	146.8	133.7
YF-8	31.6	29.2	82.0	65.9	122.0	110.6
YF-9	30.9	25.6	85.3	58.2	130.7	119.8
YF-10	27.7	32.4	83.5	76.9	148.0	130.9
YF-11	30.3	26.0	85.2	67.4	143.0	135.4
YF-12	31.0	27.5	83.3	67.5	139.9	123.5
YF-13	30.8	29.2	82.3	70.2	128.9	116.2
YF-14	29.4	30.6	82.7	72.8	134.8	126.8
YF-15	33.4	28.1	81.7	76.4	148.6	132.8
YF-16	24.9	22.7	73.5	55.9	140.6	128.0
YF-17	26.9	28.6	74.5	73.4	134.5	123.1
YF-18	30.5	29.0	83.7	71.2	132.6	124.3
YF-19	34.9	29.5	87.2	74.8	118.0	114.0
YF-20	30.2	29.6	80.8	76.4	136.9	129.4
YF-21	29.6	30.8	77.7	68.9	133.5	114.7
YF-22	31.7	25.9	85.5	64.4	133.3	128.4
NC-7 (st)	27.0	17.5	50.3	40.9	118.4	113,4
Average	30.0	27.4	77.8	65.5	133.0	123.3
Reduction*	9%		16%		7%	
LSD (5%$_A$)	2.93	4.52	6.27	3.58	6.36	7.48
LSD (5%$_B$)	1.45		3.16		2.82	
LSD (5%$_{AxB}$)	3.23		7.25		6.86	

*Reduction (%) = (2016-2017/2016) x 100

The differences between the 2016 and 2017 for the pod number per plant were statistically significant. While the average pod number per plant of the breeding lines was 30.0 pods plant^{-1} in 2016, it was decreased to 27.4 pods plant^{-1} in 2017. The average pod number of the lines was 9% lower in 2017 compared to 2016. The pods number per plant was affected by the environment condition such as air and soil temperature. High temperature was negatively affects on pod number per plant of peanut varieties. The average maximum air and 10 cm soil temperature data during the June, July and August were higher in 2017 (Table 1 and 2). For this reason, pod number per plant of the breeding lines was lower in 2017 than 2016.

Ishag (2000) and Kaba et al. (2014) reported that peanut plant has indeterminate growth habit. For this reason, flowering and pod formation continues long time during the growing period. The peanut plants produced many flowers but, only 15-20% of flowers produce mature pods (Lim and Hamdan, 1984). The air and soil temperature affects on flowering, pegging and podding in peanut plants.

Prasad et al. (1999a) reported that the threshold day temperature for pollen production and viability was 34ºC and there were strong negative linear relations between both pollen production and pollen viability and accumulated temperature >34ºC. They suggested that day temperature >34ºC decreased fruit-set and resulted in fewer numbers of pod. Decreased fruit-set at high temperatures was mainly due to poor pollen viability, reduced pollen production and poor pollen tube growth, all of which lead to poor fertilization of flowers.

Ono et al. (1974), Ono (1979) and Dreyer et al. (1981) reported that air and soil temperature both are important factors to determine the yield of peanut as peanut flowers develop aerially and pods in the soil. The optimum soil temperature range for pod formation and development is between 31ºC and 33ºC and soil temperatures above 33ºC significantly reduced the number of mature pod and seed yields. Day temperatures above 35ºC during the reproductive phase reduce fruit-set, and consequently the number of pod and ultimately seed yields (Ketring, 1984 and Prasad et al., 1999b). Talwar et al. (1999) indicated that increase in peg numbers of peanut cultivars when temperature was increased from 25/25ºC to 35/30ºC, but the pod numbers decreased with the increase in temperature. Prasad et al. (2000) suggested that the high soil temperature significantly reduced flower production, the proportion of pegs forming pods and 100-seed weight.

As it can be seen in Table 3, the differences between the breeding lines were statistically significant for the pod number per plant in both years. The pod number of breeding lines varied between 24.9-34.9 pods plant^{-1} in 2016 and between 22.7-32.4 pods plant^{-1} in 2017. The pod number per plant of the lines was different in 2016 and 2017. The pod number of the breeding lines was higher in 2016 than in 2017. The highest pod number reduction was obtained from YF-22 (18.3%) and YF-9 (17.2%) peanut breeding lines. The reduction of pod number was lower in breeding lines compared to NC-7 (35.2%) variety. The yield components of peanut are influenced by temperature and the high temperature negatively effects on pod number per plant. Peanut varieties differ in their sensitivity to high temperatures. Ketring et al. (1982) indicated that temperature plays a critical role in the growth and development of peanut plants and it appears that optima are different depending on the phase (reproductive or vegetative) of development.

Between the lines and year interaction on pod number per plant was statistically significant (Table 3). Pod number of the breeding lines was different in 2016 and 2017. The highest pod number per plant was obtained from YF-19 (34.9 pods plant^{-1}) in 2016 and YF-10 (32.4 pods plant^{-1}) in 2017. Tai and Hammons (1978) and Wynne and Isleib (1978) reported that the evaluation of peanut cultivars for genotype x environment interaction on yield and yield components seems to indicate only minor effects of genotype x location and genotype x year interactions, but there were relatively large genotype and genotype x location x year interactions. Since temperature is critical for peanut plant growth and development, attempts have been made to determine temperature requirements of peanut cultivars at different stages of their development (Ketring et al., 1982).

Pod weight per plant

As it can be seen in Table 3, the differences between the years for the pod weight per plant were statistically significant. The pod weight per plant was 77.8 g plant^{-1} in 2016 and it was decreased to 40.9 g plant^{-1} in 2017. The pod weight reduction per plant was calculated 12.3 g plant^{-1} (16%) in 2017.

Ketring et al. (1982) indicated that temperature plays a critical role in the growth and development of peanut plants and it appears that optima are different depending on the phase (reproductive or vegetative) of development. The optimum soil temperature for individual pod growth rate is between 31ºC and 33ºC (Ono et al., 1974 and Dreyer et al., 1981). Prasad et al. (2000) investigated the effects of daytime soil and air temperature of 28 and 38ºC, from start of flowering to maturity and they reported that 50% reduction in pod yield at high temperatures. Cox (1979) reported that air temperature above 26/22ºC, reduced the pod weight per plant. Ketring (1984) reported that 25 and 20% reduction in mature seed weight at 35ºC compared to 30ºC for Tamnut 74 and for Starr peanut cultivars, respectively. Prasad et al. (2003) reported that the seed yield decreased progressively by 14%, 59% and 90% as temperature increased from 32/22ºC to 36/26, 40/30 and 44/34ºC, respectively.

The differences between the breeding lines were statistically significant for the pod weight per plant in both years. The pod weight per plant of breeding lines varied between 73.3-91.2 g plant^{-1} in 2016 and between 55.9-78.1 g plant^{-1} in 2017. The yield components of peanut are influenced by air temperature and the high air and soil temperature negatively effects on pod yield. Peanut varieties differ in their sensitivity to high temperatures. The pod weight reduction was found the highest in YF-6 (30.6%) and YF-9 (27.1%) lines.

Virginia market type peanut varieties had larger pods and seeds compared to other market types. The yield and some agronomic characteristics of peanut are influenced by genotype and environmental conditions. Some researcher reported that the pod weight per plant in Virginia market type peanut varieties was varied between 37.28-93.67 g plant^{-1} depending on variety and management (Gulluoglu, 2011; Gulluoglu et al., 2016; Arioglu et al., 2016; Gulluoglu et al., 2017 and Kurt et al., 2017).

Between the lines and year interaction on pod weight per plant was statistically significant (Table 3). Pod weight of the breeding lines was different in 2016 and 2017. The highest pod number per plant was obtained from YF-6 (91.2 g plant^{-1}) in 2016 and YF-7 (78.1 g plant^{-1}) in 2017. Tai and Hammons (1978) and Wynne and Isleib (1978) reported that the evaluation of peanut cultivars for genotype x environment interaction on yield and yield components seems to indicate only minor effects of genotype x location and genotype x year interactions, but there were relatively large genotype and genotype x location x year interactions. These findings are supported by the Cox (1979), Golombek and Johansen (1997), Prasad et al. (1999a) and Prasad et al. (2000).

100-seed weight

The average 100-seed weight of breeding lines was 133.0 g in 2016 and 123.3 g in 2017 (Table 3). The differences between the 2016 and 2017 for the 100-seed weight were statistically significant. The average 100-seed weight of the lines was 7% lower (9.7 g) in 2017 compared to 2016. The high temperature during the pod filling period was negatively affects on 100-seed weight of peanut varieties. As it can be seen in Table 1 and 2, the air and soil temperature was the higher in 2017 than in 2016. This high temperature was negatively affected the daily production and the seed size has been lower.

Cox (1979) and Hatfield and Prueger (2015) indicated that temperature is a primary factor determining the growth and development of plants. Prasad et al. (2000) reported that peanut plants are susceptible to both high air and soil temperature due to their aerial flowering and subterranean fruiting habit, respectively. Peanut plants produce their pods under the soil. For the peanut crop with its subterranean fruiting habit, soil temperature could have a major influence on reproductive growth and development of pods. It is evident that extremes of soil temperature limit reproductive growth and yield of peanut (Ono, 1979 and Ong, 1986).

Williams et al. (1975a) indicated that the largest number of pods and seed were produced at the intermediate temperature (27.0ºC mean daily max. and 14.5ºC mean daily min.), while the largest mean seed weight occurs at the coolest temperatures. Cox (1979), Ketring (1984) and Ong (1984) reported that increasing daytime temperature from 26-30ºC to 34-36ºC significantly reduced the number of subterranean pegs and pods, seed size on seed yield by 30-50%. Ketring (1984) and Prasad et al. (1999b) indicated that the optimum mean air temperature for vegetative growth of peanut seemed to range between 25 and 30ºC. Day temperatures above 35ºC during the reproductive phase reduce fruit-set and consequently the number of pod and ultimately seed yields. Prasad et al. (2000) reported that high soil temperature significantly reduced pod formation and 100-seed weight. The combined treatment of high soil and air temperatures reduced fruit-set and pod weight by 58% and 57%.

The differences between the lines for the 100-seed weight were statistically significant in both years. The 100-seed weight reduction of the breeding lines varied between 3.7 g and 18.9 g. The average 100-seed weight reduction of the lines was calculated about 7.3%. The 100-seed weight reduction was the highest in YF-21 (14.1%) and YF-5 (13.3%) and the lowest in YF-1 (3.0%) and YF-22 (3.7%) lines. All of the breeding lines were negatively affected by the high air and soil temperature. Year x breeding lines interaction on 100-seed weight of peanut was statistically significant. The highest 100-seed weight was obtained from YF-15 (148.6 g) and YF-11 (2135.4 g) in 2016 and 2017, respectively. Virginia market type peanut varieties had larger pods and seeds compared to other market types. Some researchers reported that the 100-seed weight of the peanut varieties varies from 112.52 to 138.05 g (Gulluoglu et al., 2016; Arioglu et al., 2016; Gulluoglu et al., 2017). Similar results were reported by some other researchers (Cox, 1979; Ketring, 1984; Golombeck and Johansen, 1997; Prasad et al., 2000; Caliskan et al., 2008 and Canavar and Kaynak, 2008).

Pod yield per hectare

The data belonging to pod yield of breeding lines in 2016 and 2017, and yield reduction in 2017 has been presented in Table 4.

The differences between the 2016 and 2017 for the pod yield per hectare were statistically significant. While the average pod yield of the breeding lines was 7926 $kgha^{-1}$ in 2016, it was decreased to 6222 $kgha^{-1}$ in 2017. The average yield of the lines was 21.5% lower in 2017 compared to 2016. The pod yield was affected by the environment condition such as air and soil temperature. High temperature was negatively affects on pod yield of peanut lines.

As it can be seen in Table 1, the soil temperature in July and August has been higher than 35ºC. Ono et al. (1974), Ono (1979) and Dreyer et al. (1981) reported that the optimum soil temperature range for pod formation and development is between 31ºC and 33ºC and soil temperatures above 33ºC significantly reduced the number of mature pod and seed yield of peanut. The average maximum air and 10 cm soil temperature data during the June, July and August were higher in 2017 than in 2016 (Table 1). For this reason, pod yield of the breeding lines was lower in 2017.

The average maximum temperature data during the growing period (June, July and August months) in 2016 and 2017 as a five days interval were presented in Table 2. As it can be seen in Table 2, the maximum air temperature was higher in 2017 than 2016 during the flowering, pod formation and pod filling stages of the peanut lines. In these stages, the maximum air temperature was observed above on 42-43ºC in a day in Adana region and the growth and development of peanut plants were negatively affected.

Ketring et al. (1982) indicated that air temperature plays a critical role in the growth and development of peanut plants and it appears that optima are different depending on the phase (reproductive or vegetative) of development. Ketring (1984) and Prasad et al. (1999b) indicated that the optimum mean air temperature for vegetative growth of peanut seemed to range between 25 and 30ºC while that for reproductive processes ranged between 20 and 25ºC. Day temperatures above 35ºC during the reproductive phase reduce fruit-set and consequently the number of pod and ultimately seed yields.

Table 4. The pod yield of peanut breeding lines (F6 and F7) in 2016 and 2017 and the comparison of the years for yield potential

Breeding Lines (A)	Pod yield (kg ha^{-1}) Years (B)		Yield reduction in 2017 (kg ha^{-1})	Yield reduction in 2017 (%)
	2016	2017		
YF-1	7147	6599	548	7.7
YF-2	8643	6482	2161	25.0
YF-3	8531	6004	2527	29.6
YF-4	8627	6447	2180	25.3
YF-5	9025	6356	2669	29.6
YF-6	8165	5754	2411	29.5
YF-7	8277	7420	857	10.4
YF-8	7942	6257	1685	18.8
YF-9	8420	5532	2888	34.3
YF-10	7608	7306	302	4.0
YF-11	8404	6400	2004	23.9
YF-12	9073	6416	2657	29.3
YF-13	7592	6666	926	12.2
YF-14	8770	6913	1857	21.2
YF-15	9232	7260	1972	21.4
YF-16	6064	5307	757	12.5
YF-17	8213	6973	1240	15.1
YF-18	8675	6767	1908	22.0
YF-19	8834	7108	1726	19.5
YF-20	7767	7261	506	6.5
YF-21	7242	6546	696	9.6
YF-22	8643	6118	2525	29.2
NC-7	5523	3885	1638	29.7
Average	7926	6222	1704	21.5
LSD (5%)	733.0	787.0		
LSD (5%$_{B}$)	1185.1			
LSD (5%$_{AxB}$)	1327.1			

Cox (1979), Ketring (1984) and Ong (1984) reported that increasing daytime temperature from 26-30ºC to 34-36ºC significantly reduced the number of subterranean pegs and pods, seed size on seed yield by 30-50%. Ketring (1984) reported a 25 and 20% reduction in mature seed weight at 35ºC compared to 30ºC for Tamnut 74 and for Starr cultivars, respectively. Prasad et al. 2003 reported that the seed yield decreased progressively by 14%, 59% and 90% as temperature increased from 32/22ºC to 36/26, 40/30 and 44/34ºC, respectively. As it was explained above that many researchers have found similar results for the yield reduction.

It can be seen in Table 4, the pod yield of the breeding lines varied between 7147-9232 kgha^{-1} in 2016 and 5307-7306 kgha^{-1} in 2017 (Table 4). The differences between the lines for the pod yield per hectare were statistically significant. The yield reduction of the breeding lines was different and the pod yield reduction varied between 4.0-34.3%. The highest yield reduction was obtained from YF-9 (34.3%) and the lowest from YF-10 (4.0%) breeding lines. The agronomic characteristic and pod yield of peanut varies depending on growing conditions and varieties. The yield components of peanut are influenced by temperature and the high air and soil temperature negatively effects on pod yield. Peanut varieties differ in their sensitivity to high temperatures

Ono et al. (1974) found that the greatest fruiting percentage and the largest individual pods of peanut variety were formed at a fruiting zone temperature of 31 to 33ºC. Ketring et al. (1982) reported that the temperature is critical for peanut plant growth and development attempts have been made to determine temperature requirements of peanut cultivars at different stages of their development. Ketring (1984) reported indicated that 25% and 20% reduction in mature seed weight at 35ºC compared to 30ºC for Tamnut 74 and for Starr cultivars, respectively.

The interaction between the breeding lines and years was statistically significant and it was shown in Figure 2. The pod yield of peanut varies depending on growing conditions and varieties. For this reason, Pod yield of the breeding lines was different in 2016 and 2017.

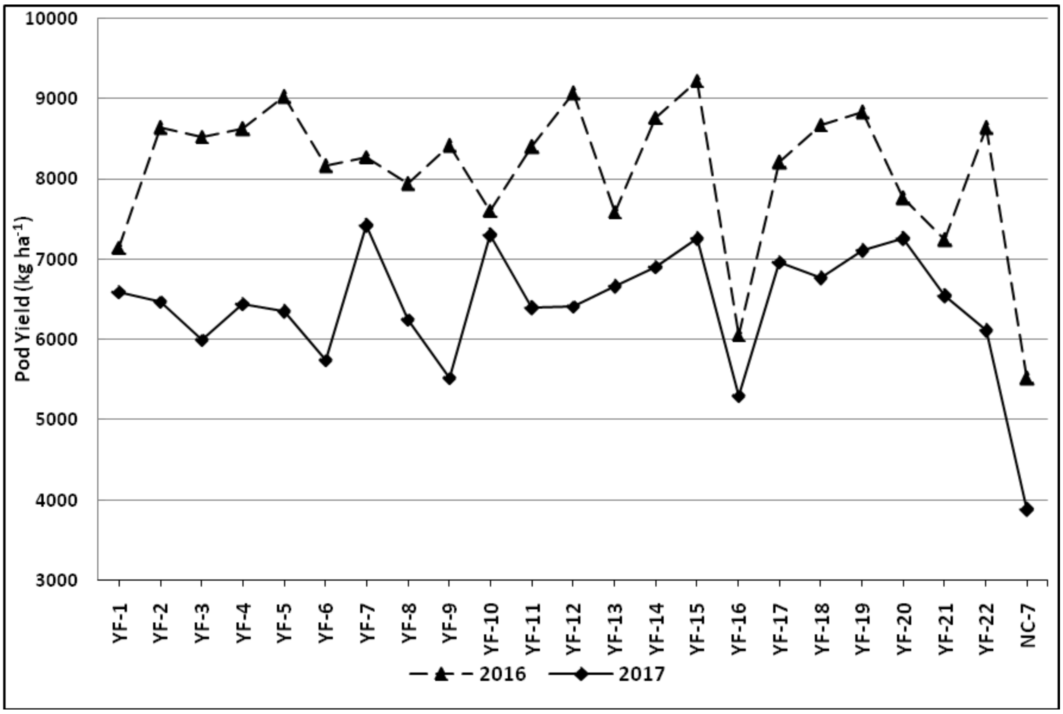

Figure 2. The seed yield of peanut breeding lines in 2016 and 2017

Tai and Hammons (1978) and Wynne and Isleib (1978) reported that the evaluation of peanut cultivars for genotype x environment interaction on yield and yield components seems to indicate only minor effects of genotype x location and genotype x year interactions, but there were relatively large genotype and genotype x location x year interactions. Yadava and Kumar (1978) reported that some genotypes, with respect to pod yield and seed weight are apparently more stable across environments than others. Williams et al. (1978) reported that the effect of weather and genotype x environment interactions on yield of peanut found that different components of the environment (temperature, radiation and water stress) have significant effects on yield only at specific phases of growth and development. For instance, maximum temperature was significantly related to yield at all growth phases.

CONCLUSION

The expected changes in temperature over the next 30-50 years are predicted to be in the range of 2-3°C. In most regions this global warming will negatively impact plant growth and development. As a consequence, the yields of a variety of important crops 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. The growth and development of peanut plant is affected by the environmental factors such as soil and air temperature.

The optimum soil temperature range for pod formation and development is between 31ºC and 33ºC and soil temperatures above 33ºC significantly reduced the number of mature pod and seed yield. The optimum mean air temperature for vegetative growth of peanut seemed to range between 25 and 30ºC while that for reproductive processes ranged between 20 and 25ºC. Day temperature above 35ºC during the reproductive phase reduces fruit-set and consequently the number of pod and ultimately seed yield.

The temperature is a critical factor that controls plant growth and development. High air temperature during the flowering, pod formation and pod filling may also have detrimental effects on peanut growth, development and pod yield. Maximum temperature above 35ºC cause heat stress, which has harmful effect on pod formation and seed development of peanut. The pod yield was reduced about 21.5% in 2017 compared to 2016 due to air temperature exceeded to 35ºC during the growing period. Breeding of peanut varieties tolerant to heat stress is getting more important to obtain high yield in peanut farming at the future.

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