YIELD LOSS AFTER BELATED SOWING AND EFFECTIVENESS OF SEED VERNALIZATION IN WHEAT

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Abstract. Due to climate change, high temperatures during sensitive developmental stages of wheat, such as seedling emergence, flowering, and grain filling, have a negative impact on yield. This study aimed to evaluate the response of wheat cultivars to high temperatures through belate sowing and using vernalized seeds, at Isparta University of Applied Sciences, Türkiye. Sowing was carried out on three dates: a winter sowing date (mid-October) and two late sowing dates (April 4 and May 1). Only control seed was used for the winter sowing, while at the late sowing control and vernalized seeds (4 and 8 week) were used. Winter sowing, a common practice in the Mediterranean climate, produced the highest grain yield (mean 5.74 t ha^{-1}). The grain yield was 2.3 t ha^{-1} for sowing on April 4 and 1.3 t ha^{-1} for sowing on May 1, resulting in 60% and 77% yield reductions, respectively, for late sowings. Winter (WW) and alternate growth habit wheat (AW) cultivars responded differently to seed vernalization. Spring growth habit (SW) cultivars were not affected by seed vernalization treatments. The adaptability of the landrace cultivars, particularly regarding the sowing dates, was relatively higher. Seed vernalization has the potential to produce economically acceptable grain yields within a shorter growing season, and it can be considered as an alternative wheat cropping practice with appropriate cultivar selection.
Keywords: *growth habit wheat, vernalized seed, sowing time, wheat landraces*

Introduction

Wheat (*Triticum* L.) continues to be an assential crop for human nutrition (food security) and especially for countries struggling with famine, such as African countries. Global warming will negatively affect wheat production (Porter et al., 2014) in addition to many other negative seffects. Higher temperatures decrease the number of grains in the spike and grain filling period in wheat (Meehl et al., 2007). Even an increase of 1°C in global mean temperature will likely reduce the yield by an average of 6% (Asseng et al., 2015) and impair the performance of wheat cultivars currently used.

Therefore, it is essential to develop cultivars suitable for potential climatic changes (Tao et al., 2017). Low vernalization demand and low photoperiod sensitivity are crucial for adapting wheat to tropical regions (Bespalova et al., 2010). The development of cultivars with no photoperiod sensitivity began in 1968 at the International Maize and Wheat Improvement Center (CIMMYT) (Rajaram et al., 2002). As in many African countries, crop production research in ecological regions unsuitable for wheat has yielded very successful results recently (Clearinghouse, 2021). Increasing food demand and climate changes have led to the need to develop wheat cultivars with high heat resistance, cultivate outside the classical growth period, differentiate the growing periods, adapt to challenging growth conditions, and reduce the need for vernalization and photoperiod sensitivity. Despite having a large plant genome (He et al., 2019), the development of new wheat cultivars may seem complicated because of the lack of genetic characteristics.

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Late sowing is one of the methods that may be used to identify the types resistant to heat stress (Ni et al., 2018). Therefore, this study aimed to reveal the specific responses of the cultivars used in the experiment to late sowing and seed vernalization practices.

Material and methods

The research was carried out in the experimental field (37°50’26.1”N 30°32’10.6”E) of Isparta University of Applied Sciences during the 2017–2018 and 2018–2019 growing seasons. Wheat cultivars used in the experiment are listed in *Table 1*.

Table 1. *Wheat cultivars used in the experiment*

No	Cultivar	Species	Growth habit	No	Cultivar	Species	Growth habit
1	Bezostaja-1	*T. aestivum* L.	WW	14	Gap	*T. durum* Desf.	SW
2	Akbaşak	*T. durum* Desf.	WW	15	Gediz-75	*T. durum* Desf.	SW
3	Burgos	*T. durum* Desf.	WW	16	Kayra	*T. aestivum* L.	SW
4	Dumlupınar	*T. durum* Desf.	WW	17	Meta-2002	*T. aestivum* L.	SW
5	Gerek-79	*T. aestivum* L.	WW	18	Ç-1252	*T. durum* Desf.	AW
6	Kunduru-1149	*T. durum* Desf.	WW	19	Levante	*T. durum* Desf.	AW
7	Lütfübey	*T. aestivum* L.	WW	20	Tosunbey	*T. aestivum* L.	AW
8	Sarı Buğday	*T. durum* Desf.	WW	21	Zencirci-2000	*T. aestivum* L.	AW
9	Sönmez-2001	*T. aestivum* L.	WW	22	Einkorn[c]	*T. monococcum* L.	AW
10	Zerun	*T. aestivum* L.	WW	23	Emmer-1[a]	*T. dicoccon* (Shrank) Schübl	AW
11	Basribey-95	*T. aestivum* L.	SW	24	Emmer-2[b]	*T. dicoccon* (Shrank) Schubl	AW
12	Cumhuriyet-75	*T. aestivum* L.	SW	25	Gökala	*T. durum* Desf.	AW
13	Efe	*T. aestivum* L.	SW	26	Karakılçık	*T. durum* Desf.	AW

According to Atar (2020) landraces wheat are evaluated as alternate growth characteristics
[a]Spike color is white
[b]Spike color is brown
[c]Population

The experiment was set up in randomized blocks using a split-plot design with three replications. Sowing dates placed on the main plots were winter sowing in mid-October, April 4, and May 1. Non-vernalized seeds were used for winter sowing as a control. Late sowing treatments (April 4 and May 1) consisted of the control without vernalization, four weeks (28 days), and eight weeks (56 days) of vernalized seeds. Therefore, there were a total of seven different sowing treatments as a function of sowing time and vernalization combination (1WS, Winter sowing; 2AC, April 4 sowing – control; 2AV1, April 4 sowing – 28-day vernalization; 2AV2, April 4 sowing – 56-day vernalization; 3MC, May 1 sowing – control; 3MV1, May 1 sowing – 28-day vernalization; 3MV2, May 1 sowing – 56-day vernalization).

The experimental soil comprised 16% clay, 45% silt, and 39% sand. 200 kg/ha of composite fertilizer (Super Ekin™, 13-25-5 +10 (SO_3) + Zn (0.5)) was applied to all plots before sowing. In addition, 300 kg ha^{-1} Ammonium Nitrate (33-0-0) fertilizer was top-dressed to the plots during the tillering period (Feekes 3-5). The trial area was irrigated regularly (when it was not raining) by drip irrigation after manually controlling the soil moisture. Weed control was performed using a herbicide (HEKTAŞ ESTER’H®- 480 g/l 2,4-D acid equivalent to Isooctylesterelle). No other pesticides

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were sprayed because no disease or pest that could cause economic damage was detected. Climatic data during the experiment are given in *Table 2*.

Table 2. *Monthly and long-term mean temperature and precipitation during the wheat growing period*

Year/month		1	2	3	4	5	6	7	8	9	10	11	12
Temperature °C	2017									21.0	13.0	6.7	5.0
	2018	3.1	6.3	9.2	14.2	16.8	20.0	24.3	24.3	20.5	13.8	9.1	3.5
	2019	2.5	4.5	7.3	9.9	16.8	20.7	23.5	24.4				
	Long term	1.7	2.6	5.9	10.5	15.5	20.1	23.4	22.9	18.3	12.8	6.9	3.0
Precipitation mm	2017									5.7	46.5	41.7	31.9
	2018	89.2	32.2	69.3	6.3	63.1	69.4	4.1	14.2	1.6	31.8	48.6	107.1
	2019	97.0	55.4	40.3	50.8	34.2	53.3	9.5	2.7				
	Long term	81.0	68.2	58.9	51.2	55.9	35.6	15.6	14.2	18.4	37.8	44.3	86.4

Vernalization

Seeds were soaked in 2% sodium hypochlorite solution for 1 min for surface sterilization and immediately washed with distilled water. Seeds were soaked in distilled water for 5 h at room temperature (20-22°C) and placed in the refrigerator at 4°C after drying the surface (Midmore et al., 1982; Petr and Hnilička, 2002). Plastic seed containers were covered with cling film so that the seeds did not lose their moisture. Seeds were successively vernalized for 4 and 8 weeks (Ortiz-Ferrara et al., 1995; Bespalova et al., 2010; Luo and He, 2020). Control and vernalized seeds were sown at the sowing time mentioned above. Sowing was performed in 1.5 m long rows (450 seeds per m^2) (Petr and Hnilička, 2002). To clearly see the effect of vernalizations, the applications of the same cultivar were planted side by side (control, 28 days vernalization (DV), 56 days vernalization) at 20 cm intervals (Midmore et al., 1982). A gap of 1 m was left between the rows of the cultivars and 0.5 m on the row. The growth stages were recorded according to Feekes (Feekes 6, Feekes 11.4). These data were organized based on the number of days since sowing. Harvesting was done manually.

Statistical analysis

The obtained data were analyzed using the SPSS (Version 25.0, IBM SPSS Inc., USA) statistical package program. The treatment means were separated by Duncan’s multiple range test with the probability of error set at 0.05.

Results

According to the variance analysis results, no differences were found between the harvest index in the first year and Feekes 6 and 11.1 in the second year in terms of growth habit. In contrast, the other traits examined were found to be significantly different *Table 3*.

As acontrol, winter sowing demonstrated superiority over other treatments regarding plant height, biomass, and grain yield parameters in both years (*Table 4*). April 4 and May 1 sowings resulted in a 51-62% and 74-85% decrease, respectively, in biomass and grain yield compared with winter sowing. In addition, the effect of the vernalization treatments was negative, and plant height, biomass, and grain yield values were higher

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in the control treatment. The lowest value for the harvest index was obtained from sowing on April 4, followed by winter sowing and May 1 sowing. Vernalization treatments increased the harvest index compared with the control. The later the sowing date, the shorter the development time (Feekes 6 and Feekes 11.4). Shortening of the development time by vernalization treatments was evident every year (*Table 4*).

Table 3. *Values of mean square of variance analysis results in wheat*

		df	Plant height	Biomass	Grain yield	Harvest index	Feekes 6	Feekes 11.4
2017-18	Growth habit	2	12438**	4334379**	217950**	15^{ns}	23356**	31711**
	Sowing time	6	6421**	15452396**	1113196**	263**	140644**	184731**
	Variety	25	1555**	553059**	34362**	115**	129**	253**
2018-19	Growth habit	2	29968**	6140665**	122854**	6706**	5015^{ns}	7630^{ns}
	Sowing time	6	8580**	33232645**	2053927**	4289**	178551**	230443**
	Variety	25	3974**	761697**	101641**	424**	132**	136**

*, ** and ns: significant at 0.05, 0.01 and no significance, respectively

Table 4. *Wheat growth characteristics according to the sowing dates and vernalization applications*

	Plant height (cm)		Biomass (t ha^{-1})		Grain yield (t ha^{-1})		Harvest index (%)		Feekes 6 (days)		Feekes 11.4 (days)	
Sowing dates	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
1WS	86 a	90 a	19.4 a	26.2 a	5.0 a	6.5 a	26 ab	25 c	171 a	182 a	245 a	256 a
2AC	65 b	77 b	8.9 b	13.2 b	2.0 b	2.9 b	21 e	22 d	53 b	58 b	106 b	112 b
2AV1	64 b	77 b	7.3 c	12.0 c	1.7 c	2.6 c	21 e	22 d	48 c	49 d	104 c	109 c
2AV2	62 b	76 b	6.8 c	12.0 c	1.9 b	2.7 bc	25 bc	23 c	47 c	48 cd	103 c	107 d
3MC	52 c	64 c	5.4 d	5.2 d	1.5 d	2.3 d	25 bc	45 a	38 d	51 c	85 d	100 e
3MV1	50 d	45 d	4.2 e	2.8 f	1.1 e	1.2 f	24 d	41 b	30 e	49 d	81 e	96 f
3MV2	48 d	49 d	3.9 f	3.3 e	1.1 e	1.6 e	27 a	45 a	30 e	44 e	82 e	97 f

1WS, winter sowing; 2AC, April 4 sowing – control; 2AV1, April 4 sowing – 28-day vernalization; 2AV2, April 4 sowing – 56-day vernalization; 3MC, May 1 sowing – control; 3MV1, May 1 sowing – 28-day vernalization; 3MV2, May 1 sowing – 56-day vernalization

While there was no difference between AW and WW in plant height, biomass, and grain yield. These two species were significantly superior to SW (*Table 5*). However, SW had a higher yield than WW cultivars in the second year. The SW cultivars performed better than WW and AW with respect to the harvest index. The WW cultivars naturally had a longer duration for jointing and maturation times (Feekes 6 and Feekes 11.4) than the wheat cultivars with other growth habits. As expected, the duration of the growing phase (Feekes 6 and 11.4) was classified as WW, AW, and SW depending on the growing habit.

All cultivars may have different inherent potential yields. Therefore, significant differences were found between the cultivars regarding the traits analyzed in both years. During winter sowing, the highest plant height was found in the Gökala variety (130 cm) in the first year and the Karakılçık variety (115 cm) in the second year. The Gökala variety draws attention with its high plant height compared to other varieties in other sowing periods. In winter sowing, the Kunduru variety (25.6 t ha^{-1}) had the highest gross yield, and the Kayra variety (7.2 t ha^{-1}) had the highest grain yield in the first year. While

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Karakılçık variety (37.1 t ha^{-1}) had the highest gross yield, and the Zencirci variety (9.7 t ha^{-1}) had the highest grain yield in the second year. In spring sowings and vernalization applications, the Emmer variety was significantly superior to the other varieties in gross and grain yield in the first year. In the second year, the Kayra, Cumhuriyet 75, Einkorn and Emmer varieties yielded more than the others. In terms of harvest index, high values were found in Levanta and Tosunbey varieties in winter sowing in the first year, in the Cumhuriyet 75 variety in April 4 sowing, and in the Emmer variety in May 1 sowing. In the second year, the harvest index of different varieties was higher at different sowing times (*Tables A1* and *A2*). In winter sowing, the Gap variety was the earliest maturing variety in the first year and the Meta-2002 variety in the second year; in late sowing, the Sönmez-2001 and Zerun varieties were the earliest maturing varieties in the first year and the Meta-2002 variety in the second year. The Einkorn variety was the latest maturing variety in both years and sowing times. (*Table A3*).

***Table 5**. Wheat growth characteristics according to the growth habit*

	Plant height (cm)		Biomass (t ha^{-1})		Grain yield (t ha^{-1})		Harvest index (%)		Feekes 6 (days)		Feekes 11.4 (days)	
Growth habit	**2017-18**	**2018-19**	**2017-18**	**2018-19**	**2017-18**	**2018-19**	**2017-18**	**2018-9**	**2017-18**	**2018-19**	**2017-18**	**2018-19**
WW	70 A	81 a	10.3 a	14.2 a	2.5 a	2.9 b	24 ns	22 c	91 a	82 ns	152 a	143 ns
SW	55 B	56 b	7.9 b	10.5 b	1.9 b	3.2 ab	24 ns	36 a	60 b	70 ns	117 b	128 ns
AW	74 A	83 a	11.5 a	14.2 a	2.7 a	3.5 a	24 ns	28 b	71 b	77 ns	129 b	136 ns
Mean	66 B	73 A	9.9 B	13.0 A	2.4 B	3.2 A	24 B	29 A	74 B	76 A	133 B	136 A

Lowercase indicates the difference between growth habits. Capital letters indicate the difference between years. Identical letters means that there is no statistical difference between the means

Because some varieties could not meet the need for vernalization, some varieties did not reach maturity in late sowing and completed their development as hay. For both years, winter sowing facilitated all cultivars to achieve full maturity with their expected yield potential. In the first year, in April 4 sowing, 13 (Bezostaja-1, Akbaşak, Dumlupınar, Gerek-79, Kunduru-1149, Lütfübey, Sarı Buğday, Zerun, Ç-1252, Levante, Zencirci-2000, Gökala, Karakılçık), 5 (Bezostaja-1, Gerek-79, Sarı Buğday, Zerun, Gökala) and 8 (Bezostaja-1, Akbaşak, Dumlupınar, Gerek-79, Sarı Buğday, Zerun, Levante, Zencirci-2000) varieties did not develop in control, 28-day and 56-day vernalization treatments, respectively. In May 1 sowing, 15 (Bezostaja-1, Akbaşak, Dumlupınar, Gerek-79, Kunduru-1149, Lütfübey, Sarı Buğday, Sönmez-2001, Zerun, Gediz-75, Ç-1252, Levante, Zencirci-2000, Gökala, Karakılçık) in control treatment, 13 (Bezostaja-1, Akbaşak, Dumlupınar, Gerek-79, Kunduru-1149, Lütfübey, Sönmez-2001, Zerun, Gediz-75, Levante, Zencirci-2000, Gökala, Karakılçık) in 28-day vernalization treatment and 14 (Bezostaja-1, Akbaşak, Dumlupınar, Gerek-79, Kunduru-1149, Lütfübey, Sönmez-2001, Zerun, Gediz-75, Ç-1252, Levante, Zencirci-2000, Gökala, Karakılçık) in 56-day vernalization treatment. In the second year, April 4 sowing, 6 (Bezostaja-1, Akbaşak, Gerek-79, Lütfübey, Zencirci-2000, Karakılçık) cultivars did not develop in the control treatment, while all cultivars developed in 28- and 56-day vernalization treatments. In May 1 sowing, 16 (Bezostaja-1, Akbaşak, Burgos, Dumlupınar, Gerek-79, Kunduru-1149, Lütfübey, Sarı Buğday, Sönmez-2001, Gap, Ç-1252, Levante, Tosunbey, Zencirci-2000, Gökala, Karakılçık), 15 (Bezostaja-1, Akbaşak, Gerek-79, Kunduru-1149, Lütfübey, Sarı Buğday, Sönmez-2001, Zerun, Efe, Gap, Ç-1252, Levante, Zencirci-2000, Gökala, Karakılçık) and 14 (Bezostaja-1,

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Akbaşak, Burgos, Gerek-79, Kunduru-1149, Lütfübey, Sarı Buğday, Zerun, Gap, Gediz-75, Kayra, Meta-2002, Ç-1252, Levante, Zencirci-2000, Gökala, Karakılçık) varieties did not grow in control, 28, and 56-day vernalization treatments, respectively.

Discussion

The superiority of yield in winter sowing is evident from *Tables A1* and *A2*. This is primarily due to the critical need for a robust root system during early development stages (Feekes 1-5). The most suitable sowing time for wheat, a cool-climate cereal, is in late fall. Winter sowing promotes tillering and a strong root structure. contributing to higher yields when the vernalization requirement is met (Dirik and Sakin, 2018). However, April 4 (the second sowing time) represents an exceedingly late spring sowing in accordance with the climate characteristics of the Mediterranean climate. Indeed, *Table 4* clearly demonstrates the potential yield loss resulting from the delay in spring sowing. If spring sowing is postponed until the beginning of April or later, yield loss could be severe. As seen in previous research, SW cultivars exhibit relatively low and unstable yields (Zhao et al., 2018; Shourbalal et al., 2019). Winter sowing naturally took longer to reach the jointing (Feekes 6) and maturity (Feekes 11.4) stages than late sowing. However, vernalization applications, especially in the first year, expedited the development period of the plant in both late sowings (*Table 4*).

Elevated temperatures during sensitive developmental stages of wheat. such as seedling emergence, flowering, and grain filling have a negative impact on wheat development and yield (Páscoa et al., 2017). Delay in sowing exposes plants to heat stress during crucial stages such as pollination and grain filling (Asseng et al., 2011). Therefore, various yield components such as yield, biomass, harvest index, spike length, number of spikelets, and thousand-grain weight may decrease by as much as 50% in certain years (Maçãs et al., 2000; Zang et al., 2022). Using WW cultivars in late sowing would intensify yield loss even further. However, this study results draw attention to the exceptional performance of AW cultivars in late sowing. In the first year of the experiment, AW cultivars achieved a potentially higher yield than SW cultivars, and in the second year, their yield was on par with that of SW cultivars.

Sowing dates play a crucial role in determining the growth period length.. As expected, the Growing Degree Day (GDD) is critical for achieving developmental stages (McMaster and Wilhelm, 1997). The climate data from the experimental period revealed that daily temperature averages increased as the sowing date was delayed. However, vernalization treatments resulted in early development in both years and sowing periods compared with the control. This earliness varied between 3and 8 days (*Table A3*). Notably, there was a similarity in terms of earliness between the 28 DV and 56 DV applications.

In the Mediterranean climate zone, the most suitable sowing time for achieving optimum yield in SW cultivars is typically in February and early March (Baloch et al., 2012; Dixon et al., 2019; Tülübaş and Kara, 2019). A drawback of using spring cultivars for winter sowing is their vulnerability to damage in winter conditions. However, during this experiment. the winter conditions were not overly severe, and the average temperatures were higher than the long-term average, which prevented the SW cultivars from facing any climatic hazards and resulted in high yields. In late sowing during both years of the experiment, AW cultivars outperformed both WW and SW cultivars in terms of yield. Although SW cultivars achieved higher yields in the second

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year, they still fell behind AW cultivars. AW cultivars hold promise as a valuable genetic resource for improving WW and SW cultivars (Blake et al., 2011). Whether AW cultivars are closer to SW or WW should be evaluated on a variety basis (Atar, 2020). The alternative growth habit, a distinctive characteristic found in some landrace wheat, provides flexibility in substituting some failed winter sowing (Jaradat, 2013). By crossing WW and SW cultivars, new cultivars with superior genetic yield potential can be developed (Kant et al., 2001) to better adapt to various environmental stresses.

There is a correlation between growth habit and the need for vernalization (Ortiz-Ferrara et al., 1995). Although applying vernalization reduces the photoperiod sensitivity, the vernalization requirement and photoperiod sensitivity cannot compensate for each other (Miralles and Richards, 2000). The results of our study determined that the vernalization application promotes jointing and shortens the development period, which may have some advantages under extreme climatic conditions. Control groups tended to spread to the ground and tillering. Vernalization induces accelerated development (Bespalova et al., 2010), provides early flowering (Ortiz-Ferrara et al., 1995; Deng et al., 2015), reduces the number of days required for the spike stage (Petr and Hnilička, 2002), and increases the number of grains and yield per spike (Keçeli, 2006). While vernalization shortens the flowering and ripening period, it may negatively affect the yield (Ahmad et al., 2020). As in this study, Bespalova et al. (2010) reported that vernalization did not accelerate the development of spring cultivars. If the AW cultivars with low vernalization need to go from stagnation to growth at sudden high temperatures in winter, they are more likely to be damaged in the next cold weather. Therefore, the high photoperiod sensitivity of AW will prevent or reduce their damage in the above mentioned situations (Bespalova et al., 2010).

In the sowing treatments on April 4, vernalization contributed positively to the yield averages of WW cultivars in both years. Although the effect on SW cultivars was positive in the first year, this effect was not recorded in the second year. In the May 1 sowing, although some positive effects were observed for the WW cultivars in the first year. there was no positive effect in the second year. In the SW cultivars, the effect of vernalization was not evident in the first year but was negative in the second year. The effect of vernalization on AW cultivars was negative in all periods. The vernalization requirement of some wheat cultivars may be more than 60 days (Petr and Hnilička, 2002; Xu and Chong, 2018), which may be the reason why some cultivars did not develop on April 4 and May 1 sowing dates. SW or AW cultivars require little or no vernalization. However, due to this study showed, there was a serious decrease in the yield as the sowing was delayed.

The response of genotypes to vernalization can change to a large extent (Tao et al., 2022). In this study, some cultivars responded differently to environmental factors, mainly climatic, in different years. For example, the Bezostaja-1 cultivar was unresponsive to vernalization in the first year but showed a marked response on April 4 sowing in the second year. Vernalization responses of the Zencirci, Gerek 79, and Lütfibey cultivars were apparently high. This positive effect was clearly recorded, especially in the sowing on April 4 with 56 DV (*Fig. 1*). Landrace wheat, such as Emmer, Einkorn, and Akbaşak, did not respond to vernalization, did not provide earliness, and even plant height (data were not given) was adversely affected. The varying responses of cultivars to vernalization and environmental conditions emphasize the importance of considering genotype-specific characteristics and climatic variations while making planting decisions and conducting experiments in different years.

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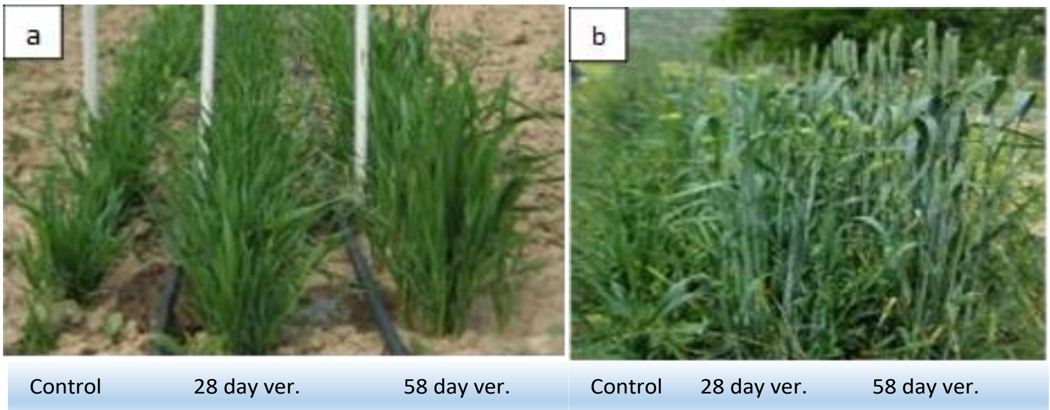

Figure 1. *Effects of wheat vernalization applications in different development stages at April 4th sowing: tillering (a) and heading (b)*

Einkorn wheat needs vernalization even if it is very low (Dubcovsky et al., 2006). Still, it can meet this requirement in every period of sowing in the Mediterranean climate zone, in other words, at higher temperatures (10-15°C). It is possible to say that the need for vernalization of the Emmer is negligibly trivial compared with that of the Einkorn, and the photoperiod sensitivity is extremely low in both cultivars (Atar, 2020). In this study we observed that Emmer (white ear) has a serious yield potential, even in the May 1 sowing and control application. This was more pronounced in the second year (*Table 2*), which was more stressful regarding climate than the second year. The Tosunbey variety, which has been developed in recently, draws attention to its similarity to Einkorn and Emmer in terms of growth characteristics. Today, new cultivars are being developed by transferring valuable genes from wild-type wheat to modern cultivars with engineered lines (Lage and Trethowan, 2008). Landrace wheat cultivars, especially Einkorn and Emmer, continue to be a very valuable genetic source for breeding new lines and cultivars.

Conclusions

In the Mediterranean climate zone, the use of WW cultivars is unquestionably accepted, necessitating sowing in the late fall. However, in special cases (inability to sow in winter, renewal of winter sowing, failure to meet vernalization, second crop, etc.), the evaluation of AW cultivars should be considered alongside SW cultivars. The AW cultivars may be good alternatives to SW cultivars in terms of yield and quality, in places where the winter is relatively moderate. In late sowing, vernalization can be used effectively depending on the variety.

AW cultivars could be a feasible source for the development of winter wheat and spring wheat cultivars. Responsive wheat cultivars to late sowing and pre-vernalized seed should be screened to select economically feasible lines and/or cultivars.

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APPENDIX

Table A1. *Wheat variety growth characteristics (2017-18)*

		1WS				2AC				2AV1				2AV2				3MC				3MV1				3MV2			
No	**Variety**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**	**Plant height (cm)**	**Gross yield (t ha^{-1})**	**Grain yield (t ha^{-1})**	**Harvest index (%)**
1	Bezostaja-1	80	18.4	4.65	25					60	1.57																		
2	Akbaşak	98	16.4	4.82	29					63	7.75	1.50	20	50	1.56														
3	Burgos	75	20.3	4.90	24	55	5.71	1.60	28	55	4.50	0.91	20	60	4.90	1.50	31	42	4.27	0.84	20	42	4.27	1.36	32	42	4.89	1.05	21
4	Dumlupınar	96	16.8	3.45	21					66	4.72	1.32	28	50	2.17							52	4.07						
5	Gerek-79	87	18.4	4.00	22																								
6	Kunduru-1149	120	25.6	6.30	25					83	8.75	1.43	16	66	4.38	0.73	17												
7	Lütfübey	82	16.7	3.87	23					54	6.11	1.18	19	50	3.45	0.84	25												
8	Sarı Buğday	86	19.9	6.09	31					58	1.57			35	1.50							44	4.04	0.74	19	44	1.63	0.53	33
9	Sönmez-2001	90	21.2	5.90	28	68	5.75	5.7	10	68	5.75	0.82	14	68	4.62	1.45	31	43	2.55			43	3.12			43	2.57		
10	Zerun	97	18.1	4.77	27	56	6.25			56	6.25			56	6.25			44	1.84			44	1.96			44	2.05		
11	Basribey-95	68	17.6	5.08	29	46	8.00	1.40	17	46	8.88	1.45	16	46	8.63	2.50	29	38	3.52	1.13	32	38	4.12	1.28	31	38	3.78	1.24	33
12	Cum-75	80	16.7	4.22	25	64	5.00	1.47	30	71	4.75	1.75	37	60	3.33	1.02	31	55	4.40	0.87	20	50	5.38	0.96	18	46	4.11	0.73	18
13	Efe	67	17.2	4.75	28	56	9.00	1.75	19	56	9.44	1.50	16	56	8.70	2.48	29	45	3.57	1.05	29	45	3.17	0.88	28	45	3.12	0.92	30
14	Gap	66	15.4	3.88	25	58	10.77	2.08	19	58	11.50	2.28	20	58	7.57	1.40	19	53	10.00	2.29	23	53	7.77	1.03	13	53	4.43	1.40	32
15	Gediz-75	80	20.8	5.62	27	53	6.78	1.21	18	47	4.97	1.23	25	47	4.33	1.33	31	42	3.05			40	2.37			40	2.63		
16	Kayra	88	23.8	7.20	30	62	7.00	1.00	14	62	3.50	0.73	21	62	7.37	2.21	30	51	4.10	0.95	23	51	5.12	1.18	23	51	4.55	1.05	23
17	Meta-2002	65	12.7	3.55	28	53	7.50	1.50	20	53	8.33	1.37	16	50	7.49	2.36	31	50	4.68	1.12	24	50	4.18	0.80	20	50	5.35	1.28	24
18	Ç-1252	79	20.5	4.50	22					64	7.77	2.77	36	64	8.81	2.74	31					42	4.59	1.40	31				
19	Levante	85	21.4	6.90	32					53	7.77	1.75	23																
20	Tosunbey	90	19.1	6.08	32	78	10.50	2.47	24	74	6.83	2.14	31	74	11.07	3.05	28	54	5.23	1.32	25	54	5.77	1.07	19	54	5.11	1.34	26
21	Zencirci-2000	85	18.5	5.17	28					65	4.21	0.50	12																
22	Einkorn	70	24.9	3.80	15	92	12.50	3.50	28	92	13.50	3.12	23	92	12.50	2.74	22	60	8.94	1.30	15	44	5.37	0.80	15	40	4.20	0.70	17
23	Emmer-1a	85	19.8	4.15	21	85	13.90	4.04	29	85	15.50	3.78	24	85	15.55	3.22	21	83	13.00	3.15	24	75	5.89	1.89	32	75	7.78	2.16	28
24	Emmer-2b	80	21.8	5.75	26	86	16.00	2.78	17	80	13.12	2.49	19	87	14.00	2.31	17	70	6.38	2.22	35	55	3.38	0.98	29	55	3.00	1.06	35
25	Gökala	130	24.4	5.60	23									86	3.66	0.53	15					68	2.00						
26	Karakılçık	105	18.2	3.92	22					55	8.16	0.66	8	65	7.57	1.78	24					52	2.45			54	3.21		

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Table A2. *Wheat variety growth characteristics (2018-19)*

		1WS				2AC				2AV1				2AV2				3MC				3MV1				3MV2			
No	Variety	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	Plant height (cm)	Gross yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)
1	Bezostaja-1	105	35.9	8.37	23					76	8.23	0.41	5	76	12.00	1.70	14												
2	Akbaşak	68	21.9	5.70	26					75	10.75	1.50	14	75	13.75	1.12	8												
3	Burgos	85	32.2	8.87	28	70	13.05	1.36	10	65	12.87	2.62	20	70	13.29	1.81	14					45	1.50	0.83	55				
4	Dumlupınar	103	25.3	6.18	24	96	14.68	1.81	12	98	15.43	2.56	17	98	13.00	2.43	19					55	0.33	0.14	42	48	0.55	0.27	49
5	Gerek-79	91	19.6	4.03	20					85	11.93	1.12	9	85	9.75	1.75	18												
6	Kunduru-1149	110	34.0	9.44	28	101	10.64	1.63	15	105	13.82	2.05	15	105	12.70	1.94	15												
7	Lütfübey	78	16.3	4.73	29					74	13.00	3.12	24	72	7.64	2.14	28												
8	Sarı Buğday	88	28.4	7.76	27	72	11.87	1.87	16	70	12.20	2.93	24	65	11.50	2.50	22												
9	Sönmez-2001	92	22.3	7.18	32	84	12.44	1.15	9	85	9.62	1.50	16	83	13.75	2.31	17									38	0.83	0.41	49
10	Zerun	107	22.1	5.73	26	98	16.11	1.47	9	79	11.30	1.23	11	80	12.82	1.64	13	80	2.63	1.05	40	30	0.70		0	44	0.90		0
11	Basribey-95	63	15.8	4.46	28	44	9.31	3.28	35	44	9.28	3.10	33	44	8.55	2.99	35	28	3.30	1.66	50	24	1.66	0.83	50	24	2.72	1.36	50
12	Cum-75	82	21.1	5.65	27	60	9.45	2.36	25	65	17.25	4.58	27	60	7.35	1.89	26	78	2.91	1.44	49	45	0.83	0.41	50	56	4.40	2.18	49
13	Efe	94	26.5	7.25	27	73	11.53	2.83	25	73	15.53	3.68	24	73	10.46	2.38	23	54	1.66	0.83	50					40	1.25	0.62	49
14	Gap	80	33.6	8.16	24	56	11.75	3.62	31	55	12.50	3.20	26	61	13.88	3.44	25												
15	Gediz-75	76	32.4	9.47	29	63	9.68	1.47	15	60	5.83	2.12	36	60	10.11	3.00	30	52	5.43	2.50	46	8	0.71	0.31	44				
16	Kayra	79	23.6	7.36	31	68	17.85	6.21	35	68	10.35	3.61	35	68	15.07	4.85	32	69	9.09	4.54	50	30	3.33	1.66	50	52	5.45	2.70	50
17	Meta-2002	74	16.8	5.32	32	56	11.00	3.69	34	56	12.57	4.14	33	50	11.64	3.90	34	36	2.22	1.01	46	25	2.22	0.99	45	35	2.22	1.11	50
18	Ç-1252	96	23.4	4.86	21	70	13.65	2.67	20	70	8.55	0.88	10	70	12.43	2.62	21									20	0.33	0.16	48
19	Levante	95	30.9	8.24	27	52	3.55	0.94	26	55	11.11	2.29	21	60	8.00	1.85	23												
20	Tosunbey	73	23.2	6.26	27	78	15.26	4.86	32	74	10.21	3.64	36	74	14.45	5.07	35					30	0.62	0.31	50	35	0.62	0.31	50
21	Zencirci-2000	110	35.9	9.66	27					83	11.17	1.11	10	83	9.62	1.87	19												
22	Einkorn	96	23.3	3.13	13	95	20.50	5.50	27	95	12.83	4.20	33	95	13.68	4.87	36	88	9.62	3.75	39	84	8.93	2.99	34	82	7.50	3.12	42
23	Emmer-1a	85	26.8	4.62	17	95	16.55	3.86	23	95	14.71	4.28	29	90	13.50	4.21	31	80	5.55	2.22	40	82	7.77	2.77	36	82	6.85	3.71	54
24	Emmer-2b	80	27.6	4.68	17	88	20.17	4.83	24	88	14.50	4.42	31	88	13.91	4.28	31	76	10.00	3.57	36	82	5.00	1.87	38	80	9.16	3.57	39
25	Gökala	108	24.3	5.06	21	115	15.38	1.94	13	116	14.08	2.41	17	110	17.14	2.85	17												
26	Karakılçık	115	37.1	7.48	20					90	13.00	1.66	13	93	10.75	1.62	15												

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Table A3. *Days from sowing to Feekes 6 and 11.4 (2017-18/2018-19)*

		2017-18														2018-19													
		1WS		2AC		2AV1		2AV2		3MC		3MV1		3MV2		1WS		2AC		2AV1		2AV2		3MC		3MV1		3MV2	
No	Vaariety	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 114	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4	Feekes 6	Feekes 11.4
1	Bezostaja-1	171	234			57	110									174	254			51	108	45	106						
2	Akbaşak	172	241			46	100	47	101							190	259			45	113	53	110						
3	Burgos	169	237	51	104	46	96	47	101	40	83	35	80	34	80	177	254	58	113	47	107	47	106			48	95		
4	Dumlupınar	170	266			45	100	46	100			29	80			178	258	57	109	48	110	48	110			48	94	49	95
5	Gerek-79	173	267													187	260			53	109	53	106						
6	Kunduru-1149	166	239			46	106	48	108							178	259	59	111	47	113	47	106						
7	Lütfübey	172	243			55	108	47	109							179	243			46	110	45	107						
8	Sarı Buğday	171	241			48	104	44	102			27	81	28	79	181	258	57	110	51	111	44	109						
9	Sönmez-2001	170	238	55	102	50	99	49	99	41	82	29	79	28	80	179	254	48	110	51	107	46	106					41	95
10	Zerun	162	266	48	105	45	99	45	99	34	82	28	79	27	79	189	257	57	112	51	108	51	105	54	100	50	97	49	98
11	Basribey-95	173	245	53	105	46	102	46	102	34	86	27	83	28	81	181	252	58	114	49	107	49	106	53	101	51	95	41	94
12	Cumhuriyet-75	173	244	54	107	46	105	46	104	39	85	30	82	29	82	180	258	58	115	46	108	48	108	53	103	50	98	46	97
13	Efe	173	249	53	105	45	103	46	102	36	85	28	83	27	82	172	250	58	113	46	109	45	107	46	100			43	104
14	Gap	170	232	52	106	45	102	45	102	36	85	30	82	29	81	173	255	59	117	50	109	45	107						
15	Gediz-75	171	234	54	108	45	106	44	105	36	83	28	80	28	81	175	254	53	115	46	112	46	108	51	95	50	98		
16	Kayra	171	244	53	106	46	104	46	104	34	86	27	82	26	82	179	256	56	113	47	108	45	108	46	98	51	97	39	96
17	Meta-2002	174	246	53	104	47	100	46	99	37	84	30	82	29	84	181	240	59	105	46	100	46	100	53	98	50	97	42	94
18	Ç-1252	174	242			46	105	46	104			33	80			180	258	59	114	51	108	47	108					43	96
19	Levante	170	240			48	106									180	254	58	111	45	108	45	107						
20	Tosunbey	170	266	56	109	49	106	50	106	36	82	31	79	28	80	191	258	60	115	53	111	53	108			50	97	50	96
21	Zencirci-2000	169	235			60	110									171	256			55	112	48	109						
22	Einkorn	176	256	65	111	58	111	61	109	47	93	39	89	42	89	205	276	69	118	58	115	58	115	52	108	46	106	46	106
23	Emmer-1a	169	243	47	106	39	104	47	103	37	86	32	83	30	84	191	262	57	108	51	106	54	107	51	98	44	85	44	95
24	Emmer-2b	173	240	48	106	41	102	41	101	40	87	28	84	27	84	193	262	56	110	51	108	53	108	50	97	44	95	44	94
25	Gökala	165	241					47	107			32	79			188	260	55	110	44	111	48	107						
26	Karakılçık	169	237			49	101	47	100			34	79	33	80	180	256			48	106	45	102						

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