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The Evaluation of Photosynthetic Characteristics and Seed Yield of Wheat with Different Growth Habits at Different Planting Dates

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Abstract

In recent decades, the introduction of high-yielding cultivars under optimal conditions has been the main focus of grain research programs. The identification of wheat cultivars that have acceptable yields on different planting dates has been taken into account. The present split-plot test was performed with three replications in two periods, 2016-2017 and 2017-2018. The main factor included three planting dates (October 20, November 20, and December 20 as early, normal, and delayed planting dates), and the sub-factor included six wheat cultivars (Zare and Heidari with winter growth habits, Pishgam and Alvand with intermediate growth habits, and Sirvan and Pishtaz with spring growth habits). The results indicated that delay in planting reduced the soil plant analytical development, the ratio of variable chlorophyll to maximum chlorophyll, and chlorophyll content. In 2018-2017, the soil plant analytical development was significantly higher in Zare and Heidari cultivars with winter growth habits than Sirvan and Pishtaz cultivars with spring growth habits. The highest total chlorophyll content was observed in cultivars with winter and intermediate growth habits, but cultivars with spring growth habits showed lower total chlorophyll content. Delay in planting decreased the number of spikes in different wheat cultivars, but this reduction was greater in cultivars with winter growth type. In delayed planting, intermediate and spring cultivars had a higher number of seeds. On October 20 and November 20, the highest seed yield was obtained in cultivars with winter and intermediate growth habits during 2016-2017 and 2017-2018. The results indicated that the seed yield was higher in early planting, especially in cultivars with winter growth type, but the intermediate and spring cultivars had higher seed yield in delayed planting.

Keywords: Growth type; Seed yield; Chlorophyll content; Harvest index

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Introduction

In many developing countries, agriculture is a key socioeconomic stimulus and one of the most important sources of employment and income. Given that 83 million people are added to the world's population each year, it is estimated that the total food demand will increase up to 40% by 2030 and up to 70% by 2050 [1]. One of the most growing crops to meet this demand is wheat, which (after rice) is considered as the second most important food source in developing countries because it provides more calories and protein (20%) than any other crop [2]. Wheat demand is expected to be increased by 60% [3].

Wheat plays a main role in human nutrition in terms of nutritional value and is particularly important due to its high share in the diet of people worldwide [4]. Cultivation of this plant is possible in many regions of the world and different climates, but the environmental pattern change has caused a decline in crop yield over years. However, a part of this yield loss can be reduced by adopting proper management methods such as proper planting dates, cultivars, fertilizers, and irrigation [5]. Therefore, techniques such as planting adaptive cultivars, the study of physiological reactions, evaluations on various planting dates, and other conditions, which provide further development of planting in arid and semi-arid areas, will be effective [6]. The producers have continuously improved the quality of wheat by focusing on factors affecting seed yield, and more recently, the quality of technology. The quality of wheat, which is ideal for processing various food products, has been improved by careful research studies on proteins [7]. In recent decades, the main focus of grain breeding research programs has been on the introduction of high-yielding cultivars under optimal conditions. Therefore, the breeding programs have focused on the identification and introduction of autumn wheat cultivars that have acceptable yields on different planting dates [8]. The economic importance of grains, especially wheat, requires the evaluation and application of any strategy to optimize the production system of this crop [9].

It is predicted that unforeseen periodic events as a result of climatic changes will affect phenology and growth that will threaten sustainable production [10]. Crop studies conducted in specific locations for specific seasons are intensive and challenging topics that include the impact of climate change, crop management practices, and genotype selection in specific environments [11]. Therefore, choosing the right planting date is a proper way to use the genetic capacity of cultivars [12]. Choosing the appropriate planting date in different regions is very important due to the variety of environmental conditions for different years and different responses of different cultivars [13]. Early wheat planting increases the production of infertile tillers, and the plant is at risk of frostbite, and a large number of florets become sterile due to spiking early varieties in the autumn [14]. The late planting reduces tillering and thus decreases the density of fertile stems and reduces the length of each growth stage, thereby reducing the absorption of solar radiation [15]. Therefore, the effect of planting date on wheat production is well known, and it changes yield that is important for the development of sustainable agriculture [16].

Accordingly, improving various quantitative and qualitative yield indices by determining an appropriate planting date is crucial for production. Research reports indicate that a proper planting date has successful effects on the quantity and quality of yield under a normal situation. Lack of knowledge about appropriate cultivars and planting date decreases yield per unit area. Due to inappropriate planting time resulting from the climatic change in most regions, the plant does not have enough time to grow properly [17]. Therefore, the successful production of wheat provides full knowledge about the phenology of different stages and depends on favorable environmental conditions. Therefore, better management of planting dates in cultivars with different growth types is a part of innovation in the present research that can be useful from the perspective of wheat seed producers. The present study evaluated the photosynthetic characteristics and yield of wheat with different growth habits on different planting dates. The results of some research related to the subject are as follows. Zhang states that straw mulch reduces soil moisture and makes less than 60% of farm capacity improves for crops cultivation for 2 to 10 days as a result of reducing soil moisture days [18]. Straw mulch increases the net photosynthetic rate, stomatal conductance, maximum carboxylation rate (V_{cmax}) and maximum photosynthetic electron transfer rate (J_{max}) of flag leaves, especially in post-flowering measurements during which the above parameters increased up to 20.6%. Compared to pre-pollination measurements, the values of V_{cmax} and J_{max} decreased after pollination, but the reduction percentage was around SM 10.8-25.7% for V_{cmax} and 22.0% -49.6% for J_{max} less than N conditions. On the other hand, it can be stated that about 41.4% for V_{cmax} and 29.3% -61.3% for J_{max} V_{cmax} and Jmax had a significant linear correlation with leaf nitrogen content and the relationships between them were not affected by mulch.

Anjum states that hybrid conditions were more suitable for low irrigation and in general the biological and seed yields were significantly affected by the moisture regime and they started to produce the crop [19]. In this case, the conditions, planting date, and irrigation regime were investigated in order to measure their effects on soil crop production (SPAD), and chlorophyll a and b content were also considered for carotenoids. Planting dates and irrigation regimes had significant effects on Relative Water Content (RWC), Water Saturation Deficiency (WSD), Water Uptake Capacity (WUC), and water retention capacity (WRC). However, only the WUC differed significantly among all cultivars. Phenological data show that hybrid cultivars have more days for ripening and seed growth than the local cultivar.

Shafiqi states that based on the results of the study, late-season drought stress and delay in planting date reduce the Relative Leaf Water Content (LRWC), total chlorophyll content, Proline, and grain yield and increase the Stomatal Resistance (SR), Canopy temperature and Leaf Soluble Carbohydrates (CLS). The highest grain yield (4505.6 kg/ha) was obtained under NI and PD1 conditions. The significant interaction of planting date, irrigation and cultivar on LRWC, SR, and CLS showed that ES Hydromel cultivar was the most tolerant hybrid cultivar with the highest LRWC and the lowest levels of SR and CLS compared to other cultivars in unfavorable conditions.

Sedri states that having access to water and nutrient management are two important factors that affect high yield, high quality wheat production [20]. The main and interaction effects of nitrogen and potassium fertilizers on quantitative-qualitative characteristics and drought tolerance of Iranian dry land wheat cultivar Azar-2 were evaluated. Four levels of nitrogen (N0, N30, N60 and N90 kg/ha), along with four concentrations of potassium (K0, K30, K60, and K90 kg/ha), were applied in dry land (drought stress) and without stress. N × K interaction conditions on nitrogen and grain protein content were significant at 5% and 1% probability levels, respectively. Different trends of SSI, STI, K1STI and K2STI indices were observed with interactive levels of nitrogen and potassium. The lowest SSI index (0.67) was observed in N30 K30, while the highest STI (1.07), K1STI (1.46) and K2STI (1.51) were observed by N90 K60 and N90 K90.

Huang states that the results of factors affecting plant cultivation conditions showed that flooding occurred in stage V6 has the greatest impact on corn growth and grain yield, followed by V3, VT and R3 stages, and that weight of 100 seeds in the corn has the greatest effect on corn growth. Grain yield and other indices affected corn yield by affecting 100 grain weight per cob [21].

Materials and methods

Designing tests and treatments

The present split-plot was conducted with three replications in Mobarakeh, Iran, at a longitude of 51 o49' E, latitude of 32 o34' N, and altitude of 1680 m during two time periods, 2016-2017 and 2017-2018. The main factor includes three planting dates (October 20, November 20, and December 20 as early, normal, and delayed planting dates), and the sub-factor includes six wheat cultivars (Zare and Heidari with winter growth habits, Pishgam and Alvand with intermediate growth habits, and Sirvan and Pishtaz with spring growth habits).

Experiment

Before the experiment, we took samples from a 0 to 30 cm depth of soil and detected the physical and chemical properties of the soil (Table 1).

Table 1: The soil physical and chemical analysis.

Year	Depth (cm)	Texture	EC (dS/m)	pH	O.C	TNV (%)	N	P	K	Mn mg kg^{-1}	Fe	Cu	Zn
2016-2017	0-30	Loam Silty	1.3	7.8	0.87	28	0.09	9.3	168	4.1	5.4	2.1	1.9
2017-2018	0-30	Loam Silty	1.2	7.8	0.91	30	0.06	10.2	182	3.6	4.7	1.6	2.2

TNV: Total Neutralizing Value; OC: Organic Carbon.

The amounts of rainfall and the average minimum and monthly temperatures during the test. Earth preparation steps were performed before the experiment. To this end, an area of 1,500 m^2 was ploughed with a mould-board plough, and then discs were used, and the land was leveled. Fertilizer was utilized based on soil test results as 100 kg/ha of triple superphosphate, 100 kg/ha of potassium sulfate, and 100 kg/ha of urea before planting. The rest of the urea fertilizer (200 kg/ha) was applied as top-dressing at stem elongation and the beginning of wheat flowering stages.

Iron, zinc, and manganese fertilizers were also used from their sulfate sources at the rate of 0.2% that was sprayed at two stages at the beginning of stem elongation and the beginning of spiking. Each plot was 5 m long and 2 m wide and consisted of eight planting rows at a distance of 25 cm. A distance of 50 cm was considered between the two sub-plots and 1 m between the two main plots. The number of seeds for each experimental plot was determined and distributed based on the density of 400 seeds per square meter and based on the 1000 seeds weight of each cultivar. Irrigation was performed immediately after planting. All agricultural care, including pest, disease, and weed control, was applied uniformly. In each subplot, we considered 50 cm from the beginning and end of the rows as the margin.

Trait measurement

Amounts of photosynthetic indices: Photosynthetic indices were measured from fully developed young leaves at the flowering stage.

The Soil Plant Analytical Development (SPAD) index was measured, five leaves were selected from each plant and the index was measured using SPAD-502, made in Japan. The fluorescence chlorophyll was measured using chlorophyll fluorimeter, model hansatech LTD pocket PEA, made in England. To this end, the plant leaves were protected from sunlight to adapt to the darkness using special clamps for 15 min. Thereafter, the device sensor was put inside the clamps and the ratio of variable fluorescence to maximum fluorescence (FV/FM) was recorded.

Chlorophyll a, b, and total chlorophyll (Chlorophyll a+b) content was measured using Arnon's method by random sampling of mature leaves and extraction with acetone. Optical absorption was read using a spectrophotometer Vis 2100, made in the USA, at 645 and 663 nm. Finally, their values were calculated according to Equations 1 to 3 [22].

Chlorophyll a=)mgg^{-1})=(12.7 × OD.663)-(2.69 × OD.645) × V/1000 × W (Equation 1)

Chlorophyll b=)mgg^{-1})=(22.9 × OD.645)-(4.68 OD.663) × V/1000 × W (Equation 2)

Chlorophyll a+b=)mgg^{-1})=(8.02 × OD.663)+(20.2 × OD 645) × V/1000 × W (Equation3)

Where, V: sample size, OD: Optical Density, W: Wet weight.

Vegetative traits and yield: To determine the plant height, 10 plants were randomly selected in the middle line of each plot, and their mean was calculated after necessary measurements. One square meter of the ground floor was used to measure the biological yield of plants, and the whole plants were weighed. Yield and its components were measured by separating seeds and weighing seed yield based on 12% moisture. The number of seeds in each spike was also counted. Harvest index was obtained through dividing seed yield by biological yield in percentage. The soluble carbohydrates of stems were measured at the flowering stage using Nelson's method and protein content by Novozamsky's method [23,24]. To this end, the amount of seed nitrogen was first calculated using Kjeldahl and then was multiplied by 6.25 to measure the seed protein.

Statistical analysis: The variance of data was analyzed for different tests using SAS 9.1 and data mean was compared using Duncan's test at 5% probability level.

Results and Discussion

The planting date and cultivar had significant effects on SPAD, chlorophyll fluorescence, chlorophyll a, b, and total chlorophyll content, but the interaction of planting date and cultivar did not affect the traits (Table 2).

Table 2: Analysis of variance for the effects of planting date and cultivar on the amount photosynthetic pigments of wheat.

year	Source of variation	df	SPAD value	Fv/Fm	Chla	Chlb	Chla+b
2016-2017	replication	2	34.58**	0.001**	2.68**	0.567**	0.887**
	Planting date	2	102.22**	0.009**	0.617**	0.314**	1.813**
	Error 1	4	8.46	0.0004	0.044	0.067	0.05
	cultivar	5	3.35 ns	0.00007 ns	0.014 *	0.017 **	0.055 **

	interaction	10	2.41 ns	0.0001 ns	0.102 ns	0.001 ns	0.016 ns
	Error 2	30	3.53	0.0001	0.005	0.005	0.015
	CV (%)		3.81	8.35	3.28	6.34	11.21
2017- 2018	replication	2	65.35**	0.00006 ns	0.888**	0.217**	0.252**
	Planting date	2	97.41**	0.011**	0.618**	0.694**	0.620**
	Error 1	4	10.42	0.001	0.023	0.041	0.109
	cultivar	5	12.18 ns	0.00006 ns	0.034**	0.035**	0.123**
	interaction	10	5.34 ns	0.0002 ns	0.007 ns	0.003 ns	0.010 ns
	Error 2	30	3.63	0.0002	0.009	0.007	0.02
	CV (%)		3.86	4.24	9.87	7.9	9.24

Ns, * and**: Not-significant and significant at 5% and 1% error probability, respectively.

Furthermore, the effects of planting date, cultivar, and their interaction affected height, the number of spikes, the number of seeds, 1000 seeds weight, biological yield, seed yield, harvest index, and seed protein.

Soil Plant Analytical Development (SPAD) and chlorophyll fluorescence

Delay in planting decreased the soil plant analytical development (SPAD) so that the rate of decrease in SPAD index on December 20 compared to October 20 in 2016-2017 and 2017-2018 was 9.2 and 8.9 percent, respectively. The SPAD index rates did not show any statistically significant difference on the planting dates of October 20 and November 20 (Table 3). Furthermore, the SPAD index was significantly higher in Zare and Heidari cultivars with winter growth habits in 2017-2018 than Sirvan and Pishtaz cultivars with spring growth habits.

Table 3: Comparison of mean interactions of planting date on amount photosynthetic pigments of Wheat (2016-2017 and 2017-2018).

Planting date	SPAD value		Fv/Fm		Chlorophyll a (mg g-1 leaf fresh weight)		Chlorophyll b (mg g^{-1} leaf fresh weight)		Chlorophyll a+b (mg g^{-1} leaf fresh weight)	
	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018
20 October	51.46^{a}	51.59^{a}	0.727^{a}	0.733^{a}	2.51^{a}	2.51^{a}	1.29^{a}	1.25^{a}	3.80^{a}	3.74^{a}
20 November	49.53^{a}	49.64^{ab}	0.693^{b}	0.711^{ab}	2.36^{a}	2.35^{a}	1.20^{ab}	1.09^{a}	3.56^{b}	3.44^{a}
20 December	46.72^{b}	46.96^{b}	0.684^{b}	0.684^{b}	2.14^{b}	2.12^{b}	1.03^{b}	0.86^{b}	3.17^{c}	2.98^{b}

Means followed by the same letters in each column are not significantly different by Duncan test at 5% probability level.

With a delay in planting, the ratio of variable fluorescence to maximum fluorescence (FV/FM) of wheat showed a decreasing trend. The highest value of FV/FM was observed in 2016 -2017 and 2017-2018 on the planting date of October 20, indicating an increase of 6.2% and 6.6%, respectively, compared to December 20. The ratio of variable fluorescence to maximum fluorescence was not significantly different in different wheat cultivars (Table 4).

Table 4: Comparison of mean interactions of cultivar on amount photosynthetic pigments of Wheat (2016-2017 and 2017-2018).

Cultivar	SPAD value		Fv/Fm		Chlorophylla (mg g^{-1} leaf fresh weight)		Chlorophyll b (mg g^{-1} leaf fresh weight)		Chlorophyll a+b (mg g^{-1} leaf fresh weight)	
	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018
Zare	49.6 4^{a}	50.85^{a}	0.704^{a}	0.710^{a}	2.33^{ab}	2.33^{abc}	1.19^{ab}	1.13^{a}	3.52^{ab}	3.46^{a}
Heidari	49.8 6^{a}	50.32^{ab}	0.702^{a}	0.713^{a}	2.33^{ab}	2.34^{ab}	1.22^{a}	1.13^{a}	3.56^{a}	3.47^{a}
Pishgam	49.46^{a}	49.91^{ab}	0.704^{a}	0.710^{a}	2.37^{ab}	2.34^{ab}	1.21^{a}	1.08^{ab}	3.58^{a}	3.43^{a}
Alvand	49.53^{a}	48.87^{abc}	0.703^{a}	0.710^{a}	2.39^{a}	2.40^{a}	1.18^{ab}	1.08^{ab}	3.58^{a}	3.48^{a}
Sirvan	48.53^{a}	48.70^{bc}	0.701^{a}	0.707^{a}	2.29^{b}	2.23^{c}	1.13^{b}	0.98^{c}	3.42^{b}	3.22^{b}
Pishtaz	48.42^{a}	47.73^{c}	0.69 6^{a}	0.705^{a}	2.29^{b}	2.26^{bc}	1.11^{b}	1.00^{bc}	3.41^{b}	3.26^{b}

Means followed by the same letters in each column are not significantly different by Duncan test at 5% probability level.

We can evaluate indices such as the amount of SPAD and the ratio of FV/FM as criteria to identify the photosynthetic status of the plant [25]. Acceleration or delay in planting date due to changes in day length, temperature, and relative humidity has a significant effect on the physiological condition of the plant during the growing season [26]. Therefore, it led to disturbance in the relative amount of chlorophyll and chlorophyll fluorescence indices on the planting date of December 20. So, an improper planting date due to unfavorable environmental conditions may cause chlorophyll degradation [27]. A decrease in FV/FM was due to disruption in the structure of chloroplasts, leading to a reduction in the photochemical capacity of the photosystem II [28]. Disturbances and changes in the pigments of the photosystem II reduce the maximum quantum yield of the photosystem in the darkness compatible conditions [29]. On the other hand, the highest relative amount of chlorophyll was obtained in leaves of Zare and Heidari wheat cultivars with winter growth habits. Thus, the planting date significantly affected wheat cultivars with different growth types.

Amount of photosynthetic pigments

The amounts of chlorophyll a content were 2.51 and 2.48 mg/g fresh weight of leaves on October 20 planting date during 2016-2017 and 2017-2018, respectively, showing an increase compared to the planting date of December 20. The amount of chlorophyll a on planting dates of October 20 and November 20 did not show any statistically significant difference. The amount of chlorophyll was significantly higher in Pishgam and Alvand cultivars with intermediate growth habits in 2016-2017 and 2017-2018 (Table 5).

Table 5: Analysis of variance for the effects of planting date and cultivar on the height and yield indices of Wheat.

year	Source of variation	df	Height	Spike number	Seed number	Seed thousand weight	Biological yield	Seed yield	Harvest index	Seed protein
2016-2017	replication	2	91. 24*	3672.5 ns	17953. 9*	93.78**	1.12**	0.04**	26.9**	0.04**
	Planting date	2	137. 4**	56787.6 **	88251. 4*	30.50**	0.16**	0.05**	33.1**	3.54**
	Error 1	4	42. 12	6122.5	1057.0 7	2.65	0.007	0.001	4.6	0.57
	cultivar	5	256. 4**	19790.8 **	145738. 05**	124.64**	0.023 ns	0.019 **	72.7**	2.13**
	interaction	1 0	62. 2**	4302.6 *	19777 .4*	6.36*	0.037**	0.008 **	12.6**	1.31**
	Error 2	3 0	18. 61	3181.4	4071.8	2.63	0.011	0.002	3.18	0.39
	CV (%)		5.6 4	9.03	7.42	4.7	8.83	9.89	4.12	5.37
2017- 2018	replication	2	8.66 ns	2134.5 ns	12688. 1 ns	0.67 ns	0.019 ns	0.002 ns	2.27 ns	1.57**
	Planting date	2	45. 5*	65734. 5**	517727. 7**	226.3**	0.038*	0.021 **	58.7**	2.40**
	Error 1	4	36. 5	5243.5	2978.1	4.7	0.01	0.006	9.18	0.54
	cultivar	5	289. 2**	44154.2 **	134059. 2**	199.9	0.025*	0.004 ns	26.4**	0.50*
	interaction	1 0	24. 5*	6693. 3**	27821. 7**	7.15*	0.018*	0.006 *	18.07**	0.60*
	Error 2	3 0	12. 07	3181.4	7705.2	1.79	0.009	0.002	2.78	0.14
	CV (%)		4.61	7.98	11.36	3.05	8.35	8.44	3.52	5.26

Ns, * and**: Not-significant and significant at 5% and 1% error probability, respectively.

The highest amount of chlorophyll b showed a significant increase on the planting date of October 20 in 2016-2017 and 2017-2018 compared to the planting date of December 20. The amount of chlorophyll b was higher in cultivars with winter and intermediate growth habits than cultivars with spring growth habits in 2016-2017 and 2017-2018.

Delay in planting caused a decrease in total chlorophyll content so that the rates of decrease in total chlorophyll content were 16.5% and 20.3%, respectively, on the planting date of December 20 compared to October 20 during 2016-2017 and 2017-2018 (Table 3). The highest total chlorophyll content was observed in cultivars with winter and intermediate growth habits, but cultivars with spring growth habits showed lower total chlorophyll content.

On the optimal planting date, plant vegetative and reproductive stages comply with favorable environmental conditions and increase the efficiency of photosynthesis, the transfer and storage of photosynthetic materials of seeds, and ultimately increase yield [30]. Therefore, wheat planting on December 20 may decrease photosynthetic pigments due to the coincidence of the late growth period with the high temperature of the region. It has been indicated that the effect of planting date on photosynthetic pigments depends on the plant's response to photoperiod and temperature [31].

Chlorophyll accumulation in green plant tissues is an important physiological trait that is directly related to photosynthesis and plant dry matter [32]. Furthermore, the chlorophyll content in wheat is affected by the cultivar, and a further decrease in chlorophyll content in winter cultivars in planting delay may bedue to more susceptibility and incompatibility of these cultivars to temperature stress at the end of the season.

Plant height

On October 20, the highest plant height was obtained in Zare and Heidari cultivars with winter growth habits during 2016-2017 and 2017-2018 (Table 6). At a lower level, Pishgam and Alvand cultivars with intermediate growth habits showed higher plant height than Sirvan and Pishtaz cultivars with spring growth habits. Furthermore, the highest plant height was observed in Zare and Heidari cultivars with winter growth habits on November 20 and December 20. Delay in planting caused a significant reduction in the plant height of different wheat cultivars. The reduction of plant height was observed in Zare and Heidari cultivars with winter growth habits on December in both years; however, cultivars with intermediate and spring growth habits were less affected by planting delay (Table 6).

Table 6: Comparison of mean interactions of planting date and cultivar in on plant height, spike number, seed number and seed thousand weight of Wheat (2016-2017 and 2017-2018).

Planting date	Cultivar	Plant Height (cm)		Spike number (number. m^2)		Seed number (in 20 spike)		Seed thousand weight (g)	
		2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018	2016-2017	2017- 2018
20-October	Zare	83.3^{ab}	84.6^{a}	747^{a}	786^{a}	913^{cd}	684^{de}	38.86^{b}	51.38^{a}
	Heidari	88.6^{a}	84.3^{a}	748^{a}	758^{a}	950^{c}	645^{de}	36.84^{bc}	48.80^{ab}
	Pishgam	80.0^{b}	75.3^{b}	669^{b}	634^{bc}	841^{d}	595^{e}	34.72^{c}	42.49^{b}
	Alvand	75.3^{bc}	70.0^{bc}	699^{ab}	685^{b}	802^{d}	651^{de}	34.60^{c}	47.61^{ab}
	Sirvan	77.0^{b}	63.6^{c}	584^{cd}	573^{c}	532^{f}	409^{f}	33.14^{cd}	42.84^{b}
	Pishtaz	76.6^{b}	71.0^{bc}	684^{b}	597^{c}	777^{d}	495^{ef}	30.28^{d}	42.20^{b}
20-November	Zare	83.3^{a}	80.3^{ab}	617^{c}	614^{c}	996^{bc}	697^{d}	42.38^{a}	51.68^{a}
	Heidari	84.0^{ab}	85.3^{a}	619^{c}	683^{b}	1084^{a}	782^{cd}	39.23^{b}	42.75^{b}
	Pishgam	78.6b	75.6^{bc}	639^{c}	561^{cd}	1008^{bc}	852^{c}	32.74^{cd}	43.17^{b}
	Alvand	73.3^{b}	77.3^{b}	621^{c}	597^{c}	869^{d}	847^{d}	35.18^{bc}	50.16^{a}
	Sirvan	67.3^{c}	72.3^{bc}	561^{cd}	558^{cd}	847^{d}	704^{d}	33.13^{cd}	39.55^{b}
	Pishtaz	70.0^{c}	67.6^{c}	489^{d}	455^{d}	822^{d}	765^{cd}	30.98^{cd}	41.37^{b}
20-December	Zare	73.0^{c}	76.3^{b}	519^{d}	462^{d}	693^{e}	855^{c}	31.30^{cd}	34.68^{c}
	Heidari	80.6^{b}	79.6^{b}	553^{d}	485^{d}	534^{f}	784^{cd}	28.32^{d}	34.78^{c}
	Pishgam	76.0b	73.0^{bc}	640^{c}	539^{cd}	846^{c}	1131^{a}	30.34^{cd}	35.19^{c}
	Alvand	78.0^{b}	73.3^{bc}	608^{c}	568^{cd}	792^{cd}	1148^{a}	35.08^{c}	43.16^{b}
	Sirvan	65.6^{c}	71.3^{bc}	579^{cd}	556^{cd}	739^{de}	1027^{b}	39.92^{ab}	48.54^{ab}
	Pishtaz	65.3^{c}	74.6^{bc}	650^{c}	627^{c}	793^{cd}	924^{bc}	34.31^{c}	39.25^{bc}

Means followed by the same letters in each column are not significantly different by Duncan test at 5% probability level.

Sufficient opportunity for growth increases the plant height. Researchers have attributed the reduction in plant growth with delay in planting to a reduction in the vegetative growth period [33]. Therefore, late planting with a lower length of growing season reduces the growth. Planting at the right time causes a set of suitable environmental factors for the emergence and survival of the plant, and the plant in its growth period faces favorable environmental conditions [34]. Therefore, a longer growth period or differences in physiological traits, such as the amount of photosynthetic pigment on October 20 compared to December 20, probably brought about higher growth indices such as height.

The number of spikes, number of seeds, and 1000 seeds weight

On October 20, the highest number of spikes per square meter was obtained in Zare and Heidari cultivars with winter growth habits in 2016-2017 and 2017-2018 (Table 6). Furthermore, Pishgam and Alvand cultivars with intermediate growth habits and Sirvan and Pishtaz cultivars with spring growth habits showed fewer spikes per square meter. On November 20, cultivars with winter and intermediate growth habits showed a higher number of spikes than spring cultivars in both years. On December 20, the highest number of spikes per square meter was observed in cultivars with intermediate and spring growth habits. Even though a delay in planting decreased the number of spikes in different wheat cultivars, their reduction was greater in cultivars with winter habits.

In 2017-2016, the planting date of November 20 increased the number of wheat seeds in different cultivars in comparison with October 20, but the planting date of November 20 significantly reduced the number of seeds in different cultivars. Furthermore, delay in planting increased the number of seeds in different cultivars with winter, intermediate, and spring growth habits during 2017-2018. The early planting on October 20 led to the highest number of seeds in winter cultivars, but a delay in planting cultivars with intermediate and spring growth habits showed more seeds. Therefore, spring and intermediate cultivars showed a higher number of seeds in delayed planting.

On October 20, the highest 1000 seeds weight was obtained in cultivars with winter and intermediate growth habits during 2016-2017 and 2017-2018. Furthermore, Sirvan and Pishtaz cultivars showed less 1000 seeds weights with spring growth habits. Delay in planting on December 20x caused a decrease in 1000 seeds weights of different cultivars and showed less 1000 seeds weights in cultivars with winter growth habits.

Late planting shortened the growth period, and the plants entered the reproductive stage sooner and then faced a lack of photosynthetic resources before the vegetative organs were fully developed to create a physiological source. Therefore, delay in planting, especially in winter cultivars, Zare and Heidari, decreased yield components. It has been reported that high ambient temperature at the swelling stage of stamen leaf pods until the emergence of spikes disrupts the division of pollen grain mother cells and their survival and can reduce the number of seeds per spike [35]. The environmental factors after pollination mainly affect the 1000 seeds weight; hence, the plants' exposure to environmental stresses such as heat at the end of the season reduces the 1000 seeds weight [36,37]. Therefore, the 1000-seed weight loss, especially in winter cultivars, seems to delay planting.

Biological yield, seed yield, and harvest index

On October 20, the highest biological yield was observed in the Zare winter cultivar, but the delay in planting caused a decrease in biological yield in this cultivar in both years. On November 20, the cultivars with intermediate growth habits showed higher biological yield than winter cultivars in both years (Table 7).

On October 20 and November 20, the highest seed yield was seen in cultivars with winter and intermediate growth habits during 2016-2017 and 2017-2018. Sirvan and Pishtaz cultivars also showed lower seed yield with spring growth habits. On November 20 and December 20, seed yield was higher in cultivars with intermediate and spring growth types than in winter cultivars. Therefore, it seems that delay in planting significantly reduced seed yield, especially in cultivars with a winter growth type (Table 7).

Table 7: Comparison of mean interactions of planting date and cultivar in on biological yield, seed yield, harvest index and seed protein of Wheat (2016-2017 and 2017-2018).

Planting date	Cultivar	Biological yield (kg.ha^{-1})		Seed yield (kg.ha^{-1})		Harvest index (%)		Seed protein (%)	
		2016-2017	2017-2018	2016-2017	2017-2018	2016-2017	2017- 2018	2016-2017	2017-2018
20-October	Zare	14020^{a}	12520^{b}	6535^{a}	6320^{a}	46.6^{ab}	50.2^{a}	11.66^{b}	6.90^{b}
	Heidari	11630^{cd}	12650^{b}	5830^{b}	6335^{a}	49.9^{a}	50.1^{a}	11.16^{b}	6.16^{c}
	Pishgam	12840^{b}	12720^{ab}	5620^{bc}	6022^{a}	43.2^{ab}	47.7^{ab}	11.58^{b}	7.16^{b}
	Alvand	13040^{b}	11430^{d}	6050^{ab}	5415^{b}	46.5^{ab}	47.5^{ab}	11.16^{b}	7.16^{b}
	Sirvan	12220^{c}	11832^{cd}	4915^{c}	5120^{c}	40.8^{b}	43.0^{ab}	11.0^{b}	6.83^{b}
	Pishtaz	12925^{b}	13330^{a}	5040^{c}	5820^{ab}	39.1^{b}	43.9^{ab}	11.50^{b}	6.83^{b}
20-November	Zare	12930^{b}	10340^{ef}	5930^{b}	5220^{c}	45.6^{ab}	50.4^{a}	11.0^{b}	7.00^{b}
	Heidari	13300^{ab}	10725^{e}	6025^{ab}	5425^{bc}	45.2^{ab}	50.2^{a}	10.83^{b}	7.16^{b}
	Pishgam	13730^{a}	13035^{a}	5520^{bc}	6108^{a}	40.3^{b}	47.3^{ab}	11.41^{b}	7.33^{b}
	Alvand	13140^{b}	12210^{bc}	6108^{b}	6320^{a}	46.5^{ab}	52.2^{a}	11.16^{b}	7.33^{b}
	Sirvan	11320^{d}	12908^{ab}	5130^{c}	6110^{a}	45.1^{ab}	47.2^{ab}	11.83^{b}	7.66^{ab}
	Pishtaz	12125^{c}	11910^{c}	4640^{c}	5720^{bc}	38.2^{b}	47.8^{ab}	11.83^{b}	7.50^{ab}
20-December	Zare	10808^{e}	10800^{e}	4710^{d}	3512^{d}	40.0^{b}	43.2^{ab}	13.50^{a}	8.16^{a}
	Heidari	12308^{b}	12300^{b}	5110^{cd}	4320^{cd}	39.4^{b}	41.6^{b}	13.50^{a}	8.16^{a}
	Pishgam	11625^{cd}	11110de	5024^{c}	5410^{bc}	43.3^{ab}	48.9^{ab}	12.50^{ab}	7.66^{ab}
	Alvand	11310^{d}	11300^{d}	5320^{c}	5400^{bc}	45.1^{ab}	47.4^{ab}	12.16^{b}	7.50^{ab}
	Sirvan	11235^{d}	11200^{d}	5116^{cd}	4320^{cd}	41.4^{b}	45.5^{ab}	12.16^{b}	8.00^{a}
	Pishtaz	12205^{bc}	12200^{bc}	5720^{ab}	5115^{cd}	40.9^{b}	46.9^{ab}	11.50^{b}	7.00^{b}

Means followed by the same letters in each column are not significantly different by Duncan test at 5% probability level

During 2016-2017, the wheat harvest index in cultivars with winter growth type increased compared to the spring type on October 20 and November 20, but there was not any significant difference between different cultivars in 2017-2018. On the planting date of December 20, the highest wheat harvest index was observed in cultivars with intermediate growth types, but it was not statistically significant [38].

Late planting shortens the plant growth period, resulting in less dry matter production. Therefore, the lower biological yield leads to a delay in planting. The researchers have reported that the detrimental effects of planting delay are due to thermal stress at the end of the growth period through affecting physiological indices [39]. The decline in growth indices, including biological yield, on December 20 was probably due to the reduction in chlorophyll content and disruption of photosynthetic activities. Since winter cultivars must undergo low temperatures to have a spring nature and subsequently enter the reproductive stage, it is very important to study the planting delay in these cultivars [40]. However, spring cultivars do not need low temperatures. These cultivars have a lower tolerance to cold weather because they enter the reproductive stage earlier. As a result, determining the optimum planting date for each cultitor with different growth type should be in a way that is in a favorable condition [41-43].

Seed protein

A delay in planting increased the amount of seed protein of wheat in cultivars with different growth types so that the highest amount of seed protein was observed on December 20 [44]. In both years, the highest seed protein was observed in cultivars with a winter growth type on December 20. According to the researchers, there is a negative correlation between seed yield and protein percentage [45]. Therefore, delay in planting by reducing seed yield increased seed protein, which seemed reasonable in the present study [46].

Conclusion

The present study examined the effect of planting date due to its effect on different stages of wheat growth such as vernalization. Late planting of Zare and Heidari cultivars with a winter growth type, which needed low temperatures for vernalization, was very dangerous because delayed planting could have led to a sharp decline in yield. Late planting shortened the vegetative growth period and the plant entered the reproductive stage earlier and faced a lack of photosynthetic resources. The seed filling period coincided with drought stress and heat at the end of the season, and the stress on seed weight caused a sharp decline in yield. Accordingly, an improper planting date significantly reduced wheat yield and its components. The winter cold damage in Sirvan and Pishtaz cultivars with spring growth type in early planting decreased their yield. The early planting is applicable since seed yield is higher particularly in cultivars with a winter growth type, but intermediate and spring cultivars should be used in late planting.

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