EFFECTS OF DIFFERENT SOWING DATES IN SOME AGRONOMIC AND MORPHOLOGIC CHARACTERISTICS IN MAIZE (*ZEA MAYS* L.)

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Abstract. This study was conducted in Turkey in Samsun conditions to determine some morphological and agronomic traits of different corn varieties planted at different sowing times. In our study, three different hybrid corn varieties (Otello, Golden Frank and Goldenver) and five different sowing times (May 13, June 3, June 21, July 9, July 29) were tested. The trial was established with 3 replications according to Randomized Complete Block Design. In the trial, 9 morphological and agronomic traits (plant height, stem diameter, leaf number, stem weight, root weight, leaf weight, cob length, cob diameter, row number) were examined. Repeated measurement analysis was conducted for plant height, stem diameter, leaf number, stem height, root weight, and leaf weight variables. Factor analysis was used for cob length, cob diameter, and row number variables for completely randomized design. Canonical Discriminant analysis was performed for classification of diversity factor. Pearson correlation coefficients were calculated to determine the correlation between variables. In the study, the highest plant height was determined as 192.16 cm, the highest leaf number as 10.22, the highest stem weight as 51.58 g, the highest root weight as 33.52 g, the highest leaf weight as 30.35 g, the highest cob length as 20.39 cm, and the highest row number in the cob as 23.25. As a result of the study, the best results were obtained from the first and second varieties with the sowing time of May 13.
Keywords: *dent corn, root weight, late sowing, second crop, Zea mays*

Introduction

Corn (*Zea mays* L.) is a cereal crop with high yield potential and is the second most widely cultivated cereal crop in the world after wheat (Anonymous, 2021). It serves as an important industrial raw material for humans, a primary source of food for animals, and the most important renewable energy crop (Xia et al., 2019).

With the increasing global population, the food needs of people are also increasing. To meet the growing food demand, it is essential to increase the yields of staple cereal crops. Environmental conditions significantly influence the growth and development of corn plants (Abbas et al., 2019). With the impact of climate change, especially during the grain filling period, a decrease in yield occurs, which is one of the main reasons for yield reduction in corn (Tao and Zhang, 2010). Yield increase in corn can be achieved through practices such as variety development, increased plant density, fertilization, and sowing time adjustment (Qian et al., 2016). Determining the most suitable sowing time is crucial for adjusting the phenological stages of the crop according to the environmental conditions of the growing region (Bonelli et al., 2016).

Changes in sowing time can alter the duration of the phenological stages, leading to an increase or decrease in yield and yield components. Sowing time may vary from region to region due to climatic differences and the length of the growing season (Abbas et al., 2019). Early sowing is generally preferred, but sufficient temperature is required for germination and emergence (Abendroth et al., 2017; Hall et al., 2016). The highest

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yield usually occurs when the growing season is the longest and soil moisture is not a limiting factor (Kucharic, 2006). In temperate and cool environments, delayed sowing results in flowering occurring well after the summer solstice, and grain filling occurs close to the end of the harvest period. Therefore, delayed sowing disrupts both grain hardening and the required photo-thermal conditions for plant growth, leading to a decrease in grain filling duration (Bonelli et al., 2016). Delayed sowing results in decreased yield, plant population, and plant height, as well as reduced photosynthetic efficiency during grain filling (Tsimba et al., 2013). Early sowing delays leaf area formation, leading to a reduction in photosynthetically active radiation. In late sowings, high temperatures shorten the plant development period, leading to a decrease in yield and, consequently, a reduction in photosynthetically active radiation (Otegui et al., 1995). Especially in regions where the sowing period is shortened due to weather conditions, determining the appropriate sowing time for the region where the crop is grown is crucial (Sher et al., 2019; Zahoor et al., 2019).

This study aims to investigate the effects of different sowing times on certain morphological and agronomic traits of corn plants and to determine the optimal sowing time.

Materials and methods

This study was conducted under in Turkey in Samsun conditions (*Fig. 1*). Samsun is a province north of Turkey (41°10’32” N, 36°55’23” E). The experiments were established in between 2022 and 2023 growing seasons in Samsun provinces Turkey. The soil analysis results of the trial area are given in *Table 1*. The soil of the trial area is close to neutral, low in salt content, and of moderate organic matter level (*Table 1*). *Table 2* provides the experimental province’s climate parameters.

Figure 1. *A general view of the trial area*

Table 1. *Soil analysis results of the trial area*

Saturation (%)	pH	Lime (%)	Total N (%)	Total salt (%)	P_2O_5 (kg/da)	K_2O (kg/da)
66	6.80	0.57	0.1565	0.088	8.8	90

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Table 2. *Climatic data for the experimental site*

	Temperature (°C)			Rainfall (mm)		
	2022	**2023**	**Long term (30 years)**	**2022**	**2023**	**Long term (30 years)**
April	12.3	12.4	11.4	41.0	113.4	55.1
May	15.0	15.1	15.8	40.6	84.0	56.5
June	21.5	21.0	20.8	81.3	161.9	56.9
July	23.5	24.1	23.9	2.8	48.3	38.7
August	26.0	25.9	24.6	34.6	0.0	45.9
September	21.7	21.9	20.9	115.8	84.3	55.3

The trial was established according to a 'Randomized Complete Block Design' with 3 replications. Each plot in the trial was created with dimensions of 5 m in length, with 4 rows of planting, in a 5 × 2.8 m (14.0 m^2) area. Plant densities in the trial were adjusted to 71,500 plants/ha (70 × 20 cm spacing). The plant materials used were Otello, Golden Frank and Goldenver (dent type) hybrid corn varieties. Five different sowing times (May 13 - June 3 - June 21 - July 9 and July 29) were applied in the trial. Samsun is a region that receives a lot of rainfall and the planting dates are set a little late due to the fact that the soil is a very heavy soil. Before each sowing, parcels were fertilized with 100 kg/ha of nitrogen in the form of 26% calcium ammonium nitrate (CAN) fertilizer and 100 kg/ha of phosphorus in the form of 45% triple superphosphate (TSP) fertilizer. An additional 60 kg/ha of nitrogen (26% CAN) was applied when plants reached a height of 50-60 cm. The second nitrogen fertilization (V5 period) was applied when the maize plant had approximately 5-7 leaves. Nine morphological traits (plant height, stem diameter, leaf number, stem weight, root weight, leaf weight, cob length, cob diameter, row number) were examined in the trial.

Repeated measurement analysis was conducted for plant height, stem diameter, leaf number, stem height, root weight, and leaf weight variables. Ten randomly chosen plants were measured, and an average of these ten plants was calculated. For root measurements only, measurements were made on 3 plants in each plot A 0-40 cm deep and 0-20 cm wide section was formed around each plant and the plant was removed together with the root. The root was cut 1 cm below the green parts and was subjected to washing. After the washed roots were dried, the root weights were weighed. Factor analysis was used for cob length, cob diameter, and row number variables for a completely randomized design. Canonical Discriminant analysis was performed for the classification of diversity factor. Pearson correlation coefficients were calculated to determine the correlation between variables.

Results and discussion

The effects of sowing time and variety applications on the examined traits, along with standard errors, were provided in *Table 2* based on the analysis of variance. While the sole effect of variety applications was statistically significant ($P < 0.05$) only on plant height, the effect of sowing time applications was significant ($P < 0.05$) on plant height, stem diameter, leaf number, stem height, and leaf weight values. The interaction

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effect of sowing time and variety appeared significant (P < 0.05) on root weight, cob length, cob diameter, and row number (*Table 2*).

Plant height (cm)

The highest plant height, measured at 192.16 cm, was observed in the first variety planted on May 13, while the shortest plant height, measured at 91.09 cm, was recorded in the third variety planted on July 29. The effect of varieties on plant height values was found to be significant (P < 0.05), with the tallest plant heights obtained from the first variety. As sowing time was delayed, a decrease in plant height values was observed. However, higher plant height values were obtained on July 9 compared to June 21, but decreased again on July 29. Idikut et al. (2005) reported in their study that the use of different varieties in corn had a significant effect on plant height, and as sowing time was delayed, plant height decreased, which is consistent with our findings. Plant height, being a genetic trait, is influenced by various factors such as the earliness or lateness of the variety used, environmental conditions, soil properties, fertilization, and planting density (Kavut, 2009). The variation in plant height can be attributed to geographical conditions where the plant is grown, climatic conditions during the growing season, and different genotypes. Liaqat et al. (2018) reported the significant effect of different sowing times on plant height in corn, stating that as sowing time was delayed, plant height decreased. Early-planted corn plants have more daily life cycles for vegetative growth compared to late-planted ones, resulting in longer heights (Kharazamshahi et al., 2015).

Stem diameter (cm)

While the interaction of variety and sowing time applications and the sole effect of variety applications on stem diameter were statistically insignificant, the effect of sowing time was found to be significant (P < 0.05). The highest stem diameter of 18.23 cm was obtained in the first variety on July 9, whereas the lowest stem diameter value of 10.63 cm was recorded in the first variety on June 3. Stem diameter values increased with delayed sowing times, while a lower value was obtained on July 29 compared to the values obtained on June 21 and July 9 sowing times. Stem diameter, generally being a genetic trait, can vary due to practices such as sowing time, fertilization, and planting density (İptaş and Acar, 2003; Yılmaz et al., 2007). Stem diameter plays a crucial role in preventing the plant from leaning due to factors such as wind and water, especially as the plant grows upright above the soil (Kavut and Soya, 2012).

Leaf number (count)

While the effect of sowing time applications on leaf number was statistically significant (P < 0.05), the effect of varieties was found to be insignificant. The highest leaf number of 10.22 was obtained on May 13 sowing time, whereas the lowest leaf number of 7.29 was recorded on July 29 sowing time in the third corn variety. It is observed that higher leaf numbers were obtained in early sowings (*Table 2*). Physiologically, an increase in leaf number in plants leads to an increase in the photosynthetic area and, consequently, photosynthetic activity. Increased photosynthesis also enhances carbohydrate formation, making leaf number an important factor for plants like corn (Gençtürk, 2007; Alan et al., 2005).

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Stem weight (g)

While the effect of variety and variety × sowing time interactions on stem weight was found to be insignificant, the effect of sowing time applications was significant ($P < 0.05$). The highest stem weight of 51.58 g was obtained on May 13 sowing time. As sowing times were delayed, a decrease in stem weight was observed, with the most significant decrease occurring on July 29 sowing time. Early sowing extends the vegetation period of plants. With prolonged vegetation periods, plants undergo more photosynthesis, produce more nutrients, and increase lignification in the stem. It is presumed that the decrease in weight with delayed sowing times is due to this factor.

Root weight (g)

While the effect of variety and sowing time applications on root weight was found to be insignificant, the effect of variety × sowing time interactions was significant ($P < 0.05$). The highest root weight values were obtained as a result of the interaction of May 13 sowing time with the first and third varieties. The lowest root weight was obtained as a result of the interaction of July 29 sowing time with the first variety. Root formation and development in corn are important processes for plant yield. Liu et al. (2017) stated that sowing time, row spacing, fertilization, and harvest time do not have individual effects on corn root weight, but their combined effects exist. Similarly, in our study, while variety and sowing time applications individually did not affect root weight, the interactions were significant.

Leaf weight (g)

When the effects of applications on leaf weight values were examined, while the effect of variety and variety × sowing time interactions was found to be insignificant, the effect of sowing time applications was significant ($P < 0.05$). As sowing time was delayed, leaf weight values decreased, with values obtained on July 9 being higher compared to the earlier sowing time of June 21. Liaqat et al. (2018) reported that leaf area decreased with delayed sowing times and that the effect of sowing time applications on leaf area was significant. As leaf area increases, leaf weight also increases, thus in our study, leaf weight and consequently leaf area increased with delayed sowing times. Early sowing can provide more suitable weather conditions for vegetative growth of corn, resulting in a higher leaf area index (Shah et al., 2012).

Ear length (cm)

Ear length values were determined between 20.39 and 10.25 cm. While the effect of sowing time and variety applications on ear length was found to be insignificant, the effect of sowing time × variety interactions was significant ($P < 0.05$), with the highest ear length values obtained on May 13, the first sowing time. As sowing times were delayed, ear length values decreased, with values obtained on July 29 being higher than those obtained on June 21 and July 9.

Ear diameter (cm)

While the interaction of sowing time × variety applications had a significant effect on ear diameter ($P < 0.05$), the individual effects of applications were insignificant. The highest ear diameter value of 45.97 cm was obtained from the third variety on May 13

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sowing time, and the lowest ear diameter value of 31.39 cm was obtained from the third variety on July 9 sowing time. As observed in most of the examined characteristics, ear diameter values decreased until July 29, the latest sowing time, while values obtained on July 29 were higher than those obtained on June 21 and July 9.

Row number (count)

As shown in *Table 3*, the effect of sowing time × variety interactions on row number was significant (P < 0.05). Row number values ranged between 23.25 and 12.

Table 3. *Agronomic and morphologic trait means and standard error for maize varieties; V1 (Otello), V2 (Golden Frank) and V3 (Goldenver) within sowing date*

		SD1[a]	**SD2[b]**	**SD3[c]**	**SD4[d]**	**SD5[e]**	**V × SD**
Plant height	V1[a]	192.16 ±4.85	146.86±5.32	120.12±6.32	137.96±6.78	102.97±6.48	-
	V2[ab]	181.80±5.03	141.88±5.89	113.39±6.64	137.98±7.28	109.95±7.63	
	V3[b]	175.36±4.33	142.89±5.33	115.52±6.11	126.27±6.01	91.09±6.07	
		SD1[c]	SD2[c]	SD3[a]	SD4[a]	SD5[b]	V × SD
Stem diameter	V1	12.94±0.54	10.63±0.63	16.94±0.67	18.23±0.41	15.02±1.92	-
	V2	12.46±0.58	12.72±0.69	16.28±0.57	17.57±0.05	13.47±0.43	
	V3	12.34±0.53	11.19±0.67	17.35±0.71	18.13±0.35	14.81±0.37	
		SD1[a]	SD2[b]	SD3[c]	SD4[b]	SD5[c]	V × SD
Leaf number	V1	9.86±0.15	8.79±0.97	7.49±0.24	9.16±0.27	7.64±0.28	-
	V2	10.22±0.15	9.29±0.23	7.68±0.26	9.23±0.30	7.81±0.31	
	V3	9.97±0.14	9.21±0.20	7.74±0.27	9.85±0.83	7.29±0.27	
		SD1[a]	SD2[b]	SD3b[c]	SD4b[c]	SD5[c]	V × SD
Stem weight	V1	42.27±5.89	25.58±4.27	21.78±4.51	25.61±6.01	13.72±4.38	-
	V2	51.58±8.59	39.66±7.77	22.49±5.98	17.45±4.37	17.38±5.37	
	V3	40.42±6.18	30.18±5.37	25.71±4.77	27.68±6.84	17.76±4.34	
		SD1	SD2	SD3	SD4	SD5	V × SD
Root weight	V1	33.52±5.44[a]	18.74±3.29[b]	9.62±1.81[cd]	9.82±2.47[cd]	6.04±1.11[d]	*
	V2	21.07±3.47b	13.20±2.95[bc]	6.12±1.35[cd]	9.59±1.93[cd]	11.01±3.43[cd]	
	V3	32.29±4.99[a]	13.25±2.33[bc]	11.83±2.22[cd]	14.08±3.18[cd]	8.39±1.81[cd]	
		SD1[a]	SD2[b]	SD3b[c]	SD4[b]	SD5[c]	V × SD
Leaf weight	V1	30.35±2.88	17.88±2.66	14.67±3.00	15.11±2.50	11.55±2.78	-
	V2	29.61±3.55	19.16±3.13	11.25±2.45	15.33±2.81	10.00±1.95	
	V3	28.83±3.11	19.41±3.13	14.92±2.59	21.26±3.15	13.41±3.03	
		SD1	SD2	SD3	SD4	SD5	V × SD
Corncob height	V1	19.10±0.21[ab]	17.79±0.74[ab]	14.50±1.84[cd]	14.17±2.49[cd]	16.53±0.46[bc]	*
	V2	20.39±0.27[a]	10.50±2.00[f]	10.25±0.25[f]	14.73±1.18[cd]	17.67±0.23[ab]	
	V3	19.56±0.33[a]	13.50±1.39[de]	10.50±1.21[f]	11.17±1.48[ef]	19.55±0.39[a]	
		SD1	SD2	SD3	SD4	SD5	V × SD
Corncob diameter	V1	42.90±0.36a[b]	41.36±1.87[bc]	36.14±3.65[def]	33.27±3.12[ef]	35.65±0.91[def]	*
	V2	43.11±0.39[ab]	35.07±1.07[def]	34.29±2.32[def]	34.30±1.70[def]	37.66±0.62[cde]	
	V3	45.97±0.52[a]	35.68±2.07[def]	34.26±2.69[def]	31.39±1.93[f]	38.87±0.41[bcd]	
		SD1	SD2	SD3	SD4	SD5	V × SD
Ordinal number	V1	19.62±3.71[abc]	14.86±0.59[bcd]	15.00±0.57[bcd]	13.33±0.66[cd]	13.92±0.28[cd]	*
	V2	20.86±4.30[ab]	12.00±2.00[d]	12.00±0.01[d]	14.00±0.26[cd]	14.23±0.25[bcd]	
	V3	23.25±3.44[a]	14.89±0.48[bcd]	14.50±0.50[bcd]	14.33±0.80[bcd]	14.84±0.26[bcd]	

V1: Variety1 (Otello), V2: Variety2 (Golden Frank), V3: Variety3 (Goldenver), SD; Sowing date. Upper lower cases indicate statistical significance at 0.05. Existing of "*" in Ç × SD column indicates that Variety × Sowing date interaction is statistically significant and in this situation, labeling by upper lower cases used in interaction cells. Existing of "-" in Ç × SD column indicates that Variety × Sowing date interaction is statistically insignificant, and labeling by upper lower cases used on headers for Variety and Standard deviation main effects, if they statistically significant

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The highest row number values were obtained from the first sowing time on May 13. Having more grains on longer ears will lead to higher yields (Babaoğlu, 2003; Çalışkan et al., 2007). Kaya and Kuşaksız (2012) mentioned in their study that sowing time did not have any effect on ear row number in corn, while variety and sowing time × variety interaction had a significant effect.

Correlation analysis

The correlation coefficients obtained from the correlation analysis conducted among the examined characteristics are presented in *Table 4*. Most of the correlations between the characteristics were found to be significant. There is a positive and highly significant ($P < 0.01$) correlation between ear length and ear diameter, with the highest coefficient (0.776**) calculated between these two characteristics. In our study, as plant height increases, leaf number also increases, and a positive and significant correlation (0.472**) is observed between them. Positive and significant correlations were calculated between ear length and all other characteristics except plant height. All negative correlations between the characteristics were found to be insignificant. All coefficients between the characteristics are given in *Table 4*. Malik et al. (2005) reported a positive correlation between plant height and leaf number in corn, Nemati et al. (2009) reported a positive correlation between corn ear diameter and corn ear weight, Rafiq et al. (2010) reported a positive correlation between plant height and row number in corn, and Uwizeyiman et al. (2018) reported positive correlations between plant height and ear diameter, and between ear diameter and ear length in corn. These results are consistent with our study.

Table 4. *Correlation coefficients between agronomic and morphologic traits*

Traits	Plant height	Stem diameter	Leaf number	Stem weight	Root weight	Leaf weight	Corncob height	Corncob diameter	Ordinal number
Plant height	1								
Stem diameter	0.328**	1							
Leaf number	0.472**	0.201**	1						
Stem weight	0.213	-0.042	0.085	1					
Root weight	0.048	0.027	-0.262	0.389**	1				
Leaf weight	0.191	0.106	0.063	0.624**	0.413**	1			
Corncob height	0.093	0.209*	-0.079	0.345*	0.316*	0.344*	1		
Corncob diameter	0.227*	0.126	-0.080	0.146	0.243	0.284	0.776**	1	
Ordinal number	0.078	-0.031	-0.072	0.114	0.481**	0.211	0.299**	0.388**	1

Canonical discriminant analysis

Fisher's linear discriminant functions and Classification Function Coefficients have shown that the most important features in classification are plant height, leaf number, and stem weight, respectively (*Table 5*). Classification Function Coefficients are provided in *Table 6* according to genotypes. For future studies, Plant Height has been identified as the most preferred feature.

Nine agronomic and morphological traits were analyzed using multivariate discriminant function analysis, revealing that the first two canonical variables cover 67.4% and 52.3% of the total variation between contributions, respectively. The first canonical variable (*Fig. 2*) has a high eigenvalue for Otello and Golden Frank of maize

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entries, accounting for 72.1% of the total variance between varieties, while the second canonical variable belongs to maize entries for Otello and Goldenver (*Table 5*). 72.1% of the original grouped cases were correctly classified. These results indicate that Turkish maize entries grouped as V1 (Otello), V2 (Golden Frank), and V3 (Goldenver) based on agronomic and morphological traits were classified according to race characteristics using multivariate discriminant function analysis.

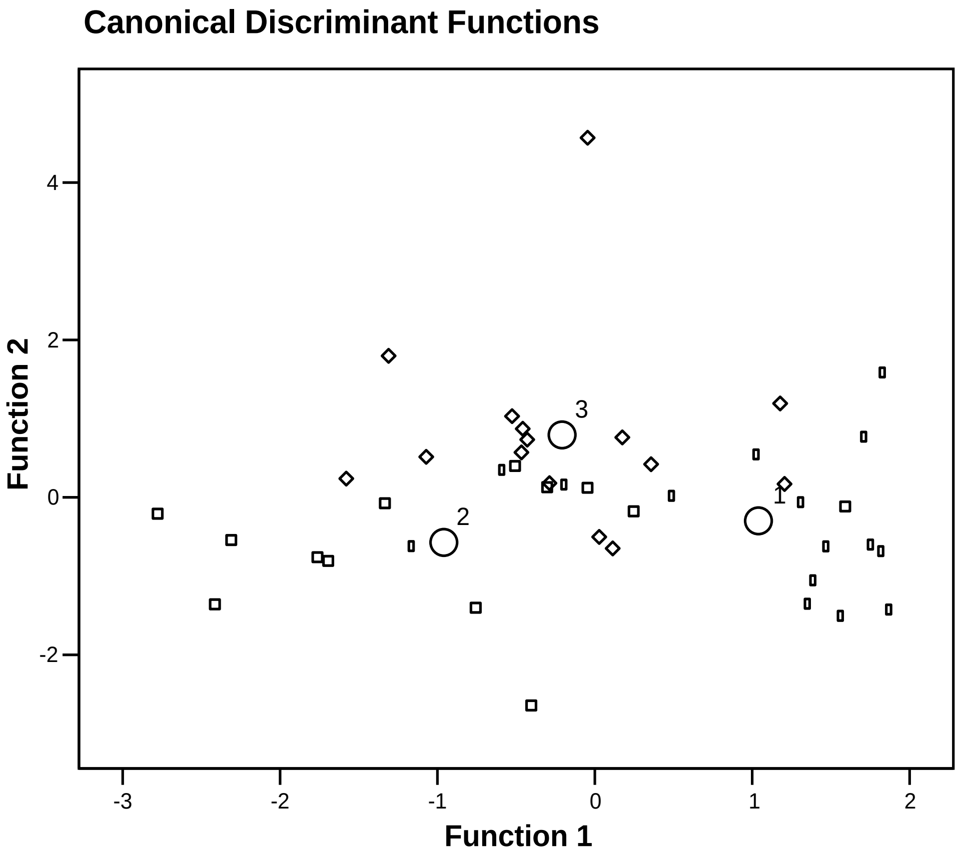

Figure 2. *The grouping of Maize based on multivariate discriminant function analysis. Maize varieties were displayed as Otello (1), Golden Frank (2), and Goldenver (3)*

Table 5. *Fisher's linear discriminant functions and classification function coefficients*

Traits	Corn hybrid varieties		
	1 (Otello)	**2 (Golden Frank)**	**3 (Goldenver)**
Plant height	0.393	0.331	0.355
Stem diameter	-0.145	0.024	-0.160
Leaf number	7.593	6.790	6.946
Stem weight	0.195	0.252	0.198
Root weight	-0.130	-0.156	-0.167
Leaf weight	-0.117	-0.146	-0.080
Corncob height	-2.918	-3.050	-2.816
Corncob diameter	3.313	3.256	3.171
Ordinal number	1.716	1.729	2.049
(Constant)	-139.427	-119.020	-125.447

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Table 6. *Multivariate discriminant function analysis: Eigen values for multivariate variables (CV) and trait loads*

	CV 1	CV 2
Multivariate correlation	0.674	0.523
Eigenvalue	0.721	0.376
% of variance	65.7	34.3
Traits		
Plant height	0.703	-0.124
Leaf number	0.479	-0.254
Stem weight	-0.279	-0.107
Ordinal number	-0.033	0.714
Stem diameter	0.170	-0.279
Corncob height	0.228	0.238
Leaf weight	-0.008	0.238
Root weight	0.000	0.151
Corncob diameter	0.143	0.143

Conclusion

In our study, various maize varieties were investigated for different planting times regarding some agronomic and morphological traits. Measurements and analyses revealed that the best results were obtained from the first planting time on May 13th for the first and second varieties (Golden Frank).

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