Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 2 (12): 909-912, 2003
ISSN 1682-3974

Effects of Shoot Apex Development on Yield and Yield Components in Spring Bread Wheat (*Triticum aestivum* L.)

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Abstract: The objective of this study was to determine the shoot apex development periods and their growing degree-days accumulations and their influences on yield and yield components in spring bread wheat. According to the results of the study, vegetative period, spikelet development period and floret development period varied between 43-71, 17-44 and 32-72 days, respectively. Average growing degree-day accumulations at shoot apex development periods were 529.5 -664.0, 255.3 - 358.0 and 544.3 - 591.5, respectively. The correlation coefficients between yield components and shoot apex development periods showed that the relationship between vegetative period and grain yield was significantly positive. Under these aspects, long vegetative period, short spikelet period and floret development period positively affected grain yield.

Key words: Spring wheat, shoot apex development, growing degree-day, yield

Introduction

Head size in spring wheat is visually monitored early in the growing season. An understanding of cereal plant development can give extra insight into other aspects of crop production. This approach may help to explain and predict the influences of stress factors occurring at certain times during life cycle on yield. The main factors affecting apex development are temperature, day length and variety. The husbandry decisions affect the environmental influences on crop. Sowing date is one of the most important decisions, which determines the exposure of crop to the day length and the temperature during the growing period. Also winter and spring wheat varieties differ in their response to these factors because their development differ from each other under the same growth conditions (Kirby and Appleyard, 1984).

Development and differentiation of shoot apex occurs during morphological growth of wheat plant. Shoot apex is one of the most important organs affecting wheat grain yield and its growth is occurred at four subsequent periods which are defined as the vegetative development, spikelet development, floret development and grain filling periods. In many studies, the relationships between the duration of these periods and wheat grain yield as well as yield components were investigated. Kitchen and Rasmusson (1983) determined positive correlations between plant height and floret development period and also between number of kernel per ear and spikelet development period. According to Korkut and Unay (1987), winter wheat varieties with short vegetative and spikelet but long floret development periods resulted with higher yields. However, there was no correlation between duration of apex development and heading periods in winter wheat (Korkut, 1992). Frank *et al*. (1988) reported that duration of the period from apex double ridge formation to terminal spikelet formation was critical in determining number of spikelets per head in spring wheat. Giunta *et al*. (2001) found that anthesis date was delayed due to increased number of leaves formed during vegetative period. They commented that the number of spikelets per spike was associated with leaf number, but this relationship was also influenced by temperature during spikelet development period.

Environmental conditions in spring and early summer may change spike size by limiting the number of spikelets formed. Temperature and day length are both known to affect spike development (Bulman and Smith, 1993). Similarly, Dawson and Wardlow (1984) concluded that high temperatures hastened spike development from floral initiation to anthesis and could reduce the number of spikelets per spike. Furthermore, it was found that high temperatures during floret development period negatively affected yield and yield components.

Studies of Haji and Hunt (1999) on genotype x environment interactions in winter wheat revealed that an increase in grain yield of many genotypes was associated with the lowest and the average minimum temperatures in January. Also, the precipitation during the vegetative period in May and the grain filling period in July was found to be responsible for increased grain yield of wheat. As there is little information on the relationship between growing day degree (GDD) accumulation during shoot apex development periods and grain yield, it is concerned in this study to investigate this approach with spring bread wheat (*Triticum aestivum* L.) in Meander valley in the western part of Turkey.

Materials and Methods

The spring wheat, cv. Gönen was sown on 9th November, 1st December, 15th December and 1st January. The experiment was designed according to a randomized block design with four replications. Experimental plots were kept 11 m^{-2} (5 m long) and consisted of 11 rows with 0.2 m distances, containing about 500 plants m^{-2}. Each plot was fertilized with 80 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} K_2O before sowing and 80 kg ha^{-1} N during tillering period.

For monitoring shoot apex development periods, first plant samples were collected after 15 days from crop emergence and the following samples were taken with three-day intervals. After washing plant samples, shoot apices were taken out of main stem tissues and examined under binocular (Kirby and Appleyard, 1984). During the period from emergence to heading, shoot apex development was divided into three major periods as vegetative period (VP), spikelet development period (SDP), floret development period (FDP). The longevity of each period was determined by recording number of days. The GDDs' for each period were calculated as described by Cook and Veseth (1991). According to this method, 0°C were accepted as threshold growth temperature of wheat plant and GDDs' were calculated as follows:

$$GDD=[(\text{maximum temperature} + \text{minimum temperature})^{-2}]-0°C$$

At harvest time, plants were cut and the plot yields (kg ha^{-1}) were detected from 7.2 m^{-2}areas after side effects were discarded. Also, the yield components, such as ear kernel weight, plant height, ear length, number of kernel per ear and thousand-kernel weight were determined with randomly chosen 10 plants from each plot. The observed values of the yields and the yield components were tested statistically and the means were compared with LSD at 0.05 probability level. Correlation coefficients among observed parameters were estimated.

Results and Discussion

Shoot apex development periods at the different sowing dates for 1997-1998 season and 1998-1999 season are shown in Table 1. The results of two years showed the same trends. The vegetative periods (VP) differed from 47 to 71 days in 1997-1998 and from 43 to 59 days in 1998-1999 seasons. In both years the durations of vegetative periods were the shortest ones at the first sowing dates. There were the increases in the durations of the vegetative periods at the second and the third sowing dates. At the fourth sowing date, a slightly decrease in the duration of VP was observed. The spikelet development periods (SDP) changed from 17 to 28 days in 1997-1998 season and 28 to 44 days in 1998-1999 season. In both seasons the SDPs decreased at the third and fourth sowing dates. The longest floret development period (FDP) was determined at the first sowing date in both seasons. The duration from SDP to FDP was found as 72 days for 1997-1998 and 53 days for 1998-1999. The longevities of periods were decreased with delayed sowing dates in both seasons. From the results it can be concluded that all the apex development periods showed the similar trends depending on the sowing dates, but the longevities of periods were different in both growing seasons and this difference between two years could be attributed to the variations in the climatic factors, which was also supported of Kirby and Appleyard (1984) as well as Korkut (1992).

Table 1: Shoot apex development periods and their GDDs' at the different sowing dates in 1997-1998 and 1998-1999 seasons

Year	Sowing Date	VP	SDP	FDP	VP_{GDD}	SDP_{GDD}	FDP_{GDD}
1997-1998	1. November 15	47	28	72	672	300	717
	2. December 1	55	28	54	665	250	547
	3. December 15	71	25	47	648	288	532
	4. January 1	67	17	43	671	183	570
	Average	60.0	24.5	54.0	664.0	255.3	591.5
1998-1999	1. November 15	43	35	53	538	332	568
	2. December 1	50	44	43	507	453	574
	3. December 15	59	28	40	576	322	547
	4. January 1	51	30	32	497	325	488
	Average	50.8	34.3	42.0	529.5	358.0	544.3

VP: Vegetative period; SDP: Spikelet Development Period; FDP: Floret Development Period; VP_{GDD}: GDD accumulations at VP; SDP_{GDD}: GDD accumulations at SDP; FDP_{GDD}: GDD accumulations at FDP

The average VP_{GDD} value was 664. It changed from 648 to 672 in the first season. GDD values for SDP varied from 183 to 300. At FDP, the first sowing date reached to the highest GDD value (717) and decreased at the second and third sowing dates and slightly increased at the fourth sowing date (Table 1). According to the second season's data, the GDD accumulations during VP changed from 497 to 576. As far as GDD values for SDP are concerned, they were closely similar to each other, except the second sowing date, which was fairly higher than the others. The FDP_{GDD} values varied between 488 and 574 depending on sowing dates.

Results from both seasons suggest that all GDD values determined for VP for all sowing dates were similar within the years, whereas the differences were observed between them. The observed GDD values which varied between 497 (in 1998-1999 season) and 672 (in 1997-1998 season) were higher than GDD values found in North America by Cook and Veseth (1991). The differences between two results might be explained with different wheat type and environment. While SDP_{GDD} values of all sowing dates

Table 2: Mean values of observed yield and yield components in the growing seasons

Year	Sowing date	Grain yield (t ha^{-1})	Ear Kernel Weight (g)	Thou. kernel Weight (g)	Plant height (cm)	Ear length (cm)	No. of kernel per Ear
1997-1998	Nov. 9	2.699	2,30	40,3	97,9	9,52	42,7
	Dec. 1	3.926	2,01	38,4	103,1	9,02	58,0
	Dec. 15	4.578	1,90	37,4	104,7	9,58	52,7
	Jan. 1	4.548	1,80	37,6	86,6	9,05	49,5
	$LSD_{0.05}$	0.436	-	-	5,2	-	8,3
1998-1999	Nov. 9	3.749	1,53	35,3	96,3	7,94	43,2
	Dec. 1	3.620	1,69	32,0	86,1	8,96	52,6
	Dec. 15	3.741	1,70	34,5	85,5	8,97	49,3
	Jan. 1	2.642	1,64	34,2	75,9	8,39	48,4
	$LSD_{0.05}$	0.579	-	-	7,8	-	5,7

Table 3: Correlation coefficients between yield and yield components and, shoot apex development periods and their GDD accumulations

Characters	VP	SDP	FDP	VP_{GDD}	SDP_{GDD}	FDP_{GDD}
GY	0.739*	-0.377	-0.173	0.404	-0.402	-0.297
EKW	0.094	-0.337	0.763*	0.776*	-0.334	0.709*
TKW	0.202	-0.660	0.737*	0.908**	-0.720*	0.564
PH	0.156	-0.137	0.693	0.649	-0.255	0.338
EL	0.574	-0.367	0.363	0.698	-0.227	0.416
NK/E	0.490	-0.024	-0.334	0.162	-0.082	-0.505

VP : Vegetative period,
SDP : Spikelet Development Period,
FDP : Floret Development Period,
VP_{GDD} : GDD accumulations at VP,
SDP_{GDD} : GDD accumulations at SDP,
FDP_{GDD} : GDD accumulations at FDP,
GY : Grain Yield,
EKW : Ear Kernel Weight,
TKW : Thousand Kernel Weight,
PH : Plant Height,
EL : Ear length,
NK/E : Number of Kernel per Ear.
*; Significant at 0.05 probability level
**; Significant at 0.01 probability level

were fairly close to each other in the second growing season, there was a decline from first sowing date to fourth one in the first year. As observed GDD values were not found to be constant for both seasons, it could be concluded that the other environmental factors rather than GDD influenced the SDP, like in the case of VP.

At FDP, GDD values for both seasons differed slightly from each other. The total GDD accumulations during the periods, from emergence to the heading were between the 1310-1690 GDD. Similar results were obtained by Cook and Veseth (1991), who reported that bread wheat accumulated 1400 GDD from sowing to the heading.

In the first season (1997-1998), the grain yields of third and the fourth sowing dates were significantly higher than those of the second and the first sowing dates (Table 2). In the second season (1998-1999), the grain yield of the first sowing date was the highest and followed by the third and the second sowing dates, but the means were not significantly different. However, a lower yield, which was significantly important, was obtained at the fourth sowing date. These results were in accordance with Tiwari and Sharma (1999) and Patel *et al.* (1999) indicating that early or late bread wheat sowing dates resulted with a reduction in grain yield depending on seasons.

In both seasons no significant differences were found among the sowing dates in terms of ear kernel weight, thousand-kernel weight and ear length. Mean values of these yield components in average of four sowing dates in 1997-1998 and 1998-1999 seasons were determined as 2,00 and 1,64 g for ear kernel weight; 38,4 and 34,0 g for thousand kernel weight and 9,29 and 8,36 cm for ear length, respectively (Table 3). Although there is no significant influence of thousand kernels weight on grain yield was detected in this study, Tarekegne (1996) found that this component had a significant effect on grain yield. When the plant height was evaluated in the first season, the highest plant height was observed at the third sowing date and followed by the second and the first sowing dates (Table 3). The plant height was highly correlated with the sowing dates in the second season, that the delaying sowing dates decreased the plant height. In general, plant height decreased in the second season comparing with the first one. Concerning the number of kernels per ear, the second and the third sowing dates were not significantly different in both seasons, while the fourth and the first sowing dates took place in different groups.

Correlation coefficients between yield and yield components and shoot apex development periods and their GDDs' are presented in Table 3. The positive correlation coefficients were determined among vegetative period (VP) and yield and yield components. The correlation between VP and grain yield was significant, whereas no significant correlation was found between VP and yield components. On contrast Korkut and Unay (1987) reported that winter wheat varieties with short VPs' had higher grain yields. This difference might be due to type of wheat. Similar correlation was found between GDD accumulation at Vegetative Period (VP_{GDD}) and yield components. The associations of VP_{GDD} with ear kernel weight and thousand-kernel weight were significantly positive. So, it may be interpreted that longevity of VP and VP_{GDD} had positive effects on spring bread wheat yields. Table 1, 2 and 3 illustrates that the third sowing date (Dec. 15) with longer vegetative periods had the highest grain yield

Correlation coefficients among the spikelet development periods (SDP) and yield components were found to be negative and non-significant. Similarly, GDD accumulation of spikelet development period (SDP_{GDD}) was negatively correlated with the yield components. A significant correlation coefficient was only found with TKW. So, it can be concluded that a prolonged SDP and higher

SDP_{GDD} accumulation resulted with negative effects on spring bread wheat yield. This result is consistent with Korkut and Unay (1987). While Kitchen and Rasmusson (1983) and Frank *et al*. (1988) found positive correlation between SDP and NK/E, this relationship was slightly negative in our results. Especially, high air temperatures during SDP from February 1 to March 20, lead to a shorter period and the lower GDD accumulation.

The correlation coefficients between PH and FDP, as well as, PH and FDP_{GDD} were positive and consistent with Kitchen and Rasmusson (1983). The longer FDP and higher GDD accumulation were negatively correlated with the grain yield and NK/E. Positive and significant correlations were found among FDP, EKW and TKW and between FDP_{GDD} and EKW. Therefore, it can be concluded that the reduction of grain yield is due to the reduction of NK/E depending on TKW increase. Grain yield was negatively affected by longevity of FDP, whereas Korkut and Unay, (1987) expressed that FDP positively affected grain yield in winter wheat. In order to discuss this phenomenon, thermal conditions during FDP should be optimum.

In conclusion, the longevity of shoot apex development periods and their GDD accumulations affected yield and yield components. With the other words, long VP, short SDP and FDP positively affected grain yield in spring wheat under field conditions at Meander Valley, Aydin-Turkey.

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