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Full Length Research Paper

Growing degree day and sunshine radiation effects on peanut pod yield and growth

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Growth and development of peanut (*Arachis hypogaea* L.) are affected by different uncontrollable environmental conditions. The objective of this work was to investigate the effect of different planting dates, thermal temperatures (growing degree days, GDD) and daily sunshine duration on morphological and agronomic traits of three commercial peanut cultivars (Gazipasa, Florispan, and NC-7) and a local cultivar. Experiments were carried out at four different planting dates in the Aegean region of Turkey during 2004 and 2005. The experimental design was a split-plot design with three replications. Planting date affected emergence, beginning of flowering, beginning gynophore formation, primary branch number, primary branch length, days to maturity and pod yield. Pod yield was significantly correlated with the primary branch length, GDD, sunshine radiation during gynophore formation, time to maturity and days from emergence to flowering. The Aegean climate has a long growing period and is a suitable environment for peanut growth. Peanut cultivars are exposed to suitable temperature regimes and sunshine during the vegetative and reproductive growth stages in the early and normal planting dates in the Aegean region. On the contrary, the peanut cultivars planted in the late planting stage were negatively affected in the vegetative and reproductive growth stages. The peanut cultivars were stressed in the late planting because of the shortened growth period and unsuitable growing conditions. Early planting, ranging from May 5 – 20, provided the essential 1450 and 1600°C GDD and 893 – 978 h of sunshine during the reproductive stage for peanuts grown in the Aegean region. The best suitable planting date was May 20 and Gazipaşa and the Local cultivar were the most promising cultivars for conditions typical of the Aegean region.

Key words: Peanut, growing degree days, morphological and agronomic traits.

INTRODUCTION

Peanut is an important food crop because of its high protein and oil content. Peanut seeds are used as a source of cooking oil and in confectionary products for human consumption. The annual world peanut production is around 35.9 million tons from 25.2 million ha of production area (FAO, 2005). The pod yield of peanuts in Aydın is about 3.6 t ha^{-1} (TUIK, 2005), which is higher than the average yield for the rest of the world (1.36 t ha^{-1}) and for Turkey (2.83 t ha^{-1}) (FAO, 2005). Climatatic conditions are the major factor in terms of crop pattern.

The flowering and maturity of peanuts is affected by certain climatic conditions and also, if the relationship between the beginning of the first flowering and maturity is known, the time of harvest can be estimated for healthy crops (Corlett et al., 1992; Önemli, 2005). Duncan et al. (1978) and Williams (2000) suggested that three physiological processes best explain the variation in peanut yields. They are (i) partitioning of the assimilate between the reproductive and vegetative structures, (ii) the length of the pod filling period and (iii) the rate of the pod establishment. Growing degree day units are often used in agronomy to estimate or predict the lengths of the different phases of development. The usefulness of GDD is based on the premise that the higher the temperature, the faster plants develop (Yoldaş and Eşiyok, 2005). GDD are frequently used to describe the timing of biological processes (Leong and Ong, 1983; Default,

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Abbreviations: GDD, growing degree days; **LSD,** least significant difference.

Table 1. The soil characteristics of the experimental area.

Depth (cm)	Texture	pH	Organic matter (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
0 – 30	Clay	8.1	1.50	45	957.5

1997; McMaster and Wilhelm, 1997; Black and Ong, 2000; Butler et al., 2002; Calıskan et al., 2008a, b). Peanuts grown in the southern Aegean region require 1450 and 1550 GDD above 10 and 13.5°C, respectively (Craufurd et al., 2002). The beginning of the peanut flowering period was reported to occur following accumulation of 313 and 360 GDD (Ketring and Wheless, 1989). Prasad et al. (2000) demonstrated that the flowering period for peanut was affected negatively by high temperatures. Planting dates can be timed to minimize the damage from frost and heat. Peanut pod yield and quality was lower for early planted peanut compared with later planted peanut because the late planting period had the greatest chance of low temperatures, rain and frost during pod filling and harvest (Boote et al., 1989; Mills, 2004; Baldwin, 2005). However, some early studies did not find a correlation between early maturity and pod yield (Frimpong, 2004).

Pod yield is a very complex characteristic that is affected by interactions among different phenology periods (e.g., emergence, flowering, maturity, etc) during the vegetative stage (Arkebauer et al., 1994). And also sunshine radiation is the primary energy source, which is one of most important processes for the soil and the plants, such as evapotranspiration, biomass partitioning, stomatal conductance, carbon exchange and water use efficiency (Leong and Ong, 1983; Figuerola and Berlinger, 2006; Brown and Halweil, 1998; Williams, 2000; Kar, 2005). Peanuts can be planted throughout a considerable part of the year with reasonable very good yields. For a better understanding of climatic and cultural effects on peanut pod yield, intensive research that evaluates different geographic locations, sowing dates and genotypes are needed (Awal and İkeda, 2002). Chapin and Thomas (2004) demonstrated that when peanut was planted on May 15, emergence occurred on May 22 and the seedling stage occurred between May 22 and July 12. Furthermore, the beginning of the flowering stage occurred at 35 days and pod formation occurred 45 days after planting. The base temperature of approximately 10°C is suitable for germination of peanuts, while the optimum temperature for emergence is between 25 - 30°C (Awal and Ikeda, 2002; Prasad et al., 2006). These results are similar to results from other groups (Ramanatha and Murth, 1994; Ramadoss and Myers, 2004). Rehman et al. (2001) and Awal and Ikeda (2003) observed that the primary branch number and the primary branch length were significantly correlated with the pod yield, which is affected by different climate and field conditions. Baydar (1992) demonstrated that the primary branch number of six different Virginia peanut cultivars varied between 6.3-10.4. Furthermore, they showed that the primary branch number plays an important role for pod yield.

The present study examined the GDD and sunshine radiation necessary for peanut maturity. The GDD and sunshine radiation during the different stages of peanut growth were studied to determine the effects of different planting dates. The most suitable planting dates to minimize climatic stresses and to achieve a maximum yield were studied.

MATERIALS AND METHODS

The field trials were conducted during the 2004 and 2005 growing seasons at Aydın, Turkey (37° 39′ E, 27° 52′ N in the West Aegean Region of Turkey). Typical Mediterranean climatic conditions are dominant in Aydın. The soils of the experimental fields were clay in texture and alkaline in reaction (Table 1). The experiments used a split-plot design with three replications. The planting dates (May 5 - 7, May 20 - 21, June 5 - 6 and June 18 - 20) were the main plots and cultivars were the subplots (Gazipasa, Florispan, NC-7 and Local cultivar). Each plot consisted of two rows of 8 m in length with an inter-row spacing of 70 cm and intra-row spacing of 20 cm. In this study, 109 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} were provided with the application of 330 kg ha^{-1} of (15-15-15) composted fertilizer prior to planting. At blooming or at the second irrigation, 60 kg ha^{-1} of Ammonium nitrate (33%) was added. Furrow irrigation was applied and hand weeding was performed throughout the growing period when necessary.

Four peanut cultivars, [Gazipasa (late maturity), Florispan (early maturity), NC-7 (late maturity) and the Local cultivar (late maturity)], were grown during the two seasons. Planting treatments were separated by 14-d intervals. Planting dates for 2004 were May 7, May 21, June 5 and June 18. Plantings in 2005 were made in May 5, May 20, June 6 and June 20. All peanut cultivars during each planting were harvested at the end of September, October, November and December, when Aydın had rainy and cold weather during both years. Each plot was mechanically dug, inverted and allowed to air-dry in the field for 7 - 13 days before harvest. The pods were mechanically combined (referred to as a combined yield) and the final combined yield was adjusted to a 10% moisture content. A 500 g sample of the pods was removed from two of the three replicates to determine the shelling percentages (Williams and Drexler, 1981; Holbrook et al., 1989). The primary branch length and primary branch number were determined from 10 randomly selected plants from each plot. The cultural practices used in these experiments are representative of the production practices in the Aegean region.

Phenological development was observed (dates of emergence, first flowering, first gynophore formation and maturation). The significance of the main effects and the interactions were determined at the 0.05 and 0.01 probability levels by the F-test. The means of the significant ($P \leq 0.05$) main effects and interactions were separated using the Fisher's Protected LSD test at P = 0.05. The data were statistically analyzed using a standard analysis of variance technique for a split-plot design using the TARIST user guide (Açıkgöz et al., 1994) and all data from this study were analyzed using the MIXED SAS procedure (SAS, 1999). Growing degree days were calculated as

Table 2. The climatic conditions during the 2004 and 2005 growing season and long-term mean (1940 - 2003) at Aydin, Turkey.

Month	Total rainfall (mm)			Mean temperature (℃)			Relative humidity (%)		
	2004	2005	1940 – 2003	2004	2005	1940 - 2003	2004	2005	1940 - 2003
May	6.6	61.0	43.8	20.3	21.7	20.2	55.7	66.0	59.0
June	0.6	7.9	14.4	26.4	25.3	24.9	47.9	59.2	51.0
July	-	9.3	3.5	29.0	29.2	27.4	47.0	59.8	48.0
August	-	12.6	2.2	27.3	28.2	26.6	50.7	62.8	51.0
September	7.3	0.5	38.1	23.9	23.5	22.5	53.8	64.1	56.0
October	0.2	39.2	47.5	20.6	17.2	17.8	60.8	70.1	64.0
November	74.7	160.4	67.1	13.6	12.7	13.0	67.3	73.8	72.0
December	73.3	38.2	110.5	9.5	9.8	9.4	75.5	75.3	73.1

Table 3. Results of analysis of variance for the various traits.

Variation source	df	Calculated means of square						
		E	FFD	FGD	PBN	PBL	M	PY
Year	1	3.010**	5.510**	168.010**	0.482*	5.368ns	225.094**	16276.042*
Planting date	3	15.872**	466.372**	709.733**	0.579**	428.700**	1783.260**	195801.944**
Year X Date	3	13.510**	30.872**	133.233**	0.344**	71.566**	231.288**	46077.375**
Cultivar	3	3.649**	268.705**	44.872**	51.649**	80.825**	5277.538**	59359.472**
Year X Cultivar	3	0.344**	4.705**	32.205**	1.169**	1.984ns	30.733**	5120.736**
Cultivar X Date	9	0.427**	1.640**	6.094**	0.387**	6.134**	8.788**	6283.028**
Year X Cultivar X Date	9	0.362**	3.288**	7.094**	0.520**	3.829**	20.705**	1662.292*

E: Emergence; FFD: the first beginning of flowering day number; FGD: the first beginning gynophore formation time; PBN: primary branch number; PBL: primary branch length; M: maturity; PY : pod yield.
**, *Significant at P≤ 0.01 and 0.05, respectively; ns – non significant.

$$GDD = [(T_{max} + T_{min})/2] - T_{base}$$

where T_{max} and T_{min} are the daily maximum and minimum air temperature, respectively, and the T_{base} is the base temperature of 10℃ (Leong and Ong, 1983 in controlled glasshouses in Leicester; Default, 1997 in South Carolina; Butler et al., 2002 in Texas; Calışkan et al., 2008 in Hatay).

The GDD from planting to the various growth stages mentioned above were calculated for each cultivar. Sunshine radiations were calculated for each cultivar by sun times in day collected during from planting to the various growth stages.

RESULTS

In general, the total rainfall for 2004 and 2005 was lower than the long-term mean during the peanut growing period in Aydın; however, the mean temperature for both years was higher than the long-term mean (Table 2). November rainfall in 2005 was greater than in 2004 and also above the average. Relative humidity is suitable for peanut growth in Aydın. Relative humidity in 2005 was higher than in 2004 which was near the average.

The results of the analysis of variance are presented in Table 3. The planting date x year and the cultivar interaction effects were significant for emergence, the beginning of flowering, time to gynophore formation, the primary branch number, the primary branch length, the days to maturity and the pod yield (Table 3). The overall main effects of planting date and cultivar showed significant differences (P ≤ 0.05) in terms of all of the observed traits (Tables 3 and 4).

All cultivars emerged between 6.1 and 11 days after planting (Table 4). The first emergence occurred for Florispan planted on June 20 of 2005; the last emergence occurred for the Local cultivar planted on May 7 in 2005. Days to first flowering for all cultivars occurred between 24 and 41.6 days during both years. Flower budding occurred the fastest with the Florispan as an early cultivar in the late planting date (June 20). The time to flower budding for all cultivars decreased with later planting dates in both years. The formation of the first flowers for all the cultivars was accelerated due to the temperature increase and the delay in planting in both years. The initiation of the first gynophore ranged between 36.6 and 57 days after planting among all the cultivars for each planting date during both years. These data indicate that the leaves and branches, which are extremely important for photosynthesis, were affected by the planting date. The primary branch number and the primary branch length of all cultivars were measured one day before harvest. The primary branch length of all cultivars was

Table 4. Effect of planting date on days to emergence, days to first flowering, days to first gynophore formation, days to maturity, primary branch number, primary branch length, and pod yield for four peanut cultivars in the West Aegean region of Turkey.

Cultivar	PD	E (day)		FFD(day)		FGD(day)		PBN (number)		PBL (cm)		M (day)		PY (kg ha^{-1})	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Gazipaşa	P1	9.0	9.8	41.0	42.0	57.0	56.6	9.16	8.46	41.2	36.10	169.0	158.0	5500	4640
	P2	9.0	10.8	35.0	37.0	47.3	52.6	8.36	8.06	38.8	40.40	157.6	151.0	6710	4983
	P3	9.3	9.0	33.3	32.0	48.0	45.0	8.93	8.00	34.5	36.23	148.0	136.0	4100	3823
	P4	8.0	7.1	32.6	30.3	45.3	36.6	8.76	7.53	27.5	31.53	143.3	133.6	3340	3933
Florispan	P1	8.0	9.1	33.3	33.6	53.3	44.6	6.53	5.16	44.8	41.36	132.0	130.0	3966	3466
	P2	8.0	9.8	27.6	28.6	43.6	49.6	5.30	5.76	41.4	40.40	122.6	122.0	4533	3933
	P3	8.6	9.0	25.3	26.0	44.0	40.0	5.03	5.36	38.2	38.20	118.0	127.6	3106	4100
	P4	8.6	6.1	26.3	24.0	41.3	37.0	5.13	5.53	31.3	36.16	113.0	115.0	2410	3016
NC-7	P1	9.0	9.8	40.3	41.0	56.6	52.6	7.90	8.53	37.9	36.96	169.0	155.0	5310	4663
	P2	9.3	10.6	33.3	38.0	47.6	50.3	7.90	8.50	38.7	36.80	159.6	151.0	6083	4500
	P3	9.3	8.8	32.3	31.0	48.0	41.3	8.40	8.46	36.3	36.70	146.0	145.0	3850	3830
	P4	9.3	7.6	32.0	29.6	45.3	40.0	8.90	8.23	24.5	31.93	138.6	145.0	3066	3850
Local	P1	9.0	9.6	39.3	41.6	55.3	54.6	8.60	8.83	39.1	35.36	168.0	154.0	6016	5050
	P2	8.6	11.0	32.0	38.0	46.0	51.5	8.33	8.50	39.4	38.10	156.6	148.3	6066	5150
	P3	9.0	8.6	32.0	31.0	47.0	42.5	8.63	8.46	35.3	36.60	145.0	144.6	3983	4000
	P4	8.3	7.6	29.3	29.6	44.0	39.6	8.00	8.23	27.6	31.16	136.6	145.0	2773	3710
LSD %5 (Y x C x PD)		0.730**	0.669**	0.278**	0.487**	1.184**	1.288**	0.603**	0.455**	1.980**	2.651**	13.910 **	12.611**	415.37**	373.38**

E: Emergence; FFD: the first flowering day; FGD: the first gynophore formation time; PBN: primary branch number; PBL: primary branch length; M: maturity; PY: pod yield.
P1: 5 - 7 May planting date; P2: 20 - 21 May planting date; P3: 5-6 June planting date; P4: 18 - 20 June planting date; Y: yield; C: cultivar; PD: planting date.

between 24.5 and 44.8 cm for the different planting dates. The primary branch length was the shortest, at 24.5 cm, with the NC-7 peanut cultivar during in 2004. The primary branch length was the longest for the Florispan peanut cultivar during in 2004. The primary branch length decreased together with the time to the first flower and time to gynophore formation when planting was delayed. The late planting date was inappropriate for the vegetative duration for all the cultivars, since all the cultivars were able to pass quickly through the flowering and generative stage with the increasing temperatures in late planting. The primary branch number was between 5 and 9 for all cases. The primary branch number was significantly lower for the Gazipaşa, NC-7 and the Local peanut cultivar when the planting date was delayed. The days to maturity of all the cultivars were significantly affected by the planting date. Generally M: The days to maturity, E: emergence, FFD: the first flowering day, and FGD: the first gynophore formation time significantly decreased when the planting date was delayed past May 5 for all cultivars in both years. A significant effect of the planting date was observed on the pod yield of the peanut cultivars. The pod yields of the cultivars, based on the different planting dates in 2004 and 2005, are illustrated in Table 4. The highest pod yield of the four cultivars was obtained from the planting on May 20 for both years (Table 4). In general, the pod yields of Gazipaşa, NC-7, Florispan and the Local peanut cultivar continuously decreased with delayed planting dates after May 20. The pod yields of the cultivars ranged between 2413 and 6710 kg ha^{-1} (Table 4). The highest pod yield was obtained from planting on May 20 in 2004. The pod yield of Florispan was lower than the other cultivars for all planting dates in 2004 and 2005. This may be attributable to the fact that Florispan is an oil cultivar with a kernel that is smaller than the other cultivars.

Our results showed that emergence, the beginning of flowering, the beginning of gynophore formation and the days to maturity for peanut cultivars were significantly affected by GDD and sunshine duration. Peanut cultivars require between 6.1 and 11.0 days, 91.2 and 145.8°C GDD and 65 and 101.8 h sunshine radiation from planting to emergence. Likewise, from emergence to the beginning of flowering, peanut cultivars require between 16 and 32.2 days, 239.5 and 465.7°C GDD and 167.8 and 361.2 h sunshine radiation. Peanut cultivars require between 10 and 21 days and 231.9 and 306.5°C GDD and 108.2 and 263.5 h sunshine radiation to proceed from the beginning of flowering to the gynophore initiation. Finally, the peanut cultivars require 72.4 and 114 days, 1043 and 1687.8°C GDD and 693.8 and 1122.4 h sunshine radiation in both years to proceed from gynophore initiation to maturity.

The data on the duration of the phenological development were averaged between the cultivars, since notable differences were observed between the cultivars in both years. There was a significantly decreased degree-day and sunshine radiation during from the gynophore initiation to maturity and from the beginning of flowering to gynophore initiation in all the cultivars in both years. There was increased degree-day, but decreased sunshine radiation from the emergence to the beginning of flowering with the delayed planting dates in 2004 and 2005. The highest degree-day and sunshine radiation was obtained from the May 5 - 7 planting and the May 20 -21 planting. The calendar days from planting to emergence, from the beginning of flowering to gynophore initiation and from gynophore initiation to maturity had no significant differences among the planting dates. However, the degree-day and sunshine radiation necessary for the Florispan cultivar was lower than for the other peanut cultivars (Gazipaşa, NC-7 and Local cultivar), because Florispan grows earlier cultivar (Table 5).

The pod yields of the peanut cultivars correlated significantly with the primary branch length, degree-day and sunshine radiation during the different phenological stages. The sunshine radiation during gynophores formation to maturity and emergence to flowering had especially significantly positive correlations with the pod yield (Table 6). The degree-day from the planting date to the flowering had a negative correlation with the pod yield. The degree-day during from gynophores to maturity had significantly positive correlations with the pod yield.

The primary branch number had significantly positive correlations with the degree-day and the sunshine radiation during emergence to flowering and gynophores to maturity. On the other hand, negative correlation was found between duration from flowering and gynophores formation. The sunshine duration during the gynophores formation to maturity had the highest level of significant correlations with both the pod yield and the primary branch number. The sunshine radiation in these stages did not correlate with the primary branch length. The duration of sunshine radiation during the flowering to gynophores stage had a significant correlation with the primary branch length. The primary branch length had a significantly negative correlation with the degree-day during planting date to emergence and the emergence to flowering phases (Table 6).

This study determined that emergence, the beginning of flowering, the beginning of gynophore formation time, the primary branch number, the primary branch length, the days to maturity and the pod yield were significantly affected by the different growth stages and the climate data.

DISCUSSION

The results show that different planting dates have a significant effect on the yield, agronomic and morphological characters of peanuts and the interactions among the planting date, cultivar and year. The yield and the yield components of the peanut were affected by climatic parameters during all the growth phases of the peanut. The phenotypic data in the current study represent the combined effects of genotypic and environmental factors that influence yield and yield components. The effects of the planting date were especially apparent for the emergence, the beginning of flowering, the beginning of gynophore formation time, the primary branch number, the primary branch length, the days to maturity and the pod yield. In general, these characteristics significantly decreased with the harvest of late plantings after the May 20 planting date in all the cultivars. This research shows that the early planting produced greater yields compared to the late planting in both years and the lowest pod yield was obtained in the latest planting date, since pod-filling and harvest time were affected by the cold weather, rain, and frost during the late planting date (Mozingo et al., 1991; Lazarini et al., 1998; Kasaı et al., 1999; Jordan, 2003; Naab et al., 2004; Johnson, 2005). Muldoon (2002) suggested that the late planting crop had a shorter period for the production of pods and also a slightly lower rate of pod production due to reduced growth and exposure of the plant to warmer weather and longer photoperiods (long day) in the late planting date. A soil temperature around 10°C is suitable for germination of peanuts, while the optimum temperature for emergence is between 25 and 30°C for peanuts (Awal and Ikeda, 2002; Prasad et al., 2006). The soil temperature for our experiment was close to the minimum for germination in May and was still within the optimum limits for germination and vegetative growth until mid-May in the experimental site (Table 5). The planting peanuts on the delayed planting dates of June 5-20 resulted in the emergence of cultivars that drastically accelerated in the soil temperature in the late plantings. However, flowering in many plants is known to

Table 5. Calendar days (CD), degree-day (THT) and daily sunshine duration (SUN) for different phenological stage of peanut depending on different planting dates and growth durations in 2004 and 2005.

2004		Planting date to emergence			Emergence to flowering			Flowering to gynophore formation			Gynophore formation to maturity		
		CD	THT	SUN	CD	THT	SUN	CD	THT	SUN	CD	THT	SUN
1.PD	Gazipaşa	9.0	103.5	95.6	32.0	401.6	357.8	16.0	317.0	167.7	112.0	1591.4	1108.2
	Florispan	8.0	91.2	86.3	26.0	299.8	291.6	20.0	357.4	213.4	79.0	1198.5	842.4
	NC-7	9.0	103.5	95.6	31.0	382.6	346.5	16.0	336.0	156.3	112.0	1591.4	1096.4
	Local	9.0	103.5	95.6	30.0	374.6	335.2	16.0	308.0	167.8	114.0	1617.4	1122.4
	Means	8.8	100.4	93.3	29.8	364.7	332.8	17.0	329.6	176.3	104.3	1499.6	908.9
2.PD	Gazipaşa	9.0	104.9	95.8	26.0	409.6	274.9	12.0	271.3	134.5	110.0	1668.4	1067.6
	Florispan	8.0	92.5	84.3	18.0	299.7	196.3	16.0	339.3	263.5	79.0	1321.1	836.1
	NC-7	9.3	104.9	95.8	24.0	376.0	242.4	14.0	309.3	157.3	112.0	1687.8	1090.3
	Local	8.6	105.9	95.8	24.0	358.0	242.4	14.0	306.6	157.3	110.0	1672.2	1074.1
	Means	8.7	102.1	92.9	23.0	360.8	239.0	14.0	306.6	178.2	102.7	1587.4	893.9
3.PD	Gazipaşa	9.3	130.3	98.8	24.0	443.4	258.5	15.0	279.9	124.0	100.0	1575.6	928.7
	Florispan	8.6	130.3	98.8	16.0	287.8	167.8	19.0	361.2	214.4	74.0	1377.8	741.8
	NC-7	9.3	130.3	98.8	23.0	424.3	247.2	16.0	299.0	125.1	98.0	1557.3	895.8
	Local	9.0	130.3	98.8	23.0	424.3	247.2	15.0	280.0	124.0	98.0	1568.3	884.8
	Means	9.0	130.3	98.8	21.5	394.9	230.2	16.3	305.0	146.9	92.5	1427.2	788.5
4.PD	Gazipaşa	8.0	125,6	73.8	23.0	360.4	258.7	13.0	341.9	144.7	98.0	1393.0	885.3
	Florispan	8.6	143.9	84.7	18.0	342.1	203.7	15.0	269.8	166.6	72.0	1043.7	693.8
	NC-7	9.3	143.9	84.7	22.0	442.1	247.2	13.0	241.9	144.7	93.0	1348.3	850.2
	Local	8.3	125,6	73.8	21.0	413.2	235.9	15.0	271.6	167.5	92.0	1342.0	857.2
	Means	8.6	134.7	79.3	21.0	389.5	236.4	14.0	281.3	155.8	88.7	1283.2	741.6
2005													
1.PD	Gazipaşa	9.8	115.0	92.3	32.2	397.9	296.9	14.6	291.7	166.4	101.4	1612.0	1004.2
	Florispan	9.1	101.0	81.7	24.5	324.9	216.8	11.0	304.8	121.2	85.0	1400.0	887.2
	NC-7	9.8	115.0	92.3	31.2	403.1	285.8	11.6	306.5	132.3	102.4	1595.3	1025.4
	Local	9.6	115.0	92.3	32.0	417.9	296.9	13.0	252.6	143.6	99.4	1588.0	996.8
	Means	9.6	111.5	89.6	29.9	386.0	274.1	12.5	288.9	140.9	97.1	1548.8	978.4
2.PD	Gazipaşa	10.8	135.0	85.4	26.0	339.7	274.4	15.6	226.3	176.8	98.4	1537.8	938.0
	Florispan	9.8	123.0	81.7	18.8	239.5	191.1	21.0	256.8	229.8	72.4	1383.0	850.2
	NC-7	10.6	135.0	85.4	27.4	307.3	286.1	12.8	278.7	142.5	100.7	1537.8	963.3
	Local	11.0	135.0	85.4	29.0	291.6	297.1	13.5	255.4	153.9	96.8	1534.0	950.3
	Means	10.6	132.0	84.5	25.3	294,6	262.2	15.7	254.3	175.8	92.1	1498.2	925.5
3.PD	Gazipaşa	9.0	122.5	101.8	23.0	391.3	251.5	13.0	251.3	145.2	91.0	1285.0	939.8
	Florispan	9.0	122.5	101.8	17.0	249.8	188.8	14.0	311.7	152.9	87.6	1203.0	771.8
	NC-7	8.8	122.5	101.8	22.2	391.3	240.5	10.3	232.1	111.6	103.7	1342.0	960.6
	Local	8.6	122.5	101.8	22.4	371.1	230.5	11.5	231.9	134.4	102.1	1342.0	983.1
	Means	8.8	122.5	101.8	21.2	350.9	227.8	12.2	256.8	136.1	96.1	1293.0	913.8
4.PD	Gazipaşa	7.1	128.0	76.4	23.1	465.7	253.5	14.3	243.7	163.9	94.0	1303.0	829.3
	Florispan	6.1	110.6	65.0	17.9	377.1	199.3	13.0	265.5	143.5	78.0	1268.0	737.2
	NC-7	7.6	145.8	87.7	22.0	427.5	242.4	10.4	264.1	108.2	99.4	1253.0	878.0
	Local	7.6	145.8	87.7	22.0	386.0	242.4	10.0	284.6	108.2	105.4	1273.0	914.0
	Means	7.1	132.6	79.2	21.3	414.1	234.4	11.9	264.5	131.0	94.2	1274.3	839.6

be distinctly sensitive to the photoperiod and thermaperiod environment (Roberts et al., 1986). Having been planted between June 5-20 in both years, the peanut cultivars were exposed to high air temperatures and longer sun radiation in each day. Shortly after emergence, days to emergence, the beginning of flowering, time to gynophore

Table 6. Correlation coefficients between the pod yield, the primary branch number, the primary branch length and the degree-day and the daily sunshine duration during the different phenological stages (2004 - 2005).

Traits	PBN	PBL	PY
THT (planting date to emergence)	0.23ns	-0.83**	-0.46ns
THT (emergence to flowering)	0.78**	-0.65**	-0.05ns
THT (flowering to gynophore formation)	-0.49ns	0.44ns	-0.01ns
THT (gynophore formation to maturity)	0.67**	0.39ns	0.94**
SUN (planting date to emergence)	0.34ns	0.36ns	0.37ns
SUN (emergence to flowering)	0.73**	0.12ns	0.68**
SUN (flowering to gynophore formation)	-0.65**	0.51*	0.10ns
SUN (gynophore formation to maturity)	0.77**	0.28ns	0.86**
PBN		-0.32ns	0.48ns
PBL			0.51*
PY			

THT: Degree-day; SUN: daily sunshine duration; PY: pod yield; PBN: primary branch number, PBL: primary branch length.

formation time and maturity were decreased with delayed planting date (Table 5). The cool temperatures after the early planting caused considerably increased emergence times at the two earliest sowing dates and the plants were exposed to sub-optimal temperatures for root and vegetative growth after emergence in both years. Similar findings were also reported by Awal and Ikeda (2002), Banterng et al. (2003), Prasad et al. (2006) and Caliskan et al. (2008a, b). Also, the low temperature, rainfall and frost at harvest time during the late planting date reduced the pod yield and the yield components similar to the present findings (Calişkan et al., 2008a; Canavar and Kaynak, 2008). Though the peanut is an indeterminate plant, all cultivars tend to rapidly decrease both the vegetative and generative stages in late planting dates during these stages in the late planting in Aydın. Thus shortened plant nutriment produced less biomass in the late planting date that resulted in shortened plant lengths, which is similar to previous research result (Banterng et al., 2003).

The degree day units are often used in agronomy to estimate or predict the lengths of the different phases of development. The concept of degree days is based on the premise that the higher the temperature, the faster plants and insects are able to grow. Because of the complexity of the climate-soil-crop systems, computer simulation techniques are among the most practical approaches available to assess climate change impacts on agriculture. Differences in the degree-day and sunshine radiation during the duration of gynophore formation to maturity were largely related to the number of developing pegs and timing of pod filling. The degree-day and the sunshine radiation during gynophore formation to maturity gradually decreased with delayed planting in both years. The cultivars planted between June 5-20 were exposed to high air temperature and longer sunshine radiation and were thus rapidly stressed. The stages of gynophore formation to maturity were also lower in all cultivars planted in the late planting. The stages of developing pegs and the timing of filling pods of peanut were exposed to low temperature and sunshine radiation (Laurence, 1983) (Table 5). The two earliest plantings supply the longer growth for the peanut cultivars that is needed to reach the required 1450 and 1550 Growing Degree Days (GDD) for gynophore formation to maturity (Leong and Ong, 1983; Ketring and Wheless, 1989; Default, 1997; Black and Ong, 2000; Butler et al., 2002; Caliskan et al. 2008a, b). It was found that sunshine radiation of 893-978 h is the best for peanut growth during the gynophore formation to maturity.

At our experimental site, late planting from June 5 - 20 can be harvestable at the end of November and December when Aydın has mostly rainy and cold weather. The late planting date did not produce normal peanut height, because sufficient temperature accumulation was not achieved in the Aegean region during this time. Frimpong (2004) reported that plant height is significantly affected by the planting date and environmental factors, a finding that is similar to our present results (Table 5). Some mature pods were lost due to detaching under unsuitable soil conditions (mud) at the last harvest time from the June 6-20 plantings. The present study experimental site mainly had rainfall at the late harvesting time, which resulted in heavy and muddy soil. Therefore, the number of pod per plant from all the cultivars was significantly decreased in harvest from the June 6-20 planting dates (Laurence, 1983; Gardner and Auma, 2003; Çalışkan et al., 2008).

The different planting dates changed the agronomical and morphological traits of the peanut cultivars. The planting date led to great differences in the final nut-in-shell and kernel yields. During the two studied years in the West Aegean region of Turkey, the most suitable period for peanut planting was the May 5-20 period.

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