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RESEARCH PAPER

Effect of sowing date and plant density on yield and yield components of three maize (*Zea mays* L.) genotypes in Takhar climatic conditions of Afghanistan

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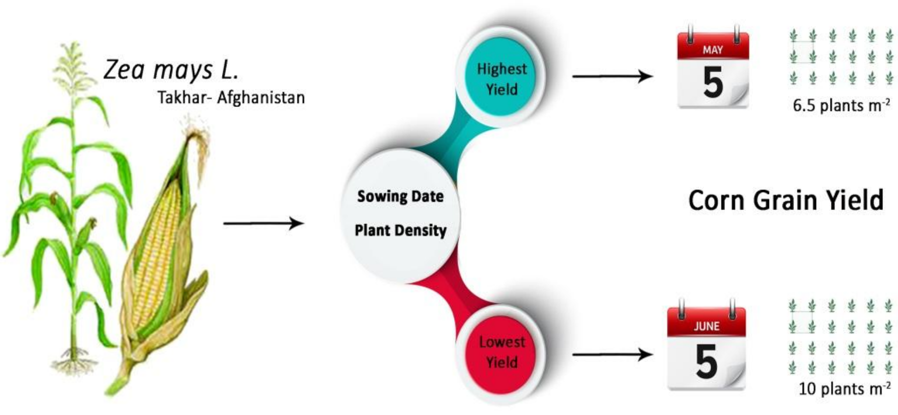
Highlights

- The highest corn grain yield was obtained from the sowing date (May 5) and plant density of 6.5 plants/m^2.
- The lowest grain yield was obtained from the sowing date (June 5) and the plant density of 10 plants/m^2.
- The sowing on the May 5 is superior to June 5 in terms of grain yield and yield components.
- Among the three corn genotypes, the SC260 genotype is better than the SC600 and SC302 genotypes under the environmental condition.

Graphical Abstract



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Abstract

Crops are the main source of human food supply and among them, grains are more important, among cereals, corn (*Zea mays* L.) is an important crop due to its high grain and forage yield potential. The research experiment was conducted on maize to find out the effect of different sowing dates and plant density among three genotypes on the performance of maize, in the spring of the 2020 growing season in the Bagh-e-Zakhirah Research Farm of Takhar province Afghanistan. The experiment was laid out as a split-plot factorial in a randomized complete block design (RCBD) with three replications. Three planting dates (May 5, May 21, and June 5) as the main factor, three plant densities of 6.5, 8, and 10 plants/m^2, and three genotypes, SC260, SC600, and SC302 were considered as sub-factors. All treatments sowing date, plant density, genotype, and only interaction effect of sowing date × plant density showed significantly different effects (P< 0.01) on yield and yield components. The results of the present investigation revealed that the highest grain yield 6.99 ton/h was obtained from the sowing date (May 5) and plant density of 6.5 plants/m^2 and the lowest grain yield 6.21 ton/h was obtained from the sowing date (June 5) and plant density of 10 plants/m^2. In general, the results showed that the sowing on the 5th of May is superior to the 5th of June in terms of grain yield and yield components, and among the three corn genotypes, the SC260 genotype is more batter than the SC600 and SC302 genotypes under the environment condition. Therefore considering all results the first week of May as the sowing date and 65000 plants/h with SC260 genotype could be recommended to the maize grower for the most effective for producing maize.

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1. Introduction

Crops are the main source of human food supply and among them, grains are more important. To feed the world's growing population, increasing crop production is one of the primary goals. Among cereals, corn (*Zea mays* L.) is an important crop due to its high grain and forage yield potential Corn is one of the most important grains in the world and valuable in the tropical and temperate regions of the world, which is the third most important grain in the world after wheat and rice. Proper planting date makes optimal use of climatic factors such as temperature, humidity, day length, and also the adaptation of flowering time to the appropriate temperature (Sawan, 2018). The decrease in grain yield in the late sowing of corn is due to the coincidence of the grain filling stage with the autumn cold and also the lack of heat supply during the growing period (Afzal et al., 2020). Due to the limitation of arable land, most researchers in recent years have focused on increasing yield per unit area. Increasing production per unit area is generally possible through line-breeding and agricultural management. The most important agricultural management methods are selecting the appropriate hybrid, optimal plant density, optimal amount of fertilizer used, proper planting date, and irrigation time; therefore, increasing the yield of corn requires sufficient information about the simple and interaction effects of these factors on yield and other plant characteristics. Among the management methods to increase corn yield is the use of hybrids and suitable planting date, which many studies have been done. Proper planting dates can play an important role in increasing the quantitative and qualitative yield of the plant and minimizing the negative effects of biotic and abiotic stresses (Koca and Canavar, 2014). To achieve the desired yield, sowing at a suitable time is of particular importance, so that delay in proper sowing time leads to reduced grain yield (Buriro et al., 2015). Kamara et al., reported that delay in cultivation increases the day to flowering and the distance between the emergence of male and female inflorescences and decreases in dry matter production, yield, and yield components of corn grain (Kamara et al., 2009). The number of seeds per cob and grain yield decreases with delaying in sowing date.

Determining planting density is one of the important research priorities in planting a crop in any region. In other words, changing planting density is one of the crop management tools to take advantage of environmental factors, nutrients, and especially light, so the canopy structure of corn can have an important effect on increasing yield because photosynthetic efficiency and growth in corn are significantly depended on how the canopy is structured and the vertical distribution of light (Rahmani et al., 2016). Uniform distribution of plants per unit area In addition to depending on the genotype of the plant is possible by adjusting the distance between plants, at any density of spacing between planting rows is effective in the distribution of plants on the rows. Therefore, by reducing the distances between the rows, the planting arrangement of the plants becomes closer to the square, and thus the competition between the plants is minimized, and as a result, the yield increases (Testa et al., 2016).

(Shrestha et al., 2018) reported that although yield components such as the number of seeds per cob and 1000-seed weight decreased with increasing plant density, increasing the number of plants/h from 55,000 to 85,000 was able to compensate for the low plant yield and increase yield/h. (Qian et al., 2016) showed that with each increase of 10,000 plants/h, the weight of 1000 corn grains decreases by 6 to 9 grams. Also, with increasing density, the number of cobs per plant decreases but the number of grains produced h^{-1} increases. (Gurmu and EshetuYadete, 2020) declared that increasing plant density intensifies competition between adjacent plants and leads to shorter cob production in the plant, thus reducing the length of each row of cob seeds and consequently the number of seeds per row of cobs. This experiment aimed to evaluate the effects of three planting dates and three different plant densities on yield and yield components of three hybrid maize cultivars during the 2020 growing season in the climatic conditions of Takhar province in Afghanistan. There are some objectives of my paper as follows: 1) determining the best planting date for high grain yield in the climatic conditions of the tested area, 2) determining the optimal density for the best seed yield in the tested region, 3) Identification of the best maize cultivar in terms of high production in the tested area, and 3. Evaluation of interaction between planting date, plant density and maize genotypes in terms of yield and yield components in the tested area.

2. Material and Methods

This study was conducted in the spring of the 2020 growing season in the Bagh-e-Zakhirah Research Farm of Takhar province with 350 mm of rainfall, which is considered an arid and semi-arid region in terms of climate. This experiment was performed as a split-plot factorial in a randomized complete block design (RCBD) with three replications. Three planting dates (May 5, May 21, and June 5) as the main factor, three plant densities of 6.5, 8, and 10 plants per square meter (65, 80, and 100 thousand plants per hectare, respectively) and three genotypes, single cross 260 from the early maturity single cross 600 from the middle maturity and Single cross 302 from the late maturity were considered as sub-factors. Before the experiment performance, field soil was sampled at a depth of 0-30 cm and the physical and chemical properties of the soil were determined (Table 1).

Table 1. Physical and chemical analysis of the soil.

Soil particles											
Clay	Silt	Sand	N (%)	P (mg/kg)	K (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	Ph	Ec	Organic material (%)
38.0	42.0	20.0	0.08	8.2	330	2.6	3.2	1.1	6.3	0.74	0.8

After performing the land preparation operation according to the conventional cultivation system of the region, 250 kg/ha of triple phosphate fertilizer was added to the soil before planting and the soil was plowed and disked twice. Also, 100 kg/ha of nitrogen fertilizer from the urea source was added to the soil three times at the same time as planting. In the two to the three-leaf stage and the pre-flowering stage. Each main plot consisted of 9 sub-plots with dimensions of 2.5 x 4 (10 square meters) and 5 planting lines. The distance between replicates was 1.5 m, between main plots was one meter and between subplots was half a meter. Disinfected seeds of the cultivars by hand at 50 cm intervals between rows and 25, 30, and 40 cm between plants on the ridges to reach densities of 50, 65, and 80 thousand plants per hectare, respectively. 3 seeds were planted in each heap at a depth of 3 cm in the middle of the ridges. In the 4-6 leaf stage, a healthy and strong plant was maintained from each heap and the rest of the plants were removed. For uniformity in the emergence of seedlings, the first irrigation was done immediately after planting and subsequent irrigations were performed every seven days until the end of the growing season. Weeding was done manually. The first sampling was performed 28 days after planting and subsequent sampling was performed every 14 days until the end of the growing season (5 times) to measure plant height. Sampling was performed at the end of the growing season and physiological maturation to determine the yield and yield components of maize. For sampling in all plots, by removing two sidelines and a half meters from the beginning and end of each plot as a margin, three middle rows of 4.5 square meters were harvested to determine the final yield. For this purpose, first, the number of plants and the number of cobs were counted, and then the grain yield was determined. To measure the yield components after random selection of 10 cobs, the number of seed rows per cob, number of seeds per row, cob length, cob diameter, and 1000 kernels weight were measured separately for each sample. Analysis of variance of data for different traits was performed using SAS software (version 9.1). Mean comparisons were done using the LSD test at 5% probability level.

3. Results and Discussion

3.1. Plant height

The results of the analysis of variance showed that plant height was significantly ($P< 0.01$) affected by planting date and plant density (Table 2). The highest plant height was obtained on the first planting date (May 5) with an average of 183.59 cm and the lowest plant height was obtained on the third planting date (June 5) with an average of 173.25 cm and there was no significant difference between first and second sowing date also between second and third sowing date were insignificant. With delaying planting date, plant height decreased significantly (Table 3). The results of various studies have shown that with delaying the planting date of corn due to a shorter plant growth period, plant height is significantly reduced (Baum et al., 2019).

(Li et al., 2018) stated in the results of their research, early planting of corn increases the length of the growing season, which provides more opportunity for the plant to produce nodes and increases the length of the internodes, which leads to an increase in plant height. The highest plant height among the studied densities belonged to the first density (65,000 plants/h) with an average of 183.40 cm and the lowest plant height obtained from 100,000 plants/h with an average of 173.37 cm respectively but there was an insignificant difference between 80,000 and 100,000 plants/h (Table 4). With increasing plant density, corn plant height decreased significantly. During the growing season, the highest plant height was obtained for the lowest density. It is inferred that increasing the number of plants per unit area by reducing the light reaching the canopy floor increased the competition between plants to absorb radiation and on the other hand due to the lack of optical degradation of auxin increased the length between nodes and finally increased plant height (Rahmani et al., 2016). In the study of the effect of density on corn plant height plant height also increase with increasing plant density. The results of the study (Li et al., 2015) also confirmed the result of this experiment reported that plant height decreases with increasing plant density.

Table 2. Analysis of variance for effect of sowing date, plant density, genotype and their interaction on yield and yield components of corn.

S.O.V	df	Mean square (MS)									
		P.H	C.L	C.D	N.R.C	N.K.R	N.C.P	T.K.W	S.Y	B.Y	H.I
R	2	125.38**	0.120^{no}	0.123*	0.044^{ns}	0.279^{ns}	0.027**	164.67**	0.088**	0.215^{ns}	18.436*
S.D	2	840.53**	2.706*	144.58**	14.823**	9.182**	0.229**	2792.90**	1.516**	0.586^{ns}	109.617**
P.D	2	792.60**	7.426**	0.552**	8.012**	12.474**	0.196**	1932.82**	1.046**	2.502**	218.625**
G	4	2.08^{ns}	15.328**	0.980**	4.204**	11.217**	0.134**	794.97**	0.433**	1.457**	8.545^{ns}
SDxPD	2	26.51^{ns}	1.013^{ns}	0.219**	1.766**	1.133**	0.009**	98.51**	0.052**	1.273**	23.722**
SDxG	4	3.88^{ns}	0.355^{ns}	0.156^{ns}	0.048^{ns}	0.364^{ns}	0.000^{ns}	9.38^{ns}	0.005^{ns}	0.234^{ns}	4.931^{ns}
PDxG	2	1.06^{ns}	0.344^{ns}	0.122^{ns}	0.052^{ns}	0.049^{ns}	0.003^{ns}	12.19^{ns}	0.006^{ns}	0.289^{ns}	4.866^{ns}
SDxPDxG	8	9.64^{ns}	0.139^{ns}	0.023^{ns}	0.110^{ns}	0.161^{ns}	0.002^{ns}	19.54^{ns}	0.010^{ns}	0.263^{ns}	3.530^{ns}
Error	48	23.135	0.545	0.036	0.081	0.182	0.002	9.17	0.004	0.251	4.648
C.V		2.714	5.588	4.739	1.742	1.187	3.804	1.06	1.063	4.007	4.053

*, ** and ns significant at 0.05, 0.01, and no significant, probability levels respectively. P.H: Plant height, C.L: Cob length, C.D: Cob diameter, N.R.C: Number of row per cob, N.K.R: Number of row per cob, N.C.P: Number of Cob per plant, T.K.W: Thousand kernels weight, S.Y: Seed yield, B.Y: Biological yield, H.I: Harvest index, R: Replication, S.D: Sowing date, P.D: Plant density, G: Genotype.

3.2. Cob length

The results of analysis of variance showed that cob length was significantly affected by planting date at 5% level, plant density, and genotype at 1% level, while the interaction effect of no one planting date, plant density, and genotype was not significant (Table 2). The mean comparison showed that the first planting date (5 May) caused the highest cob length (13.42 cm) and the third planting date (June 5) caused the lowest cob length (12.85) in different densities and cultivars studied (Table 4). (Alam et al., 2020) according to the experiment of the effect of planting date on yield and yield components of corn they observed that delaying sowing date decrease cob length and eventually grain yield. Comparison of the mean cob length trait for the studied densities showed that the highest cob length (13.80 cm) was obtained with a density of 6.5 plants/m^2 and the lowest cob length (12.78 cm) was obtained with a density of 10 plants/m^2 while there was insignificant between 8 and 10 plants/m^2 (Table 4). With increasing plant density, the length of the cob was reduced because the space required by the plant was reduced and the plant absorbed fewer nutrients and at the same time transferred fewer nutrients to the cobs, which led to the production of smaller cobs. Studies have shown that with increasing plant density per unit area, the cob length has decreased significantly so that the maximum cob length was measured with 7 and 9 plants/m^2 and the lowest cob length was measured with 11 plants/m^2, respectively (Gurmu and EshetuYadete, 2020; Cao et al., 2021). In terms of the effect of genotype on cob length, the mean comparison showed that among the studied genotype, SC 260 cultivar had the highest cob length and SC302 cultivar had the lowest cob length (Table 4). The experiment results of (Chisanga et al., 2019) were confirmed the results of this experiment. They reported that cultivar SC-260 had the highest cob length and grain yield.

Table 3. Mean comparisons for the interaction effect of sowing date × plant density on yield and yield components of corn.

Sowing date	P.D (plant/m^2)	C.D (cm)	N.R.C	N.K.R	N.C.P	T.K.W (g)	S.Y (ton/ha)	B.Y (ton/ha)	H.I (%)
5 May	6.5	4.75^{a}	17.57^{a}	37.07^{a}	1.37^{a}	299.77^{a}	6.99^{a}	12.35^{abc}	56.67^{a}
	8	4.51^{ab}	17.08^{bc}	36.94^{a}	1.32^{a}	291.66^{bc}	6.80^{bc}	12.25^{bc}	55.56^{ab}
	10	4.21^{bc}	16.32^{d}	35.47^{bcd}	1.16^{bc}	286.88^{cd}	6.69^{cd}	12.48^{abc}	53.61^{abc}
May 21	6.5	4.23^{bc}	17.50^{ab}	36.88^{a}	1.36^{a}	295.44^{ab}	6.89^{ab}	12.35^{abc}	55.86^{a}
	8	3.89^{de}	16.75^{cd}	35.84^{bc}	1.31^{a}	288.77^{cd}	6.73^{cd}	12.94^{ab}	52.13^{bc}
	10	3.95^{cd}	15.64^{e}	35.44^{bcd}	1.23^{b}	276.33^{e}	6.44^{e}	12.67^{ab}	51.02^{c}
June 5	6.5	3.59^{ef}	15.67^{e}	35.95^{b}	1.23^{b}	284.44^{d}	6.63^{d}	11.82^{c}	56.16^{a}
	8	3.68^{def}	15.50^{e}	35.15^{cd}	1.11^{cd}	268.33^{f}	6.26^{f}	12.44^{abc}	50.47^{cd}
	10	3.54^{f}	15.53^{e}	34.92^{d}	1.06^{d}	266.11^{f}	6.21^{f}	13.17^{a}	47.16^{d}

The different letters show significance at level ($P < 0.01$) and the same letters no significant.

Table 4. Mean comparisons for the simple effect of treatments on yield and yield components of corn.

Treatments	P.H (cm)	C.L (cm)	C.D (cm)	N.R.C	N.K.R	N.C.P	T.K.W (g)	S.Y (ton/h)	B.Y (ton/h)	H.I (%)
Sowing dates										
May 5	183.59^{a}	13.42^{a}	4.49^{a}	16.99^{a}	36.50^{a}	1.30^{a}	292.77^{a}	6.83^{a}	12.36^{b}	55.28^{a}
May 21	174.77^{ab}	13.37^{a}	4.02^{b}	16.63^{b}	36.05^{ab}	1.28^{a}	286.85^{b}	6.69^{b}	12.65^{a}	53.00^{b}
June 5	173.25^{b}	12.85^{a}	3.60^{c}	15.57^{c}	35.34^{b}	1.13^{b}	272.96^{c}	6.36^{c}	12.48^{ab}	51.26^{c}
P.D (plant/m2)										
6.5	183.40^{a}	13.80^{a}	4.19^{a}	16.91^{a}	36.64^{a}	1.32^{a}	293.22^{a}	6.84^{a}	12.17^{b}	56.23^{a}
8	174.85^{b}	13.06^{b}	4.03^{b}	16.44^{b}	35.98^{b}	1.24^{b}	282.92^{b}	6.60^{b}	12.54^{a}	52.72^{b}
10	173.37^{b}	12.78^{b}	3.90^{c}	15.83^{c}	35.28^{c}	1.15^{c}	276.44^{c}	6.45^{c}	12.78^{a}	50.60^{c}
Genotypes										
SC 260	177.48^{a}	14.02^{a}	4.24^{a}	16.83^{a}	36.58^{a}	1.31^{a}	289.59^{a}	6.75^{a}	12.77^{a}	53.80^{a}
SC 600	177.22^{a}	13.10^{b}	4.00^{b}	16.29^{b}	36.02^{b}	1.24^{b}	284.25^{b}	6.63^{b}	12.38^{b}	53.05^{a}
SC 302	176.92^{a}	12.53^{c}	3.87^{c}	16.07^{c}	35.29^{c}	1.17^{c}	278.74^{c}	6.50^{c}	12.35^{b}	52.70^{a}

The different letters show significance at level ($P < 0.01$) and the same letters no significant.

3.3. Cob diameter

Cob diameter was significantly ($P < 0.01$) affected by the simple effects of sowing date, planting density, genotype, and interaction effect of sowing date and plant density but cob length was not significant affected by the interaction effect of sowing date with genotype and plant density with genotype (Table 2). The highest maize cob diameter (4.75 cm) was obtained from the sowing date (May 5) with a planting density of 65000 plants/ha; whereas the lowest maize cob diameters were measured from the sowing date (June 5) with 100000 plants/ha (Table 3). These showed that the cob diameter of corn decreased with the delaying sowing date from May 5 to June 5 and the increment of the planting density from 65000 to 100000 plants/ha. The thickest cobs from the lowest planting density might be due to more nutrients are available for plants and cob grains become larger. This result is in agreement with the work of (Sharifi et al., 2009; Zeleke et al., 2018) they observed that cob diameter increased with a decrease in plant density. These results show that early planting date significantly increases cob diameter. Based on the results, there was a significant (P< 0.01) difference between different hybrids in terms of cob diameter and cob length, the highest cob diameter was obtained from SC260 and the lowers cob diameter was obtained from SC302 (Table 4). There was a significant difference between different hybrids in terms of cob diameter.

3.4. Number of rows per cob

The number of rows per cob was significantly (P< 0.01) influenced by the main effect of sowing date, planting density genotype, and interaction effect of sowing date with plant density but there was no significant effect of interaction between sowing date × genotype and plant density × genotype on the number of rows per cob (Table 2). The maximum number of rows per cob (17.57) was counted from the sowing date (5 May) with a plant density of 65000 plants/ha and while the minimum number of rows per cob (15.53) was produced in the sowing date of (June 5) with the highest plant population of 100000 plants/ha (Table 3). This is a tendency that early sowing date and lowers planting density enhanced the presence of more number of rows per cob. The reason might be due to enough plant growth periods and the availability of more resources to plants on account of low planting density. The results obtained from the present experiment agree with the finding of (Gurmu and EshetuYadete, 2020) they observed that an increase in plant density and delaying sowing date resulting in decreases in the number of rows per cob. As the result of this research, there was a significant difference between genotypes in terms of the number of rows per cob the maximum number of rows per cob was counted from SC 260, and the minimum number of rows per cob was obtained from SC 302 (Table 4). Similar results were reported by.

3.5. Number of kernels per row

According to the analysis of variance table (Table 2), the number of seeds per row was significant (P< 0.01) between the planting date, plant density, genotypes, and the interaction between planting date and plant density, but except for interaction planting date and plant density all of their interaction were not significant effect on the number of kernels per row. The highest number of seeds per row (37.07) was produced with an early sowing date (5 May) and low plant populations (65000) plants/h and the lowest number of seeds per row (34.92) was counted with delaying sowing date (June 5) and highest plant populations (100000) plants/h (Table 3). The difference in the number of seeds produced in different planting dates means that due to the length of the plant growth period, pollination and inoculation of flowers, which is highly sensitive to environmental conditions, especially temperature and humidity, in the planting date of 5 May, such Conditions are provided for the plant and inoculation is well done. These results agree with the finding of (Alam et al., 2020) that reported that early planting date significantly increased the number of kernels per row of maize. The number of kernels per row decreased by increasing plant density, because high levels of plant density might be due to the reduction of light, reduce the number of seeds per row, and caused abort seeds at the end of the cob. These results were confirmed by the finding of Sharifi et al., and Gurmu and EshetuYadete. They found that the number of kernels per row significantly increases by decreasing plant density (Sharifi et al., 2009; Gurmu and EshetuYadete, 2020). There was a significant difference between the tested genotypes. The maximum number of seeds per row was obtained with SC260 and the minimum number of seeds per row was produced with SC302 (Table 4). Early maturity and medium maturity cultivars, due to the long duration of their growth period, have an increase in the number of seeds per row in the corn plant. Similar results were reported by (Oyekunle and Apraku, 2018).

3.6. Number of cobs per plant

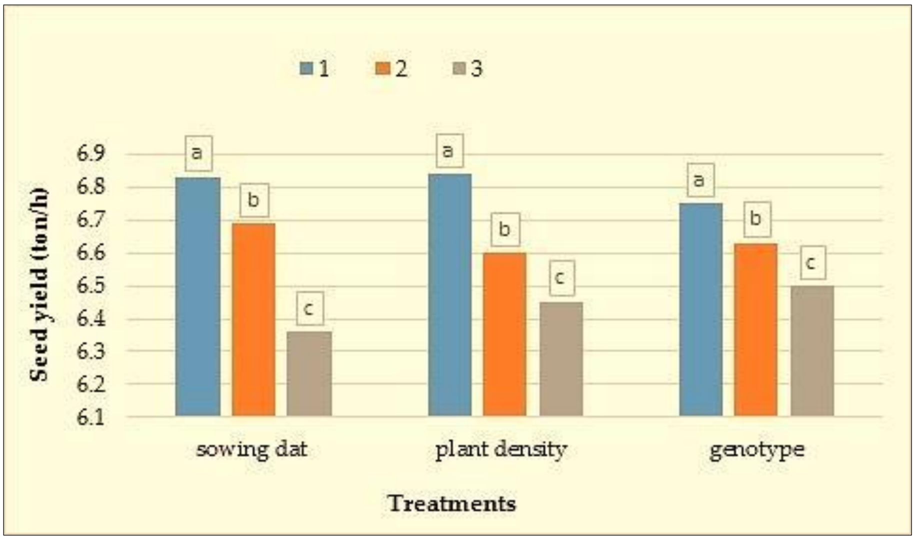
Examining the results related to the number of cobs per plant (Table 2), it was observed that the effect of sowing date, plant density genotype, and interaction effect of sowing date × plant density on the number of cobs per plant was significant (P< 0.01). The highest number of cobs per plant (1.37) was produced with a sowing date (5 May) and plant density of 65000 plants/h; whereas the lowest number of cobs per plant (1.06) was recorded with sowing date (June 5) and plant density 100000 plants/h although there was no significant difference between plant density 65000 and 80000 plants/h (Table 3). Various studies reported the effect of planting date on the number of cobs per plant was not significant but plant density on the number of cobs per plant showed a significant effect at level ($P< 0.01$). The highest number of cobs per plant at a density of 65000 plants/h was 2.5 cobs per plant and with increasing plant density decreased the number of cobs per plant (Qian et al., 2016; Assefa et al., 2018). An experiment performed on three densities (66.000, 85.000, and 110.000) plants/h, it was reported that the highest number of cobs per plant was obtained from the density of 85.000 plants/h and the number of cobs per plant decreased with increasing plant density. There is no significant difference between sowing date, plant density, and their interaction on the number of cobs per plant, also, the number of cobs per plant was genetically characterize and is less affected by environmental factors. Between genotypes, the highest number of cob per plant (1.31) was recorded with SC260, and the lowest number of cob per plant (1.17) was measured with SC302 (Table 4).

3.7. Thousand Kernels Weight

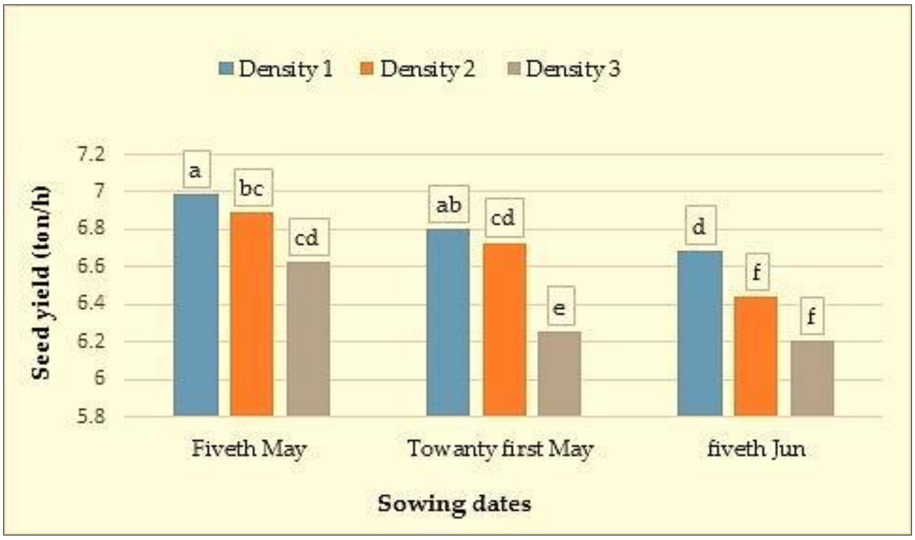
In this experiment, the effect of sowing date, plant density, genotype, and interaction of sowing date × plant density on 1000 kernels weight of corn showed a significant effect ($P< 0.001$) but the interaction effect of sowing date × genotype, plant density × genotype, and their triple interaction was insignificant (Table 2). The maximum 1000 kernels weight (299.77) was measured with sowing date (5 May) and plant density 65000 plants/h; whereas the minimum 1000 kernels weight (266.11) was obtained with sowing date (June 5) and plant density 100000 plants/h (Table 3). Delay in sowing date reduced the length of grain filling period and reduced grain filling length harmed 1000 kernels weight and finally on grain yield, which is probably due to reduced accumulation of nutrients in the seeds (Qian et al., 2016). The density of 10 plants/m^2 due to the increase in the number of plants per unit area, competition between plants has increased and this has caused the weakness of plants and as a result, the 1000 kernels weight has been significantly reduced compared to densities of 6.5 and 8 plants/m^2. This result was in agreement with the work of (Beiragi et al, 2011; Moradi et al., 2012) based on the effect of plant density on the 1000 kernels weight of corn, they showed the highest 1000 kernels weight (378.9 g) was obtained from the density of 7 plants/m^2 and the lowest was (343.3 g) for the density of 9 plants/m^2. Between tested genotypes, in terms of 1000 kernels weight, a significant difference was observed that 289.59 g has belonged to the SC260 genotype and 278.74 g was recorded for the SC302 genotype. This finding was in agreement with the results of (Moradi et al., 2012).

3.8. Seed yield

Based on the results, a significant difference ($P< 0.01$) was observed between planting dates, density, cultivar, and the interaction of planting date × density in terms of yield at the level of one percent. But the interaction effect of planting date × cultivars, density × cultivars, and their triple effect was not significant (Table 2). Comparison of the mean interaction effect between planting date and plant density showed that the highest corn grain yield in the climate of the region was related to the first planting date (5 May) and the first density (65,000 plants/h) with an average grain yield of (6.99 tons/h) and the lowest It was related to the third planting date (June 5) and the third-density (100,000 plants/h) with an average grain yield of (6.21 tons/h) (Table 3, Fig. 1). It seems that the delay in planting due to the plant growth period with a decrease in temperature in the region at the end of the season and insufficient transfer of material to the seeds caused stress in the plant harmed its growth and yield, on the other hand, excessive increase in plant density causes sterilization of flowers and reduced grain yield. The results obtained from the present experiment agree with the results of (Bhandari et al., 2018). In other study, reported that there is a significant difference between sowing dates in terms of seed yield, delay sowing date reduces seed yield (Alam et al., 2020). With increasing plant density from 6.5 to 10 plants/m^2, grain yield decreased due to competition between plants. The results of this experiment were similar to the other study indicated that plant density was a significant difference in terms of grain yield (Moradi et al., 2012). They observed that the highest grain yield was obtained from a plant density of 6.5 plants/m², so an increase in the plant density from 6.5 plants to 7.5 plants/m² caused an 11% decreased seed yield. In terms of grain yield, a significant difference was observed between cultivars, but the interaction between planting date × cultivar and plant density × cultivar was not significant (Table 2). Mean comparison showed that SC260 cultivar had the highest grain yield with an average of 6.75 tons/h and SC302 cultivar had the lowest grain yield with an average of 6.50 tons/h (Table 4). The opposite results of this experiment that there was a significant difference between cultivars in terms of seed yield that the highest yield was obtained with SC302 and the lowest yield was obtained with SC260. It seems that yield is less under environmental conditions in terms of cultivar and is genetically controlled. The results of this experiment were confirmed with the results of (Babaee et al., 2017).



(A)



(B)

Figure 1. A: Mean comparisons for the simple effect of sowing date, plant density and genotype on grain yield. B: Mean comparison for the interaction effect of sowing date with plant density on grain yield of corn.

3.9. Biological yield

Biological yields were significantly influenced (P< 0.01) by plant density, genotype, and the interaction effect of sowing date × plating density, but there was no significant between sowing date, the interaction effect of sowing date × genotype, plant density × genotype, and their triple interaction effect on biological yield (Table 2).

The maximum biological yield (13.17 ton/ha) was obtained from the highest plant density population (100000 plants/ha) and sowing date (June 5) (Table 3). It seems that at higher plant density, especially the density of 10 plants/m, the plant has been able to make good use of sunlight, moisture, soil fertility, and other factors affecting growth and increase biological yield. With increasing plant density, the amount of dry matter also increased, by increasing the number of plants per unit area due to increased competition between plants for environmental factors affecting light absorption and growth, the dry matter weight of a single plant decreases, but further increase plant per unit area, weight loss of plants and eventually the plant compensates. The highest dry weight of the plant was obtained with the highest density. These results obtained from the present experiment agreed with the other study. They reported at high plant density due to increased leaf area, the amount of solar radiation absorption followed by photosynthesis and materialization increased and as a result, the amount of dry matter increased (Khan et al., 2004). The biological yield of maize was significantly affected by genotype so that cultivar (SC260) with (12.77) tons/h and cultivar (SC302) with (12.35) tons/h had the highest and lowest biological yield, respectively (Table 4). In the other research, showed the opposite results of this experiment that the dry matter produced by the Single Cross 302 cultivar with an average of 11353.7 kg/h was more than the dry matter obtained by the Single Cross 260 cultivar (Shakarami and Rafiee, 2009). The results of this experiment were similar to the other studies, which they reported that biological yield was significantly affected by genotype and among genotypes, single cross 260 cultivar showed the highest biological yield (Poorebrahimi et al., 2018).

3.10. Harvest index

According to the analysis of variance table (Table 2), harvest index was significantly influenced ($P< 0.001$) by sowing date, plant density, and the interaction effect of sowing date × plant density; whereas harvest index was insignificant by genotype, the interaction effect of sowing date × genotype, plant density × genotype and their triple interaction effect. The highest harvest index (56.67%) was measured with sowing date (May 5) and plant density 65000 plants/h; the lowest harvest index (47.16%) was counted with sowing date (June 5) and plant density 100000 plants/h (Table 3). The reason for the low harvest index at a density of 100,000 plants/h can be explained by competition due to high density and as a result of increasing the sterility of cobs and pollination. At high densities, although the leaf area index and dry matter increase, due to high competition between plants, the ratio of grain to dry matter decreases. Harvest index was significantly influenced by sowing date, delaying in planting corn caused a sharp decline in the harvest index, so that harvest index 42.8% on June 26 and 6.6% recorded on July 11. These results were confirmed by other research thet found the effect of plant density on harvest index was significant (Shakarami and Rafiee, 2009). The highest harvest index (33.7%) was related to the density of 80,000 plants/h and the lowest harvest index (27.7%) was related to the density of 120,000 plants/h.

3.11. Correlation between seed yield and yield component

The study of simple correlation of traits showed that seed yield had a positive and significant correlation ($P< 0.01$) with, 1000 seed weight, cob length, cob diameter, number of cobs per plant, number of rows per cob, number of seeds per cob, biological yield, and harvest index but there was no significant correlation between seed yield and plant height (Table 5). As the yield component like cob length increases, the number of seeds per row increases, which has a direct effect on increasing seed yield. These results were similar to results of other researches that reported seed yield had a positive and significant correlation with cob length, the number of kernels per row, and the number of rows per cob in the plant corn. The results of a simple correlation table showed that corn seed yield had the most significant positive relationship with 1000 kernels weight (Table 5). In general, there was a significant correlation ($P< 0.01$) between all the yield components; whereas the most significant positive relationship between corn yield components with each other is related to 1000 grain weight with the number of cobs per plant (0.910) and the lowest correlation between cob diameter and cob length (0.642). The seed yield was positively and significantly correlated with 100 seed weight, cob length, and several seeds per row. These results shown that seed yield had a significant correlation with row number per cob, grain number per row, 1000-grain weight.

Table 5. Simple correlation coefficients of seed yield and yield components.

characteristics	P.H	N.C.P	C.D	C.L	N.R.C	N.K.R	T.K.W	S.Y
P.H	1							
N.C.P	-0.110^{ns}	1						
C.D	0.402^{ns}	0.713**	1					
C.L	-0.087^{ns}	0.776**	0.642**	1				
N.R.C	0.109^{ns}	0.864**	0.840**	0.744**	1			
N.K.R	-0.039^{ns}	0.903**	0.798**	0.810**	0.857**	1		
T.K.W	0.072^{ns}	0.910**	0.793**	0.744**	0.894**	0.883**	1	
S.Y	0.071^{ns}	0.910**	0.793**	0.744**	0.894**	0.883**	1.000**	1

ns, * and ** no significant, significant at 0.05 and significant at 0.01, probability levels respectively.

4. Conclusions

In general, the results of this investigation showed that sowing date and plant density were a significant effect on grain yield and yield component. The highest grain yield with an average of 6.99 ton/h was obtained from the sowing date (May 5) and plant density of 6.5 plants/m^2 and the lowest grain yield with an average of 6.21 ton/h was obtained from the sowing date (June 5) and plant density of 10 plants/m^2. In general, the results of this experiment showed that the sowing on the 5th of May is superior to the 5th of June in terms of grain yield and yield components. It was the probability that the delay in planting due to the plant growth period with a decrease in temperature in the region at the end of the season and insufficient transfer of material to the seeds caused stress in the plant harmed its growth and yield. With increasing plant density from 6.5 to 10 plants/m^2, grain yield decreased due to competition between plants. Genetic differences between different cultivars caused differences in yield and yield components; whereas compared to the three corn genotypes, the Single cross 260 genotype is better than the Single cross 600 and Single cross 302 genotype under this weather condition. The study of simple correlation of traits showed that seed yield had a positive and significant correlation with 1000 seed weight, cob length, cob diameter, number of cobs per plant, number of rows per cob, number of seeds per cob, biological yield, and harvest index but there was no significant correlation between seed yield and plant height. Therefore considering all results the first week of May as the sowing date and 65000 plants h^{-1} with SC260 genotype could be recommended to the maize grower for the most effective for producing maize, and it is suggested that this experiment be repeated in Takhar province or similar conditions to further confirm the experimental results. This experiment should also be studied in areas where corn is used as a secondary crop.

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