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Determination of the yield performance and partial seed vernalization response of wheat varieties in late spring sowing

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Abstract

Increased temperatures due to climate change, vernalization requirements, and photoperiod sensitivity limit wheat yield. The most important cultural treatment in this is the selection of suitable varieties. This study was conducted for the purpose of investigating the growth performances of 17 different wheat varieties in late spring sowing and the effects on the seed of vernalization treatment. The growth of Bezostaja 1, Gerek 79, Dumlupınar, Kunduru 1149, Mv Suba, Kızıltan 91, Esperia, Eminbey, Ç-1252, Akbasak and Sahman wheat varieties stopped at the end of tillering; they did not reach flowering stage for any of the sowing times. The Einkorn and Emmer varieties completed their growth for all of the sowing times. The Tosunbey variety had a very good yield performance in the first sowing and partially in the second sowing. It is possible to say that these varieties have very little vernalization requirement or are able to meet their vernalization requirement at higher temperatures. The varieties mentioned can be easily sown for economic yield until the middle of April in a medium latitude continental climate zone, but yield values decreased noticeably as the sowing was delayed. On the other hand, the positive effect of the vernalization method used was rather limited.

Key words: Late sowing, seed vernalization, spring sowing, wheat

Introduction

It is clear that the wheat need of the growing world population cannot be fulfilled by dry farming. In winter sowing, the growth period of wheat covers most of the year, and winter sowing may be considered obligatory in some precipitation-dependent production areas. Production in areas that are irrigated at other times of the year and for a much shorter period of time is one way to increase production. Wheat is widely sown in the winter both in Turkey and in the rest of the world in order to make use of winter precipitation and to ensure earliness. Another important reason for winter sowing is the high vernalization requirement and photoperiod sensitivity of some wheat varieties. Vernalization is considered as a necessary step before photoperiod and temperature for earing (Yasuda &Shimoyama 1965) and is defined by Chouard (1960) as the acceleration by a chilling treatment of the ability to flower. It is generally accepted that the vernalization requirement is met below 10°C between 30 and 60 days (Evans et al 1975; Flood and Halloran 1986). Perry & Belford (1991) reported that the effective temperature for vernalization ranged from 1 to 7°C, and Wort (1939) stated that the optimum temperature was 3°C. Although 0°C is regarded as the lower limit for vernalization, the upper limit is as much as 15-18°C (Ritchie 1991; Weir et al 1984).

The vernalization requirement and photoperiod sensitivity of winter wheat are considerably higher than those of spring wheat, and are highly dependent on the variety. These varieties also have a higher resistance to cold (Galiba et al 1995; Schmütz 1976; Sutka 2001), whereas the resistance of spring wheat to cold stress is low (Doorenbos &Kassam 1979).

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There is also a correlation between photoperiod and vernalization: as the vernalization requirement is met, the long-day demand decreases (Evans et al 1975) but they are not exactly equivalent.

Timely sowing is one of the major culture treatments for achieving sufficient yield (Ferrisea et al 2010). If the flowering and grain filling period occur at a time of high temperatures due to a delay in sowing, there is a risk to yield (Anderson &Smith 1990; Wu et al 2017). Wheat sowing is sometimes delayed until mid-spring for reasons such as a lack of precipitation during germination period, resulting in failure to obtain adequate plant density, damage caused by winter cold, damage caused by floods, and abandon wheat production. Increased temperatures due to climate change can also be seen as a kind of late sowing. . In that case, it becomes important to sow a spring wheat variety. Spring wheat requires little or no vernalization. In other words, the vernalization requirement is met at 7-18°C in a relatively very short time ranging between 5 and 15 days. In recently-developed wheat varieties, flowering is possible without vernalization if the temperature and photoperiod are controlled (Li et al 2017).

Climate change stands as a scientific fact. Wheat yield is highly influenced by environmental factors (Altay 2012). In the future, wheat production is predicted to increase by 7% because of the increase in temperatures, which is an inevitable result of climate change. However, it is emphasized that the varieties which are adapted to higher temperatures need to be identified, and such varieties will increase in value in the future (Asseng et al 2019). In that case, the varieties which have a lower vernalization requirement must be identified, or the vernalization requirement must be fulfilled artificially. Field experiments during warmer periods can give a better idea of vernalization sensitivity (Ortiz Ferrara et al 1995). This study was carried out to investigate the growing ability of different wheat varieties in late spring sowing, and the effects of partial seed vernalization.

Materials and Methods

The study was conducted in 2017 and 2018 under the ecological conditions of Isparta, Turkey. Normal and vernalized wheat seeds were sown at different times from the middle to the end of spring. As part of the soil preparation process, 20 kg da^{-1} of 'Super Ekin' fertilizer (13-25-5+10(SO_3)+Zn) and 8 kg da^{-1} N as ammonium nitrate were applied to the soil. Seventeen different wheat varieties (Bezostaja 1, Gerek 79, Dumlupınar, Kunduru 1149, Es-26, Mv Suba, Kızıltan 91, Esperia, Eminbey, Ç-1252, Tosunbey, Akbasak, Bolvadin, Emmer, Einkorn, Albostan, and Sahman) were used in the experiment. The experiment had a completely randomized design with three replications. The main blocks were arranged as sowing time, 500 seeds/m^2 were planted in the plots. The plots were 1 meter long (1 row); the intra-row spacing was 0.5 meters and the row spacing was 1 meter. A drip irrigation system was installed, and the plants were drip-irrigated every 15-20 days depending on precipitation. The soil of the experimental area was loamy and had an alkaline pH (8.5) and a very high lime content (29% $CaCO_3$). The daily maximum and minimum temperatures during the experiment are given in Figure 1 (MGM 2019).

Sowing times were as follows: first sowing on 14 April 2017 (without vernalization/control); second sowing on 28 April 2017 (without vernalization + 15 days' vernalization); third sowing on 15 May 2017 (without vernalization + 15 days' vernalization + 30 days' vernalization), and fourth sowing on 1 June 2017 (without vernalization + 15 days' vernalization + 50 days' vernalization). In the second year of the experiment (2018), the first sowing and second sowings were conducted on approximately the same dates. However, since none of the varieties had developed sufficiently in the third and fourth sowing times in the first year and the yields of the varieties had not reached a certain value, the third sowing and the fourth sowing were not performed. For vernalization, seeds were kept in a cold storage room at 2±2°C and 90%±5 humidity prior to sowing.

Plant germination dates (the dates when half of the seeds had germinated) were calculated in days from sowing by taking the means of all varieties. Time to Feekes growth stage were recorded when 50% of plants had shown the specified growth stage properties (Ortiz Ferrara et al 1995). For the varieties which reached grain yield, plots were harvested by hand, and plant height, spike number, and yield in grams were determined.

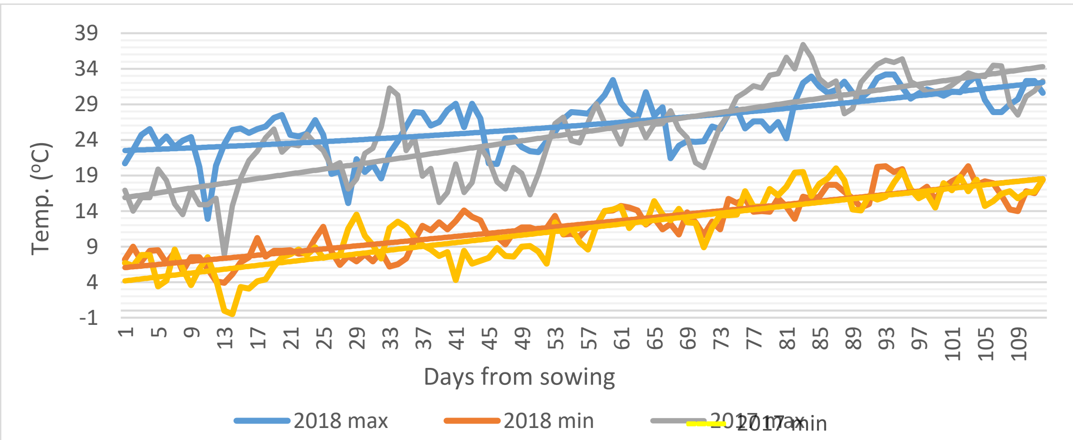

Figure 1. The daily maximum and minimum temperature values (°C) for the 2017 and 2018 growing periods (11 April-31 July)

Results and Discussion

The mean germination times from sowing of the varieties are given in Figure 2. Germination times shortened noticeably as the sowing was delayed. In the first year, germination time was 11.4 days for the first sowing time (April 14) but 6.3 and 6.1 days for the last sowing time (June 1). In the second year, however, germination time was 9.1 days for the first sowing time but 6.5 days for the second time. In both years, the date of sowing affected the germination time, but vernalization did not have any significant effect. If the soil moisture level is adequate, the most important factor which affects the germination time is temperature (Nyachiro et al 2002). Air and soil temperatures increase as the sowing is delayed. Isparta has a long-term average air temperature of 10.6 °C and a 5 cm soil temperature of 12.7 °C in April, and a long-term average air temperature of 15.5 °C and a 5 cm soil temperature of 18.9 °C in May (MGM 2019). In the experiment, germination times shortened as the temperatures increased. Compared to the first year, the second year had shorter germination times for the first and second sowing times. This is thought to be due to the higher temperature during germination in the second year (Figure 1).

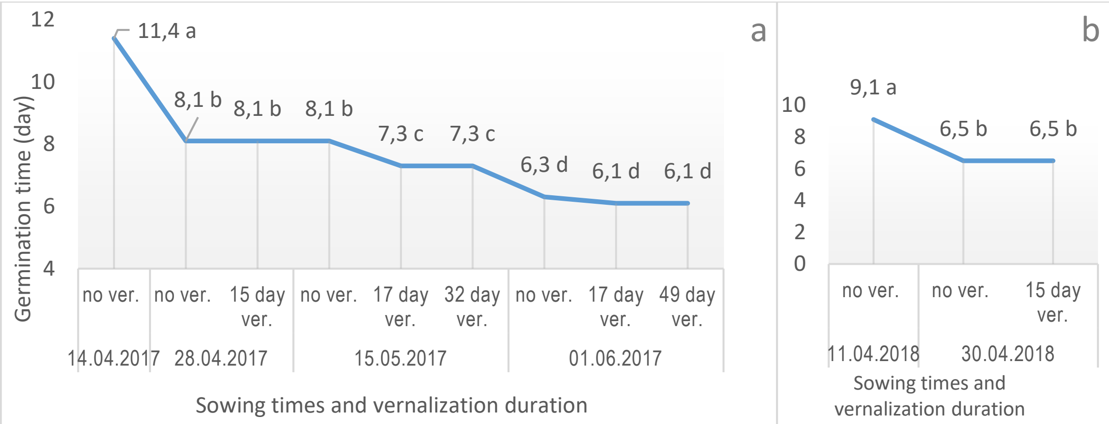

Figure 2. Mean germination times from sowing in wheat species. a: 2017, b: 2018

In the first sowing times (14 April 2017 and 11 April 2018), the growth of Bezostaja 1, Gerek 79, Dumlupınar, Kunduru 1149, Mv Suba, Kızıltan 91, Esperia, Eminbey, Ç-1252, Akbasak, and Sahman stopped at the stage when the leaves were strongly erect (Feekes 5). They remained at this stage for a certain period of time and then dried out. Table 1 shows the growth stages of the varieties which were grown and the number of days from sowing. Table 2 shows the plant height, the number of spikes per square meter and the yield values. Table 3 shows the statistical analysis of the data obtained, their mean values and the resulting groups. Not all data were included in the statistical analysis due to the lack of homogeneous data, and interactions were not taken into consideration. The comparison of the two years was based on the first and second sowing times and the varieties common to both (Tosunbey, Emmer, Einkorn). In the evaluation of each year, the varieties which grew in all of the sowing times were taken into consideration (first year: Emmer and Einkorn; second year: Tosunbey, Emmer, and Einkorn).

Regarding sowing times and varieties, in the first year, the Emmer variety (82 days) reached the flowering stage the latest in the first sowing time, and Tosunbey (67 days) reached flowering the earliest in the second, third and fourth sowing times. In the second year, the variety that the latest reached the flowering stage were Einkorn (88 days) in the first sowing time, and earliest were Tosunbey (64 days) in the second sowing time, without vernalization. In the first year, the one that matured the latest was Boldavin (111 days) in the first sowing time. Ortiz Ferrara et al (1995) report that high vernalization allows for earliness in flowering, but we did not achieve similar results in our study, indicating that the vernalization method used in the study was not effective enough.

The earliest maturity was obtained with Tosunbey in the third sowing time without vernalization. In the second year, the variety that the latest reached maturity were Einkorn (109 days) in the first sowing time, and the earliest were Albostan (87 days) in the second sowing time (Table 1). There was a difference between the two years in terms of flowering and maturation duration. The average flowering time of the varieties was shorter (73.0 days) in the first year and longer (74.5 days) in the second year (Table 3). The varieties reached maturity in a shorter period of time in the second year (97.5 days) than in the first year (101.8 days). This is thought to be due to the higher GDD (Growing Degree-Days) value in the second year (Figure 1). In general, the time required for maturation shortened as the sowing was delayed (Table 3). In the first year, vernalization had no effect in the second sowing time. However, in the third sowing time, the time required for flowering and maturation extended with the increase of vernalization. This is opposite to the conclusion that the maturation time shortens as the vernalization time extends (Tas & Celik 2008). The effect of vernalization was not significant in the second year. Einkorn proved to be a later variety than Emmer and others in the first and second years. As the sowing was delayed, the growth time shortened depending on the increasing day length. Longer illumination time and temperatures around 22 °C lead to a significant decrease in the growth time of wheat (Watson et al 2018).

Figure 3 shows the yield values according to different sowing times and vernalization durations. In the first year, six different yield values were obtained in the first sowing time. Of these varieties, Tosunbey, Emmer, and Einkorn reached their potential grain yields. It is reported by the registered institution (Field Crops Central Research Institute) that Tosunbey has a yield potential of 350-700 kg da^{-1} in the irrigated areas of the central and transitional regions in winter sowing. In our study, the yield obtained was 625 kg da^{-1} in the first year and 355 kg da^{-1} in the second year for the first sowing time. In both years, the yield values obtained in the first sowing times were within the potential yield limits. Emmer and Einkorn reached high yield values by giving a gross yield above 500 kg da^{-1} in the first year and 250 kg da^{-1} in the second year. Es-26 and Albostan attained an average yield value of 310 kg da^{-1} and

265 kg da^{-1} respectively, in the first sowing time of 2017. On the other hand, the yield value reached by Boldavin was very low (25 kg da^{-1}). These varieties did not reach the maturity in the first sowing time of 2018. Albostan did not reach the maturity in the second sowing time of the first year (28 April 2017). Other varieties reached the grain yield, but highly significant yield decreases occurred in the sowing times both with and without vernalization. The decrease in the sowing times without vernalization was approximately 90% in Es-26, 69% in Tosunbey, 46% in Emmer, and 24% in Einkorn. These rates are close to those in the sowing times with vernalization. In the second sowing time (with and without vernalization), there was no noticeable difference between Einkorn and Emmer in terms of yield. However, the yield increased by approximately four times in Es-26, and by 43% in Tosunbey. Vernalization had a positive effect on plant height in Es-26 in the second sowing time. Plant height and spike number per square meter also decreased seriously compared to the first sowing time (Table 2).

Table 1. Growth stages date of wheat varieties and days from sowing

Sowing time	14.04.2017 (No ver.)				28.04.2017 (No ver.)				28.04.2017 (15 day ver.)			
Growth stage	Feekes				Feekes				Feekes			
	5	10.1	10.5	11	5	10.1	10.5	11	5	10.1	10.5	11
Es 26	09 Jun (57)	22 Jun (70)	28 Jun (80)	01 Aug (110)	15 Jun (49)	03 Jul (67)	11 Jul (75)	06 Aug (101)	16 Jun (50)	28 Jun (61)	04 Jul (68)	06 Aug (101)
Tosunbey	09 Jun (57)	19 Jun (67)	29 Jun (77)	28 Jul (106)	13 Jun (46)	28 Jun (61)	03 Jul (67)	04 Aug (99)	14 Jun (47)	28 Jun (61)	03 Jul (67)	04 Aug (99)
Bolvadin	09 Jun (57)	20 Jun (68)	28 Jun (80)	02 Aug (111)	--	--	--	--	--	--	--	--
Emmer	06 Jun (54)	27 Jun (75)	04 Jul (82)	24 Jul (102)	13 Jun (46)	28 Jun (61)	04 Jul (68)	28 Jul (92)	14 Jun (47)	28 Jun (61)	04 Jul (68)	01 Aug (96)
Einkorn	13 Jun (61)	28 Jun (76)	03 Jul (81)	01 Aug (110)	15 Jun (49)	30 Jun (63)	05 Jul (69)	11 Aug (106)	14 Jun (47)	30 Jun (63)	05 Jul (69)	11 Aug (106)
Albostan	11 Jun (59)	24 Jun (72)	04 Jul (82)	01 Aug (110)	15 Jun (49)	03 Jul (67)	10 Jul (74)		15 Jun (49)	03 Jul (67)	10 Jul (74)	

Sowing time	15.05.2017 (No ver.)				15.05.2017 (15 day ver.)				15.05.2017 (30 day ver.)			
Growth	Feekes				Feekes				Feekes			
Stage	5	10.1	10.5	11	5	10.1	10.5	11	5	10.1	10.5	11
Tosunbey	10 Jul (57)	15 Jul (62)	20 Jul (67)	8 Aug (86)	11 Jul (58)	16 Jul (63)	22 Jul (69)	8 Aug (86)	9 Jul (56)	15 Jul (62)	26 Jul (73)	9 Aug (87)
Emmer	12 Jul (59)	18 Jul (65)	22 Jul (69)	9 Aug (87)	15 Jul (62)	18 Jul (65)	23 Jul (70)	10 Aug (88)	11 Jul (58)	17 Jul (64)	28 Jul (75)	11 Aug (90)
Einkorn	14 Jul (61)	19 Jul (66)	26 Jul (73)	22 Aug (100)	18 Jul (65)	20 Jul (67)	26 Jul (73)	23 Aug (101)	15 Jul (62)	25 Jul (72)	2 Aug (81)	24 Aug (103)

Sowing time	11.04.2018 (No ver.)				30.04.2018 (No ver.)				30.04.2018 (15 day ver.)			
Growth	Feekes				Feekes				Feekes			
Stage	5	10.1	10.5	11	5	10.1	10.5	11	5	10.1	10.5	11
Es 26	10 Jun (61)	18 Jun (69)	26 Jun (77)	19 Jul (100)	21 Jun (53)	01 Jul (63)	11 Jul (73)	06 Aug (99)	18 Jun (50)	30 Jun (62)	07 Jul (69)	06 Aug (99)
Tosunbey	01 Jun (52)	14 Jun (65)	30 Jun (81)	22 Jul (103)	21 Jun (53)	26 Jun (58)	02 Jul (64)	26 Jul (88)	20 Jun (52)	26 Jun (58)	04 Jul (66)	27 Jul (89)
Emmer	29 May (49)	20 Jun (71)	30 Jun (81)	23 Jul (102)	20 Jun (52)	28 Jun (60)	04 Jul (66)	26 Jul (88)	20 Jun (52)	28 Jun (60)	04 Jul (66)	26 Jul (88)
Einkorn	08 Jun (59)	24 Jun (75)	07 Jul (88)	07 Aug (109)	19 Jun (51)	29 Jun (61)	15 Jul (77)	12Aug (105)	25 Jun (57)	07 Jul (69)	17 Jul (79)	13 Aug (106)
Albostan	03 Jun (54)	22 Jun (73)	30 Jun (81)	14 Jul (95)	22 Jun (54)	29 Jun (61)	07 Jul (69)	25 Jul (87)	26 Jun (58)	03 Jul (65)	12 Jul (69)	25 Jul (87)

In the second sowing time of the second year (30 April 2018), Es-26 and Alabostan did not maturity. The yield decreased by 35-48% in Tosunbey, Emmer, and Einkorn in the second sowing time (with and without vernalization) compared to the first one. In the sowing time with vernalization, the yield decreased slightly in Tosunbey but increased in Emmer and Einkorn (Table 3). There was also a noticeable decrease in plant heights and spike numbers per square meter.

Table 2. Plant height (cm), spike number (no / 0.2 m^2) and yield (gr / 0.2 m^2) values according to different sowing times and vernalization duration in wheat varieties

Sowing time	14.04.2017 (No ver.)			28.04.2017 (No ver.)			28.04.2017 (15 day ver.)			15.05.2017 (no vern.)			15.05.2017 (15 day ver.)			15.05.2017 (30 day ver.)		
Variety	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})
Es 26	88	66	62	57	20	6	67	28	25									
Tosunbey	73	110	125	68	30	38	68	25	56	25	1	--	33	3	--	30	6	--
Emmer	85	120	112	82	90	61	83	75	62	50	20	14	40	15	12	40	10	12
Bolvadin	55	6	5															
Einkorn	85	125	103	83	80	78	85	65	83	40	35	11	45	40	12	35	20	8
Albostan	65	55	53	62	4	--	60	8	--									

Sowing time	11.04.2018 (No ver.)			30.04.2018 (No ver.)			30.04.2018 (15 day ver.)		
Variety	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2})	Yield (gr 0.2 m^{-2})	Plant height (cm)	Number of spikes (num. 0.2 m^{-2}))	Yield (gr 0.2 m^{-2})
Es 26	55	60	--	40	12	--	40	16	--
Tosunbey	64	62	71	58	36	46	55	28	30
Emmer	68	85	65	64	56	41	64	45	45
Einkorn	83	95	57	62	36	30	62	44	39
Albostan	55	38	--	53	20	--	46	14	--

Es-26 did not grow in the third sowing time of the first year. Tosunbey grew, but the yield obtained remained at a negligible level. The number of spikes of this variety significantly increased in the sowing times with 15 days' and 30 days' vernalization. However, the increase in the number of spikes was not reflected in yield (grains did not develop). Although plant height, spike number and yield decreased considerably in Emmer and Einkorn, they completed their growth stages in full (Table 2). Vernalization did not affect these varieties positively or negatively.

In the fourth sowing time of the first year (June 1), only Einkorn and Emmer reached approximately 20 cm in height and formed spikes. However, their grain yields remained at a negligible level. For this reason, no data are given in the tables for this sowing time. Vernalization (15 days and 50 days) had no positive or negative effects.

The measured parameters of Emmer and Einkorn, which were present in all sowing times, were used in the comparisons of the first year. In the first year, the values of the characteristics examined decreased significantly as the sowing was delayed (Table 3). There was a noticeable difference in terms of yield between the first year and the second year: yields were approximately 40% lower in the second year. In the third sowing time, plant height and yield values were the same in all of them. With 30 days' vernalization, flowering and maturation occurred later, and the number of spikes was lower than that of the control and of the 15 days' vernalization. Of the two varieties mentioned, Einkorn reaches the flowering and maturity stages much later than Emmer and other varieties. In the evaluation of the second year, the values of all characteristics examined were higher in the first sowing time than in the second one. No difference was observed between the values of the control and 15 days' vernalization in the second sowing time. As in the first year, Einkorn reached the flowering and maturity stages later than other varieties. Both the plant height and the number of spikes per square meter were higher in Einkorn and Emmer compared to Tosunbey. However, there was no difference between the varieties in terms of yield.

Table 3. The mean values and Duncan grouping of growing characteristics in wheat varieties according to different sowing times and vernalization duration

			Flowering / Feeks 10.5 (day)	Ripening / Feeks 11 (day)	Plant height (cm)	Spike number (no / 0.2 m^2)	Yield (gr / 0.2 m^2)
			Mean ±sd	Mean ±sd	Mean ±sd	Mean ±sd	Mean ±sd
Year		2017	73.0±6.04*	101.8±6.02*	79.1±9.24*	79.9±35.46*	79.8±29.09*
		2018	74.5±8.69	97.5±9.05	64.4±8.78	54.1±22.42	47.1±15.56
2017	Sowing	1.	81.3±2.42 a*	106.2±5.11 a*	85.1±9.49 a*	122.5±10.56 a*	107.5±11.94a*
		2.	70.8±3.88 c	99.9±6.85 b	83.3±4.81 a	77.3±11.64 b	71.0±12.14 b
		3.	73.5±4.69 b	95.0±7.17 c	41.7±6.14 b	23.3±11.57 c	11.8±3.78 c
	Ver.	1a**	81.3±2.42 a*	106.2±5.11 a*	85.1±9.49 a*	122.7±10.56 a*	107.5±11.94 a
		2a	70.7±4.03 c	98.7±8.02 bc	82.7±5.05 a	84.7±11.18 b	69.5±12.08 b
		2b	71.0±4.01 c	101.2±5.95 b	84.0±9.94 a	70.0±6.63 c	72.7±13.12 b
		3a	71.0±3.58 c	93.7±7.55 e	45.0±7.04 b	27.3±9.16 d	12.8±4.07 c
		3b	71.5±3.08 c	94.7±7.58 de	42.7±4.84 b	27.5±14.29 d	12.3±3.72 c
		3c	78.2±3.76 b	96.8±7.36 cd	37.5±4.46 b	15.1±6.88 e	10.1±3.66 c
	Variety	Emmer	71.8±5.77*	92.5±5.71*	63.3±21.64	54.9±44.1	45.7±38.43
		Einkorn	76.0±4.12	104.5±4.02	62.2±23.56	60.8±36.1	49.2±41.02
2018	Sowing	1.	83.5±4.19*	104.9±3.82*	71.4±9.86*	80.4±15.95*	64.5±10.45*
		2.	69.9±6.47	93.8±8.68	60.9±5.76	40.9±9.93	38.4±8.92
	Ver.	1a	83.5±4.19 a	104.9±3.82 a	71.4±9.86 a	80.4±15.95 a	64.5±10.45 a*
		2a	69.3±6.22 b	93.3±8.86 b	61.4±5.08 b	42.8±10.24 b	39.1±9.01 b
		2b	70.5±7.02 b	94.3±9.00 b	60.4±6.65 b	39.1±9.85 b	37.8±9.32 b
	Variety	Tosun	70.5±8.19 b*	93.2±8.01 b*	58.9±6.01 b*	42.1±15.85 b*	49.1±19.15
		Emmer	71.1±7.64 b	92.7±7.42 b	65.4±5.92 a	61.8±18.46 a	50.4±12.87
		Einkorn	81.8±5.42 a	106.7±2.4 a	69.0±9.96 a	58.3±28.14 a	41.9±14.48

*: significant at P≤0.05, **: 1a; first sowing- no vernalization, 2a; second sowing-no ver, 2b; second sowing-15 day vernalization, 3a; third sowing-no ver, 3b; third sowing-15 day vernalization, 3c; third sowing-30 day vernalization

In late sowing, the grain filling period corresponds to the period of high temperatures and low humidity. As a result, both the number of spikes and the dry matter yield are lower (Panozzo & Eagles 1999; Subedi et al 2007; Kara 2010). In our study, the number of spikes (Table 2) and the grain yield were adversely affected in line with sowing dates in all of the varieties which reached the grain yield (Figure 3). The most affected varieties were Bolvadin, followed by Albostan, Es-26, and Tosunbey. It is reported in some studies that wheat varieties with alternative growth properties give a better yield than summer wheat varieties (Li et al 2012). Tosunbey, one of the registered varieties in our study, has alternative growth properties, and had a high yield performance. As seen in the experiment, yield and natural resource utilization can be increased by choosing a variety with alternative growth properties (semi-winterness) and by sowing a few days earlier (7-10 days) in late spring sowing (Li et al 2012). The vernalization and photoperiod requirements of the varieties vary greatly. It is reported that there is a correlation between vernalization and photoperiod: vernalization minimizes the long-day demand (Evans et al 1975), excessive vernalization does not meet the long-day demand for earing in the varieties sensitive to photoperiod, and long-day treatments do not substitute for vernalization in the varieties that require vernalization (Flood and Halloran, 1984). Between April 14 and July 31 2017, the number of hours with a temperature below 5 °C was 46, and there were 117 hours with a temperature below 7 °C (Figure 1), corresponding to two days and five days. In the second sowing time, between 28 April and 31 July 2017, the number of hours with a temperature below 5 °C was two and there were 14 hours with a temperature below 7 °C. Between 11 April and 31 July 2018, the number of hours with a temperature below 5 °C was 4 number and 33 number with a temperature below 7 °C. In the second sowing time, between 30 April and 31 July 2018, the temperature was never below 5 °C, and the number of hours with a temperature below 7 °C was 8. These results demonstrate that the varieties that reach the maturity meet their vernalization requirement within a short time (i.e. they are able to meet their vernalization requirement when the temperature is above 7 °C). Besides, it is possible to say that the photoperiod sensitivity of these varieties is low.

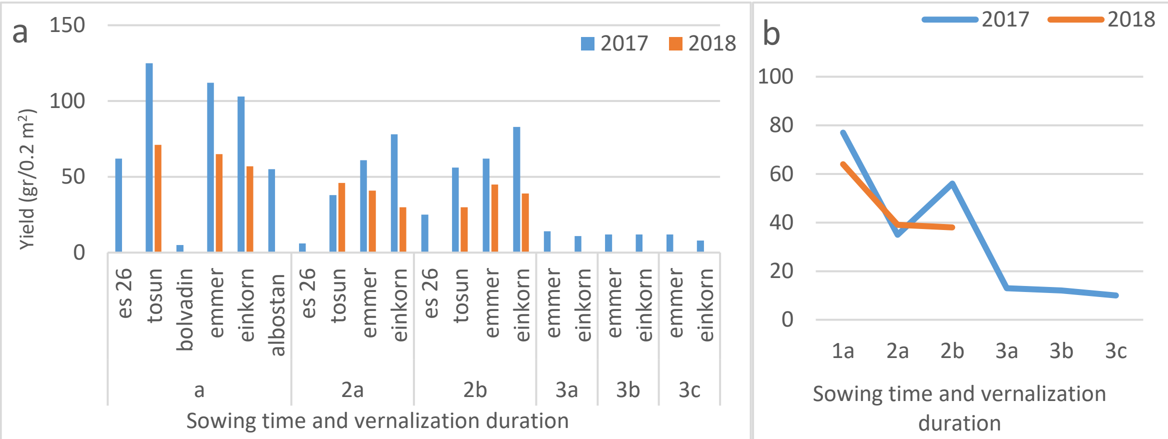

Figure 3. Wheat grain yield (gr/0.2 m^2) (a) and mean values (b) according to different sowing times and vernalization duration

Conclusion

Einkorn and Emmer completed their growth (reached the earing stage) in all of the sowing times. It can be said that these varieties have little chilling requirement or are able to meet it at higher temperatures. It seems that Einkorn and Emmer can be used as a good genetic resource for reducing the vernalization requirement in improvement and that satisfying yield can be obtained from Tosunbey until the middle of April under irrigated conditions. Of the varieties tested, Tosunbey, which has alternative growth properties, was considered to be the most suitable for wheat production in late spring sowing. In late sowing, the varieties with alternative growth properties proved to be a strong rival to spring varieties.

Conflicts of Interest

The authors declare no conflict of interest.

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