



THE INFLUENCE OF DIFFERENT PLANTING DATES AND SEEDING RATES ON MORPHOLOGICAL TRAITS, SEED YIELD AND YIELD COMPONENTS OF SPRING WHEAT GENOTYPES

Hamideh Semnaninejad¹, Ghorban Nourmohammadi¹, Valiollah Rameeh^{2*} and Ali Charati Araei²

¹Department of Agronomy, Science and Research branch, Islamic Azad University, Tehran, Iran.

²Seed and Plant Improvement Department, Agricultural and Natural Resources Research Center of Mazandaran, Sari, Iran.

Abstract

The effect of different planting dates and seeding rates on the agronomic characteristics of spring wheat (*Triticum aestivum* L.) genotypes have been studied for 2 years at Agricultural Research Station, Baiekola of Mazandaran province. The main plot was planting dates (PD) including November 20th, December 5th and December 20th, subplots were seeding rates (SD) including 300, 350, 400 and 450 (grain.m⁻²), and sub-subplots were three wheat genotypes (G) including Morvarid, Gonbad, and Ehsan. Delayed planting resulted in a significant decrease in the most traits. Increased seeding rate resulted in a significant increase in plant height, number of spikes per unit area, biological and seed yield, and it also resulted in a significant decrease in spike length, number of seeds per spike, 1000-seed weight and harvest index. Among the studied cultivars, Ehsan cultivar had the most yield compared to the other cultivars in both studied years. The interaction effect of Y × PD on plant height, spike length, 1000 grain weight, and seed yield was significant. The Interactive effect of Y × SD on the number of spikes per unit area was significant. The Interactive effect of PD × G was significant only on the 1000-grain weight. The Interactive effect of PD × SD was significant on the seed and biological yield. Due to delayed planting, a loss in yield was compensated to some extent with an increase in seeding rates. At the first planting date (November 20th), the seed rate of 350 (grain. m⁻²) produced the highest seed yield (6013 kg.ha⁻¹). The results of the correlation coefficients showed that biological yield (0.86**), harvest index (0.60**), spike length (0.75**) and Number of spikes.m⁻² (0.49**) had the highest correlation with seed yield.

Keywords: Spring Wheat, Planting date, Seeding rates, Genotype, Cropping Season.

Introduction

Wheat (*Triticum aestivum* L.) is the second most widely cultivated crop in the world (FAO, 2016) and has always been considered as one of the strategic products in developing countries (Lannucci *et al.*, 2012). World wheat production in 2017 was about 754.8 million tons, which was almost one percentage point lower than that in 2016 (FAO, 2017). In Iran, wheat is of great importance compared to other crops, since it has been the main source of food for many people in Iran for years (Malakuti, 2000). Thereby providing about 20 percent of total food calories for the people of the world (FAOSTAT, 2012). Wheat is the most widely adopted cereal among all other cereals. Due to its different genetic traits, the flexibility of phenotypes and genotypes and the existence of different genotypes, it is cultivated almost all over the world (Nourmohammadi *et al.*, 2010). Different varieties of wheat differ in terms of compatibility, yield potential, growth type and treatment group (Khalil-Zadeh *et al.*, 2009). Increasing wheat production is possible by using optimal resources such as fertilizers, organic fertilizers and irrigation, controlling factors affecting weed control, pests and diseases, and proper managements including proper landing, planting dates, and optimal use of optimum plant density (Rawson, 2000). Through adapting plant growth stages with soil and air temperature, day length, evapotranspiration, rainfall, air humidity, and other atmospheric properties, pest and disease, weeds, and so forth, planting date affects the establishment, vegetative and reproductive growth, and finally, the quantitative and qualitative yield of the crop and harvesting issues (Khajehpour, 2001). The aim of determining the optimum planting date is to place the growth stages in favorable environmental conditions and avoid environmental conditions. This case increases the yield (Salamat, 2009). Generally, the genotypes of different crops are divided into

early, late and intermediate groups and the planting dates of each group are determined by conducting some experiments for one area. Different genotypes of the same group also have significant differences (Khajehpour, 2009). Wheat cultivation in the wrong time, sooner or later than the intended time, has many adverse effects. In contrast, wheat cultivation, at the optimum time, leads to high germination rates, suitable tillering, timely phenological development, and strong plant production with the strong root system, reduced lodging, increased grain weight for all growth types and plant survivals (Hay, 1986). The late planting date in the fall may cause germination, seedling growth and tillering encounter with low temperatures. Germination and seed placement in cold soils are delayed and the germination probability of some seeds decreases accordingly (Modhej *et al.*, 2008). Delayed planting shortens the vegetative growth period (Radmehr *et al.*, 1994) and decreases the number of leaves and leaf area (Rahnema, 1994). Thus, in most studies (Radmehr *et al.*, 1994; Rahnema *et al.*, 1993; Darwinkel *et al.* 1977; Blue *et al.*, 1990), seed yield has decreased with delayed planting. Reduced yield due to delayed planting is the result of reduced number of spikes per unit area (Blue *et al.*, 1990), and reduced number of seeds per spike (Rademare *et al.*, 1994). High temperature during pollination has a negative effect on the number of seeds per spike and 1000-seed weight and seed yield, thus it can be concluded that the planting date affects soil temperature at planting time, the number of GDD received by wheat, seed yield, and yield components (Asakerehnezhad, 2016). It seems that the effect of inadequate conditions caused by delayed planting is such that the compensatory effect between yield components (Radmehr, 1994; Rahnema, 1993; Noormohammadi *et al.*, 2010) cannot compensate these undesirable effects. In areas with moderate winters, spring wheat is planted in the autumn. These types, in addition to their tolerance toward heat, do not

require vernalization. In these areas, it is not enough cold to vernalize the spring type wheat. In the case of selecting the appropriate planting date in these areas, except for the post-flowering stages, the average temperature in the environment corresponds to the optimum mean temperature for plant growth. In these areas, the wheat faces the heat of the end of the season in the post-pollination period and in some years during the flowering and pollination periods. (Siadat *et al.*, 2013). The coincidence of flowering, pollination, and grain filling periods with the heat stress at the end of the season (especially in the Mediterranean and warm regions) reduces seed yield by decreasing the number and especially grain weight (Modhej *et al.*, 2008). Determining the seeding rates is to provide an appropriate combination of environmental factors to achieve maximum qualitative and quantitative yield (Ammar *et al.*, 2004).

Hiltbrunner *et al.* (2007) considered optimum plant density in wheat as a key to maximize yield. Plant density varies according to changes in factors such as regional difference, planting date, climatic conditions (especially precipitation distribution), soil type and genotypes (Elhani *et al.*, 2007).

Considering that in the climatic conditions of Mazandaran province, especially in plain areas, the period of wheat growth stages is about one and a half months, seed yield decreases significantly due to the reduction in the duration of growth. During some delayed planting dates, the grain-filling period is shortened, though. Increasing the number of seeds can partly offset this decline. This study aimed at investigating the interactive effect of planting date and seeding rate on yield and yield components and some agronomic traits of spring wheat genotypes under Mazandaran climate conditions.

Table 1 : Soil Physio-chemical properties of experimental location

Cropping seasons	Soil depth (cm)	pH	EC×10 (ds. m ⁻¹)	T.N.V (%)	(O.M) (%)	O.C (%)	P (ppm)	K (ppm)	Sand	Silt	Clay	Soil type
2016-2017	0-30	7.0	0.64	2.4	2.24	1.65	14.5	173	50	30	20	Loam
2017-2018	0-30	7.3	0.63	3.3	2.2	1.61	13.6	180	46	34	20	Loam

Materials and Methods

This experiment was conducted during two cropping seasons (2016-2017 and 2017-2018) at Agricultural Research Station, Baiekola- Mazandaran located 12 kilometers north of Neka, with a latitude of 36° 46' N, and longitude of 53° 13' E, and elevation of 4 m, with hot and early summers and cold and wet winters. The average maximum and minimum annual temperatures of this region are 22.4°C, 12.9°C, average annual rainfall is 657.1 mm, and relative humidity is 75 percent. This experiment was carried out as a split-split plot based on RCBD during two years (2016 to 2018). Three planting dates (November 20th, December 5th, and December 20th) were considered as the main plots, seeding rates of 300, 350, 400 and 450 (grain.m⁻²) were considered as subplots and wheat cultivars (Morvarid, Gonbad, and Ehsan) were considered as sub-subplots. Seeds of the examined cultivars of spring wheat were prepared from the Agricultural Research Station, Baiekola- Mazandaran province. After determining the vitality, seed purity and seed consumption values, the seeds were disinfected with Vitavax fungicide and based on the different amounts of seedling and 1000- grain weight, the required amount of seeds for each specified cultivar was determined and packed after weighing. Soil physical and chemical properties were measured after sampling at the depth of 0-30 cm in the soil and water analysis laboratory (Table 1). Last year, Rapeseed was planted in the land. The cereal planter was used in three planting dates. Each experiment plot consisted of 6 rows with 6.6 m length at 20 cm spacing, through removing a 1.5-meter corridor. The two sidelines were considered as margins, and its four middle lines were used to determine all traits. In order to prepare the land in the plot, the test site was plowed

with a moldboard plow and then two perpendicular disks were used to grind the blocks, and the trowel was used to smooth (level) the soil. Based on the soil erosion test (Table 1), fertilizer rates were recommended as follows: 50(kg) of urea, 120 (kg) of triple superphosphate and 100 (kg) of potassium sulfate fertilizer were distributed in the soil as the base. While preparing the soil, 150 (kg) of urea fertilizer was consumed in three stages- one third in the form of base and two third in the form of two tillering and stem elongation phases. In order to control weeds, 2,4-D herbicide (1 to 1.5 lit. h), Granstar (20 to 25 gr. h) were used to control the broadleaf weeds and Topic herbicide (0.7-0.8 lit. h) was used to control the narrow leaf weeds at the end of the tillering stage. Falcon fungicide was used to control the disease (0.6 lit. h) at the time of tillering according to the climatic conditions. No irrigation was needed during the growing season due to the climatic conditions and according to the tradition of the area. The measured traits in this study were plant height, spike length, number of seeds per spike, 1000-grain weight, seed yield, biological yield, and harvest index. To measure plant height and spike length at the end of the growth season, 10 plants were randomly selected from each treatment and were measured. To measure the number of seeds per spike, 1000-grain weight, harvest index, seed yield, biological yield, and harvest index one square meter was taken from the middle of the plots after physiological examination, and removing the margins from each plot. Then, the traits were measured. After measuring and calculating the desired traits, software MSTAT-C & SAS was used to statistically analyze the collected data. Excel was also used to draw graphs and tables. The mean of data was compared at 1% level using Duncan's multi-domain test.

Table 2 : Combined analysis of variance for seed yield and yield components of spring wheat genotypes in planting date and seed density treatments

Harvest index (%)	Biological yield (Kg.ha ⁻¹)	Seed yield (Kg.ha ⁻¹)	1000-grain weight (gr)	No. of Grains. spike ⁻¹	No. of spikes. m ⁻²	Spike length (cm)	Plant height (cm)	df.	S. O. V.
145.0*	16973062	8320600**	280.9**	618.1**	5410**	87.1**	15084.8**	1	Year (Y)
55.7	42014371	1886380	172.4	155.1	1439	25.1	1400.5	4	Error Year
259.5**	339215708**	78356665**	365.5**	429.2**	36052**	145.4**	4323.4**	2	Planting date(PD)
78.8	23707518*	2237654**	16.7*	3.6	195	65.11**	405.8*	2	Y × PD
2.4	3221859	167585	9.4	5.8	5524	1.44	127.7	8	Error a
326.7**	63400697**	1720355**	315.1**	437.6**	70933**	30.6**	361.1**	3	Seeding rates (SD)
52.1	4832559	82753	4.3	13.8	1939*	1.8	100.8	3	Y × SD
20.1	22308691**	4147384**	1.6	1.9	1274	1.9	91.4	6	PD × SD
21.3	7096438	226185	1.2	1.7	1023	0.7	97.4	6	Y × PD × SD
31.0	5895813	192965	5.2	9.8	684	1.5	79.6	36	Error b
657.4**	7142775**	17898269**	3857.6**	965.2**	42008**	177.2**	2495.8**	2	Genotype (G)
25.7	4937666	53865	17.4	10.1	917	1.6	11.4	2	Y × G
9.0	3453976	553973*	19.4*	10.3	109	4.6	66.0	4	PD × G
3.2	5323386	429766	2.3	5.5	106	3.5	70.1	4	Y × PD × G
6.3	1812743	195150	6.7	2.1	2482	4.2	62.2	6	SD × G
4.2	626649	72621	1.4	2.4	1429	0.7	14.2	6	Y × SD × G
13.8	2492593	62660	1.2	3.3	1141	0.9	19.1	12	PD × SD × G
9.9	2483951	234860	1.8	1.6	1208	0.5	40.6	12	Y × PD × SD × G
26.4	3616203	217715	6.7	12.5	964	2.4	155.9	96	Error c
									CV. (%)

*and**: Significant at the 5% and 1% probability levels, respectively.

Table 3 : Mean comparison of yield and yield components of spring wheat cultivars as affected by Year, Planting date and Genotype

Harvest index (%)	Biological yield (Kg.ha ⁻¹)	Seed yield (Kg.ha ⁻¹)	1000-grain weight (gr)	No. of Grains. spike ⁻¹	No. of spikes. m ⁻²	Spike length (cm)	Plant height (cm)	Treatment
								Year
34.06b	12194a	4099b	39.41b	37.42b	327b	8.81b	73.64b	First year
35.69a	12755a	4492a	41.69a	39.71a	382a	10.08a	90.36a	Second year
								Planting date
37.01a	14794a	5442a	42.98a	38.38a	399a	11.00a	89.22a	Nov., 20
34.22b	12136b	4043b	38.17b	36.81b	378ab	9.13b	82.97a	Des., 5
33.39b	10493c	3401c	33.04c	30.50c	354b	8.21c	73.81b	Des., 20
								Seeding rates (grain.m ⁻²)
36.59ab	11215b	4090c	43.37a	38.82a	336d	10.32a	79.28b	300
37.13a	11927b	4395ab	41.40b	37.41a	366c	9.79a	80.29b	350
33.94bc	13332a	4486a	39.74c	35.02b	381b	9.05b	84.17a	400
31.83c	13423a	4211bc	37.69d	32.33c	423a	8.63b	84.25a	450
								Genotype
31.99c	12119b	3799c	37.74b	36.19b	456c	7.81c	87.59a	Morvarid
34.63b	12584a	4291b	35.04c	32.10c	471b	9.59b	75.85b	Gonbad
38.01a	12720a	4796a	48.85a	39.40a	503a	10.94a	82.55a	Ehsan

Mean followed by a similar letter(s) are not significantly different at the 1% probability level-using Duncan's multiple range test.

Table 4 : Comparison of the mean of interaction between year and planting date on spike length, Plant height, 1000-grain weight and seed yield

Seed yield (Kg.ha ⁻¹)		1000-grain weight (gr)		Spike length (cm)		Plant height (cm)		Planting Date
Second year 2017-2018	First year 2016-2017	Second year 2017-2018	First year 2016-2017	Second year 2017-2018	First year 2016-2017	Second year 2017-2018	First year 2016-2017	
5838a	5046b	44.0a	41.3bc	12.6a	9.4bc	98.7a	79.8b	Nov., 20
4105c	3982c	42.3ab	39.3cd	9.8b	8.4d	93.0a	73.0bc	Des., 5
3533d	3270d	38.8d	37.6d	7.9d	8.5cd	79.4b	68.2c	Des., 20

Means followed by a similar letter(s) are not significantly different at the 1% probability level-using Duncan's multiple range test.

Results and Discussion

Plant Height

The results of combined analysis of variance for plant height showed that the effect of year, planting date and genotype was significant at 1% probability level and interactive effect of year on plant density was significant at 5% level and other effects were not significant (Table 2).

The plant height in the first year (73.64 cm) was less than that in the second year (90.36 cm), which indicated a more favorable environmental and growth condition of the second year (Table 3).

The highest plant height (89.22 cm) was obtained at the first planting date and the lowest plant height (73.81 cm) was obtained in the third planting date (December 20th) (Table 3). Delayed planting shortened the growth period and increased the growth rate. Consequently, the plant height decreased.

Mehrpouyan *et al.* (2010) also reported that delayed planting decreased the plant height, which was consistent with the results of this experiment.

The results of the comparison showed that as plant density increased, plant height increased, as well. The highest plant height (84.25 cm) was obtained with plant density 450 (grain.m⁻²) and the lowest plant height (79.28 cm) was obtained from plant density 300 (grain.m⁻²), which were statistically divided into two distinct groups (Table 3).

Due to high seeding rates, as the plant density increased, the interspecies competition increased, as well. Thus, competition for gaining light increased, which in turn increased the plant height. Therefore, high plant density increased the length of stems, which was consistent with the results of this experiment (Kousalov, 1990).

Physiologically, the ratio of infrared light to red at the lower levels of the canopy has increased with the increasing number of seeds. Consequently, plant density prolonged internodes (Sarmadiyan and Kochaki, 1994).

In contrast, Chegeni, 2014 reported a reduction in plant height due to increasing plant density in wheat genotypes.

Moreover, the results of the mean comparison showed that Morvarid cultivar had the highest plant height (87.59 cm) and Gonbad cultivar had the lowest plant height (75.85cm). In addition, no statistical difference was observed in Morvarid and Ehsan cultivars (Table 3).

Height is a genetic trait, which is influenced by the environment. In this regard, agronomic management such as applying food in soil, plant density and planting dates are among the important factors influencing it (Moghaddam *et al.*, 1997).

Comparison of the meaningful interactions between year and planting date showed that in all planting dates, plant height of wheat genotypes was higher in the second year than that in the first year, and that the delayed planting decreased the plant height (Table 4). The highest plant height (98.7 cm) was obtained in the second year, at the first planting date (November 20th) and the lowest plant height (68.2 cm) was obtained in the first year, at the third planting date (December 20th).

Jafarnezhad and Sharif al-Husseini (2010) stated that the interactive effect of year and planting date on plant height was significant.

There was a positive and significant correlation between plant height. Moreover, the number of seeds per spike (0.42 *), number of the spike per unit area (0.42 *), seed yield (0.42*) and biological yield (0.59**) were obtained (Table 5).

Spike Length

The results of the combined analysis of variance for spike length showed that the effect of year, planting date, plant density, genotype and the interactive effect of year on planting date was significant at 1% probability level and other effects were not significant (Table 2).

Spike length in the first year (8.81 cm) was less than that in the second year (10.08 cm) (Table 3), which indicated the most favorable weather conditions, including rainfall and temperature in the second year compared to the first year.

Spike length in wheat was under the control of genetic traits of wheat genotypes and climatic conditions during its growth. (Donmez *et al.*, 2001)

The highest spike length (11 cm) was observed at the first planting date and the lowest spike length (8.9 cm) was observed at the third planting date (Table 3).

Spike length is one of the traits that is influenced by the environment and genotype. As the planting date is more delayed, a decreasing trend is observed for the spike length, which can be due to the number of seeds per spike and the lower growth due to the limited apertures (Asakerehnejad and Lak, 2016).

Yaqubian *et al.* (2017) reported that delayed planting gradually decreased the spike length. The shortened spike length in wheat, as a result of the delayed planting, was also reported by other researchers (Mehrpouyan *et al.*, 2010).

The results of the comparison showed that with an increase in plant density, the spike length decreased (Table 3). The highest spike length was obtained in a density of 300 (grain.m⁻²) and the lowest spike length was obtained in a density of 450 (grain.m⁻²). In addition, the densities of 300 and 350 (grain.m⁻²) did not differ significantly. In high densities, due to radiation constraints, the plant moderated competitive pressure by producing shorter spikes.

Zahed *et al.* (2011) reported that although there was no statistical difference between the levels of density, the spike length was decreased with increasing density from 150 to 375 (grain.m⁻²).

Moreover, the results of the mean comparison showed that Ehsan cultivar had the highest spike length (10.94 cm) and Morvarid cultivar had the lowest spike length (7.18 cm) (Table 3). Spike length was affected by the environment and genotype (Mehrpouyan *et al.*, 2010).

Demotes and Jeuffroy (2001) stated that genotypes of wheat with larger and longer spikes in comparison with genotypes with smaller and shorter spikes could share more photosynthetic materials between spikes and seeds.

Comparison of the average interactions between year and planting date showed that spike length in wheat

genotypes in the second year was more than that in the first year at all planting dates and the delayed planting decreased the spike length (Table 4). The highest spike length (12.6 cm) was observed in the second year and at the second planting dates (November 20th) and the lowest spike length (7.9 cm) was observed in the second year and at the third planting date (December 5th).

There was a positive and significant correlation between spike length and the number of seeds per spike (0.62**), number of spikes per unit area (0.68**), 1000-grain weight (0.70**), seed yield (0.75**), biological yield (0.39*) and harvest index (0.87**) (Table 5).

Number of spikes per unit area

The results of the combined analysis of variance for the number of spikes per unit area showed that the main effect of year, planting date, and seeding rates were significant at 1% level and the interactive effect of year on seeding rates was significant at 5% level, but other effects were not significant (Table 2).

The number of spikes per unit area in wheat genotypes in the first year was 427 and less than that in the second year (482) (Table 3).

The highest number of spikes per unit area was obtained 499 at the first planting date (November 20th) and the lowest number was 454 at the third planting date (December 20th) (Table 4). Reducing the number of spikes per unit area due to the delayed planting can be due to the reduced plant deployment or reduction in the number of fertile tillers.

Corny and Hegarty (2007) also reported that among the seed yield components, the number of spikes per unit area decreased with delayed planting.

In addition, increasing seeding rates resulted in a significant increase in the number of spikes per unit area (Table 3). The highest number of spikes per unit area was obtained at the seeding rate of 450 (grain.m⁻²) and the lowest number of spikes per unit area was obtained at the seeding rates of 400 (grain.m⁻²). This can be due to the increase in the number of fertile tillers by increasing plant density.

Lioverea *et al.* (2004) showed that the effect of plant density on yield and yield components in winter wheat increased the number of spikes per unit area, which was consistent with the results of this experiment.

Emam, (2003) also noted that an increase in the seeding rates was associated with an ever-increasing spike population per square meter.

The results of the study on two wheat genotypes in different seeding rates 300, 450, 600, 750 and 900 (grain.m⁻²) showed that seeding rates of 600 (grain.m⁻²) produced the highest yield and in three years of experiment, increased seeding rate resulted in a significant increase in the number of spikes per unit area (Boken and Malesvie, 2004).

The results of the comparison showed that Ehsan cultivar (503) had the highest and Morvarid cultivar (456) had the lowest number of spikes per unit area (Table 3).

Johnson *et al.* (1988) reported that there was a difference between bread wheat genotypes in terms of the number of spikes per unit area and the tiller production was

affected by the plant's genetic and environmental factors (Sarmadnia and Koochacki, 1990).

In addition, the results of the interaction between year and seeding rates indicated that in both years, the number of spikes per unit area increased through increasing seed density (Fig. 1). As it is stated about the weather conditions of the years under the study, the overall weather condition of the second year was more favorable than the first one in terms of rainfall and temperature conditions.

There was a positive and significant correlation between the number of spikes per unit area and plant height (0.42**), spike length (0.68**), seed yield (0.49**), biological yield (0.61**) and harvest index (0.72**). Moreover, there was a negative correlation between the number of spikes per unit area and number of grain per spike (-0.01*) (Table 6). The negative correlation between the number of spikes per unit area and number of seeds per spike indicated that the number of seeds per spike decreased through increasing the number of spikes per unit area.

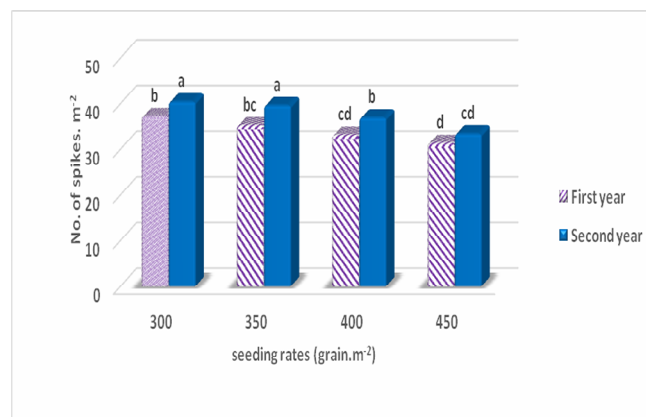


Fig. 1 : Interaction effects of year and seeding rates on No. of spike m⁻² of Wheat genotypes

Means followed by a similar letter are not significantly different at the 1% level of probability.

The number of seeds per spike

The results of a combined analysis of variance for the number of seeds per spike showed that the effect of year, date, seeding rates, and genotype was significant at 1% probability level, but other effects were not significant (Table 2).

The number of seeds per spike in wheat genotypes in the first year was (34.20) and less than that in the second year (37.59) (Table 3).

The mean comparison showed that the highest number of seeds per spike was obtained at the first planting date (November 20th) and the lowest number of seeds per spike was obtained at the third planting date (December 20th) (Table 3). The number of seeds per spike with delayed planting usually decreased due to the acceleration of developmental stages (Emam, 2003). Bakhshandeh and Rahnama (2005) also reported that the number of seeds per spike decreased through delayed planting, which was consistent with the current research's results. While Stapper and Fisher (1990) stated that the number of seeds per spike increased in later planting dates for wheat.

The mean comparison showed that the number of seeds per spike decreased with an increase in seeding rates. The highest number of seed per spike was obtained with the

seeding rates of 300 (grain. m⁻²), the lowest number of seed per spike was obtained with the seeding rates of 450 (grain. m⁻²), and no statistical difference was observed in the seeding rates of 300 and 350 (grain. m⁻²) due to the competition within the plant (Table 4). Considering that seeding rates increase is usually associated with an increase in plant development and growth, it can be predicted that increasing the seeding rates shortened the length of the period of spikelet production, thus the spike did not grow enough and the number of seed per spike was reduced.

Soomro *et al.* (2002) reported that the number of seeds spike⁻¹ decreased with the increase in seeding rates. Gebiahou *et al.* (1982) reported that an increase in the number of spikes. m⁻² to seeding rates was associated with a reduction in the number of seeds. spike⁻¹. Moreover, the results of the mean comparison showed that Ehsan and Gonbad cultivars had the highest (39.40) and lowest (32.70) number of seeds. spike⁻¹ (Table 3). Osman and Mahmoud (1981) also indicated that the effect of genotype on the number of seeds. spike⁻¹ was significant in Sudan.

There was a positive and significant correlation between the number of seeds per spike and plant height (0.42^{*}) and spike length (0.62^{**}), 1000- grain weight (0.86^{**}), seed yield (0.47^{**}) and harvest index (0.70^{**}) and there was a negative and significant correlation with the number of spikes per unit area (-0.01^{**}) (Table 5).

1000 Grain Weight

The results of combined analysis of variance for this trait showed that the main effect of year, date, seeding rates, and genotype was significant at 1% probability level, and the interactive effect of year on planting date and between year and genotype was significant at 5% level and other effects were not significant (Table 2).

1000-grain weight of different wheat genotypes in the first year (39.41 gr) was less than that in the second year (41.69 gr) (Table 3).

Tadayon and Emam, (2006) reported that as a result of more precipitation and prolonged rainfall in the second year compared with the first year, 1000- grain weight in the second year was higher than that in the first year.

The highest (42.65 gr) and the lowest (38.17 gr) 1000 grain weight were obtained at the first planting date (November 20th) and the third planting date (December 20th) respectively (Table 3). Due to the greater length of growing period, the number of fertile tillers, as well as grain weight increased because of using photosynthetic materials at the first planting date (Till *et al.*, 1978).

Anderson and Smith (1990) observed that the delay in wheat planting significantly reduced the 1000-grain weight.

The results of the mean comparison indicated that 1000-grain weight decreased with the increase in seeding rates (Table 3). The highest 1000-grain weight (43.37 gr) and the lowest 1000 grain-weight (37.69 gr) were obtained with the seeding rates of 300 and 450 (grain. m⁻²) respectively. Its reason was that the increase in a number of spikes per unit area to the increased seeding rates, increased the competition to get photosynthetic materials to transfer to the seeds, and less photosynthetic traits were assigned to grain filling, resulting in a decrease in 1000-grain weight.

Varga *et al.* (2001) reported a reduction in 1000-grain weight with the increase in seeding rates.

Doyle and Kingston (1992) also stated that the increase in plant density barley decreased 1000 grain weight. They reported the 1000-grain weight loss due to the plant density, an increase in the number of spikes per unit area to the plant density and competition between the spikes that led to the source size limit in comparison to the destination unit. The compensatory effect of the yield components on each other under the influence of different treatments such as seeding rates could lead to an increase in one component or other components. In this experiment, it was observed that the number of spikes per unit area increased with the increasing of seeding rates, but the number of grain per spike and 1000 grain weight of wheat genotypes decreased.

The mean comparison showed that Ehsan cultivar (45.85gr) had the highest and Morvarid cultivar (35.31gr) had the least 1000-grain weight (Table 3).

Koc (1996) considered 1000-grain weight of two wheat genotypes to be different, since these genotypes were different in terms of tillering and other traits.

The mean comparison of the interactive effect of year on planting date showed that in all planting dates, 1000-grain weight of wheat genotypes in the second year was higher than the first year, and the delayed planting decreased the amount of this trait in two consecutive years (Table 4). The first planting date (November 20th) in the second year had the highest 1000-grain weight (44.0 gr) and the third planting date in the first year had the least 1000-grain weight (37.6 gr).

In addition, the comparison of the interactive effect of planting date on the cultivar showed that Morvarid and Ehsan genotypes had the least and the highest 1000 grain weight at the planting date (Fig. 2). Gonbad cultivar had the least 1000-grain weight (32.9 gr) at the third planting date (December 20th) and Ehsan cultivar had the highest 1000-grain weight (51.9 gr) at the first planting date (November 20th).

There was a positive and significant correlation between 1000-grains weight and spike length (0.70^{**}), the number of seeds per spike (0.86^{**}), seed yield (0.47^{**}) and harvest index (0.72^{**}) (Table 6). Gonbad and Ehsan cultivars with higher 1000-grain weight produced more seed yield than others.

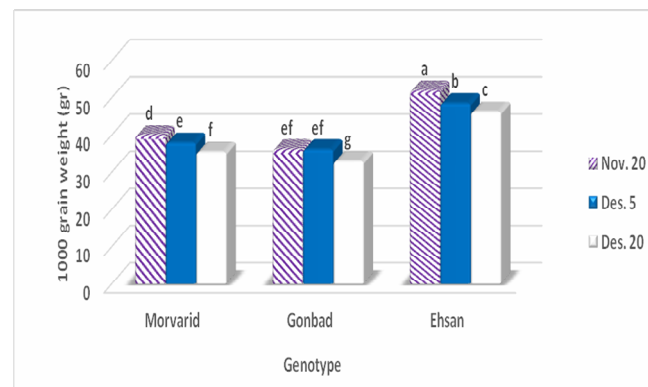


Fig. 2 : Interaction effects of Planting dates and genotypes on 1000-grain weight in spring wheat

Means followed by a similar letter are not significantly different at the 1% level of probability.

Seed yield

The results of the combined analysis of variance for seed yield showed that the effect of year, date, seeding rates, and genotype, the interactive effect of year on planting date and the interactive effect of planting date on seeding rates were significant at 1% level. Moreover, interactive effect of plant density on genotype was significant at 5% level and other effects were not significant (Table 2).

Seed yield of wheat genotypes in the first year (4409 kg.ha⁻¹) was less than that in the second year (4492 kg.ha⁻¹) (Table 4). In general, the weather conditions were more favorable than the first one in terms of rainfall and temperature in the second year.

The highest seed yield (5442 kg.ha⁻¹) was obtained at the first planting date (November 20th) and the lowest seed yield (3410 kg.ha⁻¹) was obtained at the third planting date (December 20) (Table 3).

Fowler *et al.* (2007) reported a 24% reduction in seed yield with delayed planting, as they did not receive a large part of the autumn sunlight because of plant shadows. Rezaee *et al.* (2011) reported that the delayed planting reduced the number of days until the emergence of the spike and shortened the length of the grain-filling period. In addition, the growth rate increased with delayed planting, although the growth period and cumulative GDD reduced from 240 days and 2590 °C at the first planting date (November 6th) to 190 days and 2267 °C at the fifth planting date (December 6th). This was an appropriate reasons to justify a decline in seed yield in delayed planting dates.

Seed yield for each 1 °C rise in the temperature above 15 °C during grain filling decreased to 3-4% (Wardlaw and Wrigley, 1994). The main reason for this was the reduction of accumulated starch by temperature. As the temperature increased from an average of 15 °C during grain filling, starch accumulation was not enough to compensate the shortened period of starch accumulation (Sofield *et al.*, 1977; Nicolas *et al.*, 1948).

The results of the mean comparison showed that the increase in the seeding rates, increased seed yield (Table 3). The highest seed yield (4486 kg.ha⁻¹) was obtained from seeding rates of 400 (grain.m⁻²) and the lowest seed yield (4090 kg.ha⁻¹) was obtained from the seeding rates of 300 (grain.m⁻²), but the difference in yield in the second seeding rates and the third one was not statistically significant. It seems that the main reason for the difference in seed yield in different seeding densities was the increase in the number of spikes per square meter because this trait significantly increased by the increase in the number of seeds per square meter, and had the most changes compared to the other two components. In fact, the number of seeds per spike and the higher 1000-grain weight in lower seeding densities could not compensate for the reduction in the yield resulting from the number of spikes per unit area.

Blue *et al.*, (1995) showed that the increase in the seeding rates increased seed yield through increasing the number of spikes per unit area. Rahnama *et al.* (1999) also identified the number of spikes per unit area as the most important part of durum wheat yield. In addition, mean comparison of data showed that the highest seed yield (4796 kg.ha⁻¹) and the lowest seed yield (3799 kg.ha⁻¹) were

obtained from Ehsan cultivar and Morvarid cultivar, respectively (Table 3).

In agricultural plants, what mainly determined the economic yield was the way in which photosynthetic materials were allocated between different organs (Wiegand *et al.*, 1979). Chegeni (2014) reported that there was a significant difference between wheat genotypes in terms of seed yield. Mean comparison of the interactive effect of year on planting date showed that totally, the planting dates, seed yield of wheat genotypes in the second year was higher than that in the first year. Thus, the delayed planting decreased the amount of this trait in two consecutive years (Table 4). The highest seed yield (5838 kg.ha⁻¹) was obtained in the second year at the first planting date (November 20th) and the lowest seed yield (3270 kg.ha⁻¹) was obtained at the third planting date (December 20th) in the first year. Ghodsi *et al.* (2015) stated that the higher seed yield of different planting dates in the first year compared with the second year could be attributed to the second year's climate conditions.

Finally, the mean comparison of the interactive effect of planting date on seeding rates was shown (Fig. 3). The highest seed yield was obtained at the first planting date (November 20th) and seeding rates of 350 and 300 (grain. m⁻²) and the lowest seed yield was obtained at the third planting date (December 20th) and seeding rates of 300 (grain. m⁻²). In delayed planting dates, the increase in seeding rates increased the seed yield, and somewhat compensated for the yield loss caused by the delayed planting.

Corny and Hegarty (1992) observed that at delayed planting dates, an increase in the seeding rates was associated with an increase in the seed yield. This property could be used to compensate for the yield loss in delayed planting. However, if planting dates were delayed to an extent that there were no favorable conditions for growth, an increase in the seeding rates wouldn't not result in an increase in the yields.

There was a positive and significant correlation between seed yield, plant height (0.47**), the number of grains. spike⁻¹ (0.47**), 1000 grain weight (0.47**), number of spikes per unit area (0.49**), biological yield (0.68**) and the harvest index (0.60**) (Table 5). The positive correlation between biological yield and seed yield was due to the fact that an increase in the chlorophyll content of plants produced higher photosynthesis and more estimates and ultimately higher yields.

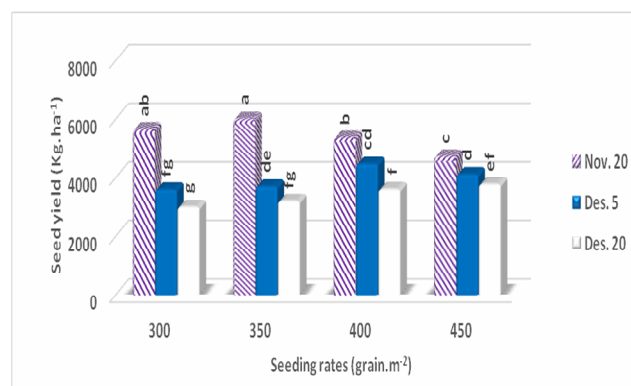


Fig. 3 : Interaction effects of planting date and seeding rates on the seed yield of wheat genotype

Means followed by a similar letter are not significantly different at the 1% level of probability.

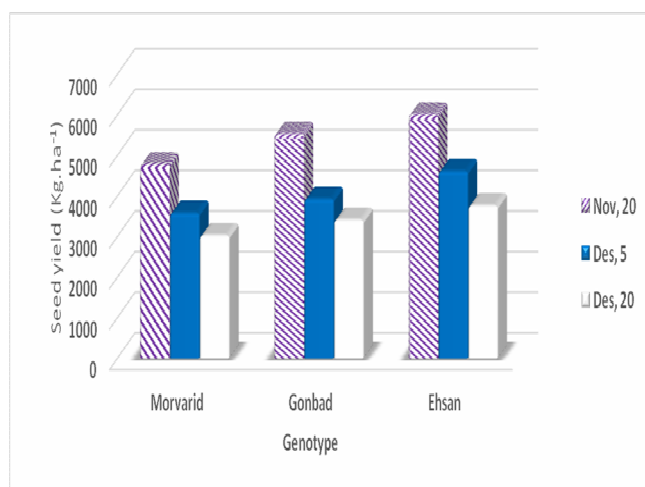


Fig. 4 : Interaction effects of planting date and genotype on the seed yield of spring wheat

Means followed by a similar letter are not significantly different at the 1% level of probability.

Biological Yield

The results of the combined analysis of variance for biological yield showed that the effect of planting date, seeding rates, cultivar and the interactive effect of planting date on seeding rates was significant at 1% level (Table 2).

The results of the mean comparison showed that delayed planting decreased the biological yield (Table 3). The highest biological yield (14794 kg.ha⁻¹) and the lowest biological yield (10493 kg.ha⁻¹) were obtained at the first planting date (November 20th) and the third planting date (December 20th). Considering that biological yield was the dry weight of aerial parts and the plant components were plant height, spike length and the number of spikes per unit area, so reducing each of these traits would reduce the biological yield.

Rezaei *et al.* (2011) reported that delayed planting decreased the growth period and increased the development and growth rate.

The results of the mean comparison showed that the biological yield increased by an increase in seeding rates (Table 3). The highest biological yield (13423 kg.ha⁻¹) and lowest biological yield (11215 kg.ha⁻¹) were obtained at a density of 450 and 300 (grain.m⁻²), respectively. There was no significant difference between the two first densities and the two last densities.

Chegeni (2014) reported an increase in seeding rates increased biological yield, which was consistent with the results of this experiment.

Increasing seeding rates affected the amount of radiation received and, by increasing the number of plants per unit area, the canopy was developed (Khajehpour, 2010). Although there may not be enough space to produce maximum tillers, increasing seeding rates increased the accumulation of dry weight of plant parts per unit area, which was due to an increase in the leaf area in the plant communities, increased absorption of radiation and food, and the rate of growth.

The results of the mean comparison of the effect of the genotype showed that the Ehsan cultivar had the highest biological yield (12720 kg.ha⁻¹) and the Morvarid cultivar

had the lowest harvest index (12119 kg.ha⁻¹). In addition, Gonbad and Ehsan cultivars were placed in the same class (Table 3).

In addition, the mean comparison of the interactive effects of planting date on seeding rates showed that during three planting dates, the biological yield increased by an increase in the seeding rates (Fig. 5). The highest biological yield (15585 kg.ha⁻¹) was observed at the first planting date (November 20th) and seeding rates of 350 (grain.m⁻²) and the lowest biological yield (8615 kg.ha⁻¹) was observed in the third planting date (December 20th) and seeding rates of 300 and 350 (grain.m⁻²). In delayed planting dates, biological yield increased with the increasing seeding rates.

There was a positive and significant correlation between biological yield and plant height (0.59**), spike length (0.39**), a number of spikes per unit area (0.61**) and seed yield (0.86**) (Table 5).

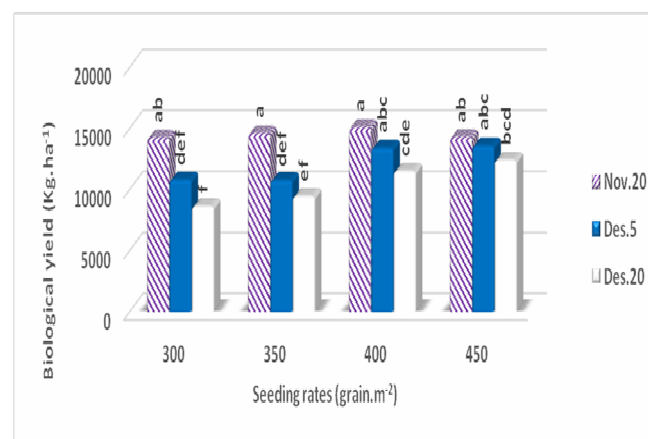


Fig. 5 : Interaction effects of planting date and seeding rates on biological yield of wheat genotype

Means followed by a similar letter are not significantly different at the 1% level of probability.

Harvest Index

The results of the combined analysis of variance for harvest index showed that the effect of year was significant at 5% level and the effect of planting date, seeding rates and genotype were significant at 1% probability level (Table 2).

The harvest index of wheat genotypes in the first year (34.06%) was less than that in the second year (35.69%) (Table 3) since the favorable weather conditions of the second year were more favorable.

The delayed planting decreased the harvest index (Table 3). The highest harvest index (37.01%) was observed at the first planting date (November 20th). The second and third planting dates did not have a significant difference (Table 3). Delayed planting shortened the growth period, resulting in lower plant height and tiller number, and consequently reduced vegetative growth, which reduced the biological yield (in the denominator).

Harvest index was the result of seed yield to biological yield ratio. It showed the plant's ability to transfer and allocate photosynthetic materials to seeds. The balance between source and reservoir and the allocation of more material from vegetative organs to reproductive organs could increase the wheat harvest index (Khan *et al.*, 2000).

Ghodsí *et al.* (2015) reported that delayed planting increased the harvest index, which was consistent with the results of this experiment.

In addition, the results showed that the harvest index decreased with the increasing of seeding rates (Table 3). The highest harvest index was obtained from the seed rate of 350 (grain. m⁻²) and the lowest harvest index was obtained from the seed rate of 450 (grain. m⁻²). In addition, the seeding rates of 300 and 350 (grain. m⁻²) and the seeding rates of 400 and 450 (grain. m⁻²) were separated into two distinct statistical groups. The results of this experiment showed that by increasing seeding rates, seed yield and biological yield increased, but biological yield increased more than seed yield.

Ghodsí *et al.* (2015) reported that the increase in seeding rates decreased the harvest index, which was consistent with the results of this experiment.

In addition, the results of the mean comparison of genotype effect showed that the Ehsan cultivar had the highest harvest index (38.01%) and the Morvarid cultivar had the lowest harvest index (31.99%) (Table 4). The higher harvest index in Gonbad and Ehsan cultivars compared to the Morvarid cultivar was probably due to the mechanism of proper absorption, aggregation, and transfer of hydrocarbon materials to the seeds at the end of the growth period. The results of this study were consistent with the research presented by (Wang *et al.*, 2004).

There was a positive and significant correlation between harvest index and the number of seeds per spike (0.70**) plant height (0.87**), 1000-grain weight (0.72**)

and seed yield (0.60**) (Table 5). This ratio was expected due to the fact that the harvest index was obtained from the seed yield and biological index.

Conclusion

One of the objectives of this research was to determine the optimum density in late planting dates compensating for the reduction in seed yield, which was due to the reduction in the length of the growth period in the cultivars examined over two years. The highest seed yield was obtained at the first planting date (November 20th) (Table 4). At the first planting date, due to the optimum temperature of the air and consequently the proper temperature of the soil, the emergence occurred some days earlier. While at the third planting date (December 20th), due to the decrease in the temperature of air and soil and the failure to receive the growing degree day, the emergence occurred some days later. It resulted in a decrease in the length of the growth period. The interactive effect of year on the planting date was significant (Table 4). The highest seed yield was obtained in the second year at the first planting date (November 20th). The highest seed yield was obtained at the seeding rates of 300 and 350 (grain. m⁻²). Ehsan cultivar had higher seed yield than other cultivars (Table 3). The interactive effect of planting date on seeding rates was significant (Fig. 2). According to the values of this chart, the appropriate seeding rates for each planting date could be determined. For example, if a farmer wants to plant a farm on November 30th, the best seeding rates would be 300 and 350 (grain. m⁻²), if he wants to plant a farm on December 30th, the best seeding rates would be 400 and 450 (grain. m⁻²).

Table 5 : Correlation coefficients among measured traits in experimental treatments

Harvest index (%)	Biological yield (Kg.ha ⁻¹)	Seed yield (Kg.ha ⁻¹)	1000 grain weight (gr)	No. of spikes. m ⁻²	No. of Grains. spike ⁻¹	Spike length (cm)	Plant height (cm)	Treatment
							1	Plant height (cm)
						1	0.13	Spike length (cm)
					1	0.62**	0.42*	No. of Grains. spike ⁻¹
				1	-0.01	0.68**	0.42*	No. of spikes. m ⁻²
			1	0.24	0.86	0.70**	0.25	1000 grain weight (gr)
		1	0.47**	0.49**	0.47**	0.75**	0.47**	Seed yield (Kg.ha ⁻¹)
	1	0.86**	0.13	0.61**	0.14	0.39*	0.59**	Biological yield (Kg.ha ⁻¹)
1	0.15	0.60**	0.72**	0.06	0.70**	0.87**	0.02	Harvest index (%)

*and**: Significant at the 5% and 1% probability levels, respectively

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