Investigation of Yield and Yield Components and Quality Characteristics of Some Dent Corn (*Zea mays* L. *indentata*) Genotypes Cultivated as Grain Crop under Semi-Arid Climate Conditions

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ABSTRACT

Maize is an important short day cereal with a wide range of uses as a raw material in human and animal nutrition industry. This study was conducted during 2016 and 2017 to identify grain yield and some quality characteristics of dent corn genotypes under semi-arid temperate climate conditions. Twelve (12) dent corn genotypes were utilized as plant material in the study. The research was carried out according to the randomized complete blocks experimental design with three replications. Significant differences were recorded between the genotypes in terms of all traits (except cob length). The plant height ranged 197.90-211.25 cm, with first cob height of 81.24-107.30 cm, cob length of 17.02-19.10 cm, cob diameter of 39.82-50.82 mm, number of kernels per cob of 423.77-590.82, and grain yield of 4650.0-10693.9 kg ha^{-1}. It was noted that the 1000-grain weight varied between 254.96-348.93 g, hectoliter weight with range of 79.06-89.83 kg hl^{-1}, starch content in grain between 62.59-69.50%, protein content in grain between 9.22-11.74%, oil content in grain between 2.67-3.98%. The maximum values of plant height and cob length were obtained from the 70May82 variety, and the maximum values of first cob height, cob diameter, grain yield, 1000-kernel weight, hectoliter weight, starch, protein, and oil content in grain were recorded from Kalipso and Samada-07 varieties. Considering these results, it is advisable to grow Kalipso, Samada-07, and 70 May82 varieties as main crops in temperate semi-arid climate of Gümüşhane and surrounding areas of Turkiye.

Keywords: maize, yield traits, quality, genotype.

INTRODUCTION

The use of agricultural land is expanding rapidly and gradually reaching the maximum level in parallel with the rapid increase in the world population. This situation has made it obligatory to improve cultural measures in crop production and obtain more crops per unit area. Researchers have focused on plants with high yield, high adaptability, high utilization possibilities, is increasing the importance of maize plants increasing (Celep, 2006).

Among the cultivated plants, maize, is the most produced crop in the world, for human and animal nutrition, industry. The majority of maize produced in developed countries is used as animal feed, while in underdeveloped and developing countries it is used as human food. In recent years, the popularity of maize has increased due to both increased production of "biofuels" (Kardeş et al., 2020). Among all cereals, maize has the maximum yield potential, utilizes solar energy very well (C4 plant), and produces the highest dry matter per unit area (Okan, 2015). It is well known that 27% of corn is used for human nutrition and 73% is used as animal feed. This consumption rate varies depending on the development rate of the countries. Moreover, 11% of the daily calories consumed in human nutrition are supplied from maize plants in the world (Celep, 2006). About 35% of the corn produced is used for human nutrition, 30% in animal nutrition, and 20% in the feed industry in Türkiye, (Celep, 2006).

Although the areas of use of corn are very wide, they can be listed as flour, semolina, bread, snack, corn flakes, canned, boiled, chips, oil, starch, crushing, roasting, popcorn, dextrin, molasses, sugar, oil, milk acid, gluten, spirit and acetone industries. Corn, which is an important feed source, especially

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in animal nutrition, is crushed and given to poultry by mixing into feed rations in large quantities in feed factories. In addition, its green parts are utilized and can also be used in silage production (Celep, 2006). Moreover, processed products of corn are also used in compared tool production, cleaning materials, explosives, pharmaceuticals, textile, and cosmetics industries (Burcu and Akgün, 2018).

The most important challenge in animal husbandry is the high level of quality roughage deficit despite the high number of livestock. Roughages are plant-based materials fed to livestock in green, dried, and silage forms (Okan, 2015; Yılmaz et al., 2017). Therefore corn plays a very important role in supplying the quality roughage needed by the animals in our country. At least 40% of the dry matter consumed by dairy cows is provided from roughage. When there is a shortage of roughage, our farmers feed their animals with grain straw, which has a very low nutrient content. However, in recent years, roughages called silage, are obtained by breaking down plants with high carbohydrate contents rich in fresh and water content, are preferred (Okan, 2015; Atakul et al., 2016).

Maize, has the largest cultivation area (209.954.361,0 hectares) after wheat in the world, has a production of 1218.205.573,82 tons and a yield of 5802.2 kg ha^{-1} (FAO, 2024). Grain corn is cultivated over 78.944.380 hectares, 8.100.000 tons with an average yield of 1026.0 kg ha^{-1} in Turkiye (FAO, 2024).

Therefore, the objective of this study was to determine the grain yield and some agronomic and quality characteristics of some dent corn genotypes in the Eastern Black Sea region (Gümüşhane-Şiran).

MATERIAL AND METHODS

The research was conducted for two years during 2016 and 2017 cultivation seasons (April-October) as a main crop in a farmers' field for the Gümüşhane-Şiran county under semi-arid climate conditions. In the research, 6 dent corn genotypes widely cultivated in the Eastern Black Sea Region, 5 FAO maturity group varieties, and Samada-07 variety registered by the Black Sea Agricultural Research Institute (a total of 12 genotypes) were used as plant material and some information about these varieties are given in Table 1.

Table 1. Some dent corn genotypes used in the experiment and the institutions from where they were obtained

NO	Cultivars/ Genotypes	FAO maturity group	Institutions from which they were obtained/ Places where the genotypes were collected
1	KALİPSO	FAO 650-700	KWS Turkish Agriculture Trade Inc.
2	70MAY82	FAO 700	May Agro Seed Growing Industry and Trade Inc.
3	PR31D24	FAO 650-670	Pioneer Seed Growing Trade Inc.
4	BOLSON	FAO 650	Polen Seed Growing Limited Company
5	DKC6022	FAO 600	Monsanto Food and Agriculture Trade Limited Company
6	SAMADA-07	-	Blacksea Agricultural Research Institute- Samsun
7	GM2901 (line)	-	Gumushane Province, Gumushane Central Native *
8	GM2902 (line)	-	Gumushane Province, Kelkit (county) Central Native *
9	GM2903 (line)	-	Gumushane Province, Şiran (county) Central Native *
10	GM2904 (line)	-	Gumushane Province, Kose (county) Central Native *
11	GM2905 (line)	-	Gumushane Province, Torul (county) Central Native *
12	GM2806 (line)	-	Giresun Province, Şebinkarahisar (county) Central Native *

* The cultivar planted by the farmer.

The soil samples taken from the experimental area at 0-30 cm depth were analyzed at Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition Laboratory and the results are given in Table 2. As can be seen in Table 2, the experimental soils were similar in both years and the first year was clay loamy (54.4%), very calcareous (19.38%), salt-free (0.017%), high in organic matter (4.08%) and slightly alkaline (8.07%). In addition, in terms of nutrients, phosphorus content was moderate (74.4 kg ha^{-1}) and potassium content (786.3 kg ha^{-1}) was adequate. The second-year experiment showed that the texture class of the soils was clay loam (63.7%), salt-free (0.013%), slightly alkaline (7.67), also organic matter percentages were good (3.41%), phosphorus level was moderate (83.7 kg ha^{-1}) and potassium content was sufficient (484.7 kg ha^{-1}) (Özyazıcı et al., 2016).

Table 2. Some physical and chemical properties of the soils of the experimental area

Years	Analyze	Saturation (%)	Total salt (%)	PH	$CaCO_3$ (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Organic matter (%)
2016	Value	54.4	0.017	8.07	19.38	74.4	786.3	4.08
	Degree	Clayey loam	Saltless	Slightly alkaline	Limy	Middle	Sufficient	High
2017	Value	63.7	0.013	7.67	8.55	83.7	484.7	3.41
	Degree	Clayey loam	Saltless	Slightly alkaline	Middle Limy	Middle	Sufficient	Sufficient

Some climatic values for the years of the research are given in Table 3. The amount of precipitation affecting grain yield was considerably higher in the first year of the experiment compared to the average of the second year. The total rainfall in the first (2016) and second (2017) years of the experiment was 395.4 and 234.3 mm, respectively, while the total rainfall for the long years (1995-2016) was 376.0 mm. During the vegetation period, the average temperature in the first, second, and long-term periods was 14.74, 15.30, and 15.39ºC, respectively. The average relative humidity was 57.08% and 51.55% in the first and second years, respectively, while the long-term average was 54.64% (Table 3).

Table 3. Climate data of Gümüşhane province for the years 2016 and 2017*

Months	Average temperature (°C)			Total precipitation (mm)			Relative humidity (%)		
	2016	2017	1995-2016	2016	2017	Long years	2016	2017	Long years
March	5.5	5.6	6.6	63.6	20.1	54.8	57.4	53.5	55.4
April	11.3	9.1	10.7	43.7	52.5	37.0	49.4	51.4	47.5
May	13.3	13.4	14.0	127.5	74.7	118.4	63.7	57.7	61.7
June	18.1	17.8	18.2	73.3	32.3	78.4	59.0	55.4	58.7
July	20.5	21.8	21.4	8.8	0.0	12.7	55.2	47.9	52.5
August	22.6	23.3	22.4	19.8	13.7	12.2	54.4	50.9	52.5
September	15.3	20.2	17.8	42.2	2.0	25.2	58.2	39.1	51.1
October	11.3	11.0	12.0	16.5	39.0	37.3	59.3	56.5	57.7
Mean/ Total	**14.74**	**15.30**	**15.39**	**395.4**	**234.3**	**376.0**	**57.08**	**51.55**	**54.64**

* Climate data was obtained from Gumushane Provincial Directorate of Meteorology.

In the experiment, which was carried out using three replications according to the randomized complete blocks design, the sowing was done manually on April 13, 2016 in the first year and April 21, 2017 in the second year on plots of 14.0 m^2 in size (2.8 × 5 m) with 4 rows in each plot, taking into account the distance between rows of 70 cm and plant to plant distance of 20 cm. A distance of 1 m was left between the plots and 2.5 m between the blocks. The experimental plots were plowed in the fall of both years and the seedbed was prepared by using a disc harrow and rake before sowing.

The experimental area was fertilized at the rate of 180 kg ha^{-1} pure nitrogen (N) and 100 kg ha^{-1} pure phosphorus (P_2O_5). All of the phosphorus was applied as Diammonium Phosphate (DAP) fertilizer at planting and half of the nitrogen was applied at planting and the other half when the plants reached 40-50 cm height. When the plants reached a height of 10-15 cm, hand hoeing, and weeding were done by hand, and when the plants reached a height of 40-50 cm, second hoeing, middle-breaking, and nitrogen fertilization were done with a tractor. In the experiment, the periods when the plants needed water, the first irrigation after planting was sprinkled, and the drip irrigation (7 times) in the following periods.

According to the weed situation in the trial area, weed control was provided mechanically (with tractor hoe besides hand hoe) when necessary. Harvesting was carried out manually on 26.09.2016 and 19.09.2017 in the first and second years, respectively, after the completion of the physiological maturity period of the grains in the cob (black spot formation period), then one row was removed from the edges of the plot to eliminate the row effect and the cobs in the remaining rows were harvested manually.

The measurements and observations of the traits examined in the research were carried out in accordance with the Ministry of Agriculture and Forestry, Technical Instructions for Agricultural Values Measurements in Trials (Anonymous, 2021). Plant height (cm), first cob height (cm), cob length (cm), cob diameter (mm), number of kernels per cob, grain yield (kg ha^{-1}), 1000-grain weight (g), hectoliter weight (kg hl^{-1}), starch (%), protein (%) and oil contents (%) in grain were measured.

The analysis of variance of the data obtained from the research was carried out according to the randomized complete blocks experimental design by using JMP 7.0.2 statistical package program (JMP, 2007). The statistical significance of the differences between cultivar averages was compared using LSD test.

RESULTS AND DISCUSSION

Plant height (cm)

The mean values of plant height of different maize genotypes and their significance groups are given in Table 4. According to the results, the difference between the mean values of the year, variety, and year×cultivar interactions were found statistically significant (*p<0.01*). The maximum plant height was obtained from genotype 70MAY82 (211.25 cm) and the minimum plant height was obtained from genotype GM2806 (197.90 cm). When the plant heights were analyzed in terms of years, the plant height obtained in the first year of the research was 222.07 cm, and in the second year, it was 185.62 cm (Table 4). The average plant height of maize varieties was found 203.84 cm. Similar to our findings, Üzen and Öktem (2022) reported that plant height values varied between 164.66 cm and 211.87 cm under Şanlıurfa conditions. Öner and Aykutlu (2017) obtained higher results compared to current findings under Ordu ecological conditions (213.53-240.83 cm), Kılınç et al. (2018) under Diyarbakır conditions (251.80-282.30 cm), Erdoğan et al. (2019) under Samsun conditions (230.00-286.67 cm), and Yılmaz et al. (2020a) under Samsun (Çarşamba) conditions (269.3-322.1 cm). Although plant height is a criterion stemming from genotypic traits, it is also greatly affected by growing conditions (Öktem, 2008; Üzen and Öktem, 2022). Genotypes that are early-grown and adapted to high altitudes are generally shorter, while genotypes that are transient and adapted to low altitude and rainy environments are taller. Plant height is affected by environmental factors as well as cultivation techniques such as plant density, fertilizer dose, and sowing time (Arteaga et al., 2016; Öztürk and Büyükgöz, 2021). The direct effect of plant height on yield in maize was determined to be 27%-34% (Sakin et al., 2016).

First cob height (cm)

According to the results of the analysis of variance, significant differences were found among genotypes in terms of first cob height (*p<0.01*). The maximum first cob height value was found for SAMADA-07 variety with 107.30 cm, while the minimum value was obtained from GM2904 (81.23 cm) and GM2905 (83.70 cm) which were statistically similar. The mean first cob height of maize varieties was 91.38 cm (Table 4). The first cob height value reported by Kabululu et al. (2017) was between 59.6-156.0 cm, which is lower compared to our findings. Kahrıman et al. (2020) found that the first cob height varied between 87.3-142.5 cm, and Yılmaz et al. (2020a) found that it varied between 100.0-156.1 cm, higher compared to our findings. Öner (2017) reported 14-191 cm, Kılınç et al. (2018) 88.0-104.7 cm, Ekinci and Duman (2021) 87.99-115.67 cm, with similar values to our findings. This difference is thought to be due to the used plant materials and environmental conditions. Although the height of the first cob is largely dependent on genetic factors, it is also affected by environmental factors (Öktem and Öktem, 2009). The height of the first cob is important in terms of suitability for machine harvesting and tilting. The cob that is close to the ground makes harvesting difficult and adversely affects cob health, whereas high cob height increases the tilting rate in tall and weak-stemmed genotypes (Öztürk and Büyükgöz, 2021). The study predicts that there is a significant variation in local populations, and the materials can be used in further breeding studies.

Cob length (cm)

The differences between the genotypes used in the experiment were statistically significant in terms of year×cultivar interactions ($p<0.05$) and years ($p<0.01$). The mean values of cob length varied between 17.02 cm and 19.10 cm; the 70MAY82 variety had the maximum cob length value (19.10 cm), while the minimum value (17.02 cm) was obtained from the GM2806. The cob lengths were 18.88 cm for first year and 17.33 cm for the second year. The general average cob length of maize genotypes was found 18.10 cm (Table 4). In previous studies, cob length was found 21.9-23.8 cm by Sönmez et al. (2013), 19.8-23.0 cm by Yılmaz and Han (2016), 10.32-17.66 cm by Kabululu et al. (2017), 13. 20-22.40 cm, 15.2-18.6 cm by Doğanlar (2018), 19.50-22.00 cm by Kılınç et al. (2018), 12.98-19.75 cm by Erdoğan et al. (2019), and 17.59-19.97 cm by Üzen and Öktem (2022). Tekkanat and Soylu (2005) mentioned in their study with consensus that generally high-yielding varieties have high cob lengths and diameters. There are many studies indicating different cob lengths under the influence of different environmental conditions. Genotype and environment interactions have a significant effect on cob length (Özmen, 2008).

Table 4. Mean values of plant height, first cob height, and cob length of maize genotypes

Cultivars/ Genotypes	Plant height (cm)			The first cob heights (cm)			Cob length (cm)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
KALİPSO	212.13 b-e	200.13 e-h	206.13 ab	100.00	88.70	94.35 abc	20.90 a*	16.20 c	18.55
70MAY82	235.03 a**	187.47 f-ı	211.25 a**	100.40	75.17	87.78 bc	20.73 ab	17.47 abc	19.10
PR31D24	225.87 a-d	183.93 ghı	204.90 ab	92.57	93.33	92.95 abc	19.43 abc	17.00 bc	18.22
BOLSON	231.90 ab	180.23 hı	206.07 ab	104.93	96.03	100.48 ab	19.37 abc	16.60 c	17.98
DKC6022	225.30 a-d	173.60 ı	199.45 ab	101.93	101.10	101.52 ab	18.90 abc	17.17 abc	18.03
SAMADA-07	227.77 abc	173.87 ı	200.82 ab	113.10	101.50	107.30 a**	18.90 abc	18.60 abc	18.75
GM2901	219.43 a-e	201.60 efg	210.52 ab	83.77	84.57	84.17 c	18.47 abc	17.30 abc	17.88
GM2902	225.07 a-d	174.70 ı	199.88 ab	90.83	83.50	87.17 bc	18.10 abc	16.83 c	17.47
GM2903	232.63 ab	182.83 ghı	207.73 ab	89.90	89.53	89.72 bc	18.60 abc	17.73 abc	18.17
GM2904	206.00 def	198.37 e-h	202.18 ab	85.27	77.20	81.23 c	18.17 abc	17.87 abc	18.02
GM2905	216.00 a-e	182.53 ghı	199.27 ab	84.70	82.70	83.70 c	17.87 abc	18.23 abc	18.05
GM2806	207.67 c-f	188.13 f-ı	197.90 b	88.37	84.00	86.18 bc	17.13 abc	16.90 c	17.02
Mean	222.07 a**	185.62 b	203.84	94.65	88.11	91.38	18.88 a**	17.33 b	18.10
LSD	Cultivar:13.33, Year:4.71, Y×C: 21.18			Cultivar:16.07			Year:0.72, Y×C: 3.82		
CV (%)	3.28			8.83			6.66		

There is no difference between the averages indicated by the same letter with a probability of *$*P<0.05$, $**P<0.01$*. CV: Coefficient of variation.

Cob diameter (mm)

Statistical difference was detected among the genotypes in terms of cob diameter (*p<0.01*). The maximum cob diameter value among the genotypes was obtained from SAMADA-07 (50.82 mm), followed by KALİPSO (49.10 mm) and 70MAY82 (48.62 mm) varieties, which were statistically similar. The minimum value was obtained from GM2806 (39.82 mm) (Table 5). The cob diameter was reported to vary between 40.26-50.36 mm by Sezer et al. (2007), 45.30-48.80 mm by Yılmaz and Han (2016), 30.60-60.20 mm by Kabululu et al. (2017), 13.20-41.40 mm by Öner (2017), 44.50 to 49.00 mm by Kılınç et al. (2018), 42.62-52.11 mm by Erdoğan et al. (2019). The differences mentioned by the aforementioned researchers are attributed to the variation of the varieties used in the study and the applied agronomic treatments. In maize, cob diameter is an essential trait that directly affects yield. It is well-known that cob diameter varies according to genotype, environmental conditions, and cultural practices (Öztürk and Büyükgöz, 2021; Üzen and Öktem, 2022). As the cob diameter rises, the number of cob rows also increase (Kılınç et al., 2018).

Number of kernels per cob (pcs cob^{-1})

There were statistical differences (*p*<0.01) among the means of the number of kernels per cob between years, genotypes, and year×cultivar interactions. The maximum number of kernels per cob was obtained from the KALİPSO variety (590.82 cobs^{-1}), while the minimum value was obtained from GM2904 and GM2905 (423.77 and 435.90 cobs^{-1}, respectively) (Table 5). In previous studies, the number of kernels per cob was reported to vary between 443.8-805.7 (Sezer et al., 2007), 668.75-721.83 (Öner et al., 2012), 321.55-606.60 (Erdoğan et al., 2019), 407.0-479.5 (Yılmaz and Topal, 2021). The number of grains on the cob, which is the most important factor of grain yield, is a function of the number of grain rows on the cob and the number of grains in the row (Bagrintseva, 2015; Öztürk and Büyükgöz, 2021). The number of grains on the cob is influenced by genetic structure as well as environmental conditions and cultivation techniques (Öktem and Toprak, 2013; Öztürk and Büyükgöz, 2021).

Seed yield (kg ha^{-1})

The difference between year (*p≤0.05*) and genotypes (*p≤0.01*) was statistically significant. The maximum grain yield was obtained from KALİPSO (10693.9 kg ha^{-1}) and SAMADA-07 (10298.4 kg ha^{-1}) varieties, while the minimum value was obtained from GM2806 (4650.0 kg ha^{-1}) and GM2905 (4985.5 kg ha^{-1}). The grain yield obtained for the first year of the research was 8439.2 kg ha^{-1} and 7546.6 kg ha^{-1} for the second year. The average grain yield of maize genotypes in the study was 7992.9 kg ha^{-1}. The genotypes 70MAY82 (9343.7 kg ha^{-1}), PR31D24 (9099.3 kg ha^{-1}), BOLSON (9333.8 kg ha^{-1}), DKC6022 (8941.4 kg ha^{-1}), and GM2902 (8718.8 kg ha^{-1}) gave grain yield above the general average (7992.9 kg ha^{-1}) (Table 5). In addition, KALİPSO and SAMADA-07 genotypes can also be used for silage considering both plant height, protein and oil content in grain. Sharply different grain yield values were obtained in studies conducted under different climatic and soil conditions. Researchers have reported 7443.0-13820.0 kg ha^{-1} in Bafra Plain (Sezer et al., 2007), 19610.0-21310.0 kg ha^{-1} under Konya conditions (Karaşahin and Sade, 2012), 6550.0-9750.0 kg ha^{-1} under Giresun conditions (Yılmaz and Han, 2016), 12326.1-15181.0 kg ha^{-1} under Diyarbakır conditions (Kılınç et al., 2018), 2794.6-13909.1 kg ha^{-1} in Samsun-Bafra and Çarşamba Plain (Erdoğan et al., 2019), 6982.0-11133.0 kg ha^{-1} in Trabzon ecological conditions (Gür and Kara, 2019), 8650.0-14533.3 kg ha^{-1} in Mardin (Artuklu) and Batman (Beşiri) conditions (Ekinci and Duman, 2021), 3193.0-11671.0 kg ha^{-1} in Trabzon (Akçaabat and Of) conditions (Öztürk and Büyükgöz, 2021), 8978.3-15063.9 kg ha^{-1} in Şanlıurfa (Üzen and Öktem, 2022). This difference is thought to be due to the used plant materials and different climatic and soil conditions. It was also reported by researchers in different studies that grain yield varies according to cultivars (Sezer et al., 2007; Soylu et al., 2008; Koca et al., 2009; Kuşvuran and Nazlı, 2014; Sakin et al., 2016; Öztürk and Büyükgöz, 2021). Although grain yield in maize cultivation depends on the yield potential of the genotype, the soil and ecological conditions of the region where it is grown also affect this factor significantly (Öztürk and Büyükgöz, 2021; Üzen and Öktem, 2022). Therefore, it is necessary to identify maize genotypes suitable for the climate and soil structure of each region.

Table 5. Mean values of cob diameter, number of kernels per cob, and grain yield of maize genotypes

Cultivars/ Genotypes	Cob diameter (mm)			Number of grain per cob (pcs cob^{-1})			Seed yield (kg ha^{-1})		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
KALİPSO	51.10	47.10	49.10 a	595.70 b	585.93 bc	590.82 a**	10728.3	10659.5	10693.9 a**
70MAY82	50.03	47.20	48.62 a	601.67 b	535.20 def	568.43 ab	9418.4	9269.0	9343.7 ab
PR31D24	48.90	47.40	48.15 ab	653.27 a**	448.83 jk	551.05 bc	9460.7	8737.9	9099.3 ab
BOLSON	48.87	46.50	47.68 abc	538.40 de	499.83 e-h	519.12 d	9559.4	9108.3	9333.8 ab
DKC6022	47.93	47.27	47.60 abc	539.53 de	487.33 g-j	513.43 d	9335.0	8547.8	8941.4 ab
SAMADA-07	52.20	49.43	50.82 a**	511.43 d-g	611.83 ab	561.63 b	10845.8	9751.0	10298.4 a
GM2901	41.47	46.37	43.92 cde	461.33 h-k	469.87 g-j	465.60 e	7767.4	7533.4	7650.4 bc
GM2902	43.97	40.57	42.27 de	506.10 d-g	548.00 cd	527.05 cd	9010.8	8426.8	8718.8 ab
GM2903	43.47	44.90	44.18 bcd	484.87 g-j	474.77 g-j	479.82 e	8590.7	5267.7	6929.2 bcd
GM2904	43.80	41.87	42.83 de	452.97 ıjk	394.57 l	423.77 f	6669.8	3871.0	5270.4 cd
GM2905	39.87	46.63	43.25 de	446.83 jk	424.97 kl	435.90 f	4704.8	5266.3	4985.5 d
GM2806	40.20	39.43	39.82 e	447.07 jk	492.87 f-ı	469.97 e	5179.7	4120.3	4650.0 d
Mean	45.98	45.39	45.69	519.93 a**	497.83 b	508.88	8439.2 a*	7546.6 b	7992.9
LSD	Cultivar:4.10			Cultivar:26.82, Year:4.11, Y×C: 42.60			Year:73.69, Cultivar: 251.20		
CV (%)	7.72			2.65			15.78		

There is no difference between the averages indicated with the same letter with $^*P<0.05$, $^{**}P<0.01$ probability.

1000-grain weight (g)

Significant differences ($p<0.01$) were found among the varieties in terms of 1000-grain weight. As can be seen from Table 6, the mean values of 1000-grain weight varied between 254.95 and 348.93 g; the SAMADA-07 variety had the maximum 1000-grain weight value (348.93 g), while the GM2806 genotype had the minimum 1000-grain weight value (254.95 g). The average 1000-grain weight of maize varieties was realized as 308.09 g. 1000-kernel weight values of 320.00-418.00 g (Sakin et al., 2016), 138.43-423.55 g (Öner, 2017), 174.00-313.00 g (Kabululu et al., 2017), 193.30-403.08 g (Ferdoush et al., 2017), 218.00-350.41 g (Erdoğan et al., 2019), 270.60-397.00 g (Öztürk and Büyükgöz, 2021) corroborated findings in the current study. On the other hand, 1000-grain weights calculated between 311.40-423.20 g (Sezer et al., 2007), 311.00-518.00 g (Shengu, 2017), 307.86-439.57 g (Üzen and Öktem, 2022) were higher compared to our results, also 184.60-249.04 g (Yılmaz and Han, 2016), 227.93-272.26 g (Yılmaz and Topal, 2021) were lower compared to our results. The 1000-kernel weight of maize varies according to the genetic structure of the variety as well as environmental conditions and cultivation techniques (Sezer et al., 2007; Sakin et al., 2016; Öztürk and Büyükgöz, 2021).

Hectoliter weight (kg hl^{-1})

The differences in hectoliter weight trait between years ($p≤0.05$) and genotypes ($p≤0.01$) were found statistically significant. It was determined that the hectoliter weight of dent corn genotypes used in the research varied between 79.06-89.82 kg hl^{-1} and the average hectoliter weight of all genotypes was 83.69 kg hl^{-1}. SAMADA-07 (89.82 kg hl^{-1}) and KALİPSO (88.26 kg hl^{-1}) genotypes had the maximum hectoliter weight values, while the minimum hectoliter weight was obtained from GM2806 (79.06 kg hl^{-1}). The average hectoliter weight was 85.30 kg hl^{-1} for the first year and 82.08 kg hl^{-1} for the second year (Table 6). Hectoliter weight values were obtained between 69.7-77.0 kg hl^{-1} by

Doğanlar (2018), which are lower compared to current findings in this study. In studies conducted under different climatic and soil conditions, the values were 63.1-69.2 kg hl^{-1} in Bursa (Karasu et al., 2015), 79.10-84.00 kg hl^{-1} in Diyarbakır (Kılınç et al., 2018), 59.53-77.89 kg hl^{-1} in Mardin (Artuklu) and Batman (Beşiri) (Ekinci and Duman, 2021), 62.51-64.64 kg hl^{-1} in Konya (Akşehir) (Yılmaz and Topal, 2021) and 87.77-95.80 kg hl^{-1} in Şanlıurfa (Üzen and Öktem, 2022). It is estimated that this is due to the differences in the used plant materials and environmental conditions. Hectoliter weight was also reported to vary according to varieties and environmental conditions (Ekinci and Duman, 2021; Yılmaz and Topal, 2021). It has been reported that hectoliter weight as well as grain yield per unit area is highly important and affects the quality of maize (Vartanlı and Emekler, 2007; Yılmaz and Topal, 2021).

Starch content in grain (%)

Table 6 presents that there were significant differences among genotypes in terms of starch content in grain (%) at $p \leq 0.01$ level. It is seen from Table 6 that the mean values of the varieties for starch content in grain trait varied between 62.59% and 69.50%. SAMADA-07 (69.50%) and KALİPSO (68.80%) varieties had the maximum starch content in grain, while the minimum starch content in grain was found in the GM2806 genotype (62.59%). The average starch content of grain of maize varieties was found 66.04% (Table 6). Previous studies reported that starch content in grain varied between 64.28-65.57% (Kılınç et al., 2018), 60.08-74.90% (Taş, 2020), 64.8-72.6% (Kahrıman et al., 2020). Starch accumulation in maize grain causes an increase in grain size and increases grain yield (Kahrıman et al., 2020).

SAMADA-07 (69.50%) and KALİPSO (68.80%) genotypes with the maximum starch content among the genotypes used in the study, which had high grain yield (10298.4 and 10693.9 kg ha^{-1}, respectively), which confirms current study (Table 5).

Table 6. Mean values of 1000-kernel weight, hectoliter weight, and starch content in grain of maize varieties

Cultivars/ Genotypes	Thousand grain weights (g)			Hectoliter weight (kg hl^{-1})			Seed starch contents (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
KALİPSO	331.38	302.40	316.89 ab	90.68	86.26	88.47 ab	69.10	68.50	68.80 ab
70MAY82	330.19	328.56	329.37 ab	87.50	83.19	85.34 a-d	66.10	65.11	65.61 abc
PR31D24	325.38	336.62	331.00 ab	86.70	82.00	84.35 b-e	66.04	67.38	66.71 abc
BOLSON	342.95	308.81	325.88 ab	87.76	83.58	85.67 abc	67.19	66.77	66.98 abc
DKC6022	328.30	296.52	312.41 ab	85.50	81.47	83.48 c-f	66.29	67.01	66.65 abc
SAMADA-07	347.44	350.41	348.93 a**	91.08	88.57	89.82 a**	70.31	68.69	69.50 a**
GM2901	315.08	295.61	305.34 bc	86.69	80.35	83.52 c-f	66.00	66.95	66.47 abc
GM2902	318.77	291.84	305.31 bc	85.04	79.43	82.23 c-f	65.42	65.31	65.36 abc
GM2903	297.48	303.80	300.64 bc	81.29	81.61	81.45 c-f	65.29	63.85	64.57 abc
GM2904	306.80	292.90	299.85 bc	80.73	79.83	80.28 ef	64.75	63.68	64.21 bc
GM2905	282.63	250.39	266.51 cd	80.75	80.35	80.55 def	66.36	63.75	65.06 abc
GM2806	290.10	219.81	254.95 d	79.82	78.30	79.06 f	62.74	62.43	62.59 c
Mean	318.04	298.14	308.09	85.30 a*	82.08 b	83.69	66.30	65.79	66.04
LSD	Cultivar:41.38			Year:3.00, Cultivar:4.87			Cultivar:4.95		
CV (%)	6.75			2.92			3.77		

There is no difference between the averages indicated with the same letter with *$p<0.05$, **$p<0.01$ probability

Protein content (%) in grains

The protein content for grain of the varieities used in the experiment was found significantly different for genotypes ($p \leq 0.05$) and years ($p \leq 0.01$). The mean values of the genotypes varied between 9.22% and 11.73%. The maximum value of protein content in grains, was found for SAMADA-07 variety (11.73%), while the minimum value was obtained from the GM2903 genotype with 9.22%. The average protein content in grain for all genotypes was 10.10% (Table 7). The difference in protein content in grain observed among the genotypes in the study is due to the genetic structure and soil characteristics of the genotypes. Tantekin and Turan (2017) between 4.09-6.27%, but they found lower values for this parameter compared to our findings.

Öktem (2008) found the protein percentage in corn grains between 5.2-10.8%, Yılmaz et al. (2020b) between 5.01-9.48%, Üzen and Öktem (2022) between 7.36-9.73%, thus they obtained values close to our results. In other studies conducted under different ecological conditions, protein content in grain values was between 7.8-9.0% in Diyarbakır (Kılınç et al., 2018), 10.62-12.85% in Samsun-Bafra and Çarşamba Plain (Erdoğan et al., 2019), 8.20-11.60% in Çanakkale conditions (Kahrıman et al., 2020), 7.45-13.66% in Mardin (Artuklu) and Batman (Beşiri) (Ekinci and Duman, 2021), 7.49-8.73% in Konya (Akşehir) (Yılmaz and Topal, 2021), 9.89-14.50% in Trabzon (Akçaabat and Of) (Öztürk and Büyükgöz, 2021).

Oil content in grains (%)

There was a significant difference (p<0.01) among the varieties in terms of oil content. It was determined that the oil content of the grain of the maize genotypes used for the experiment varied between 2.66-3.98% and the average oil content in the grain of all genotypes was 3.22%. Among the genotypes, SAMADA-07 had the highest oil content in grain (3.98%), followed by KALİPSO (3.91%) and DKC6022 (3.59%). GM2905 (2.66%), GM2904 and GM2806 (2.70%) had the minimum oil content in grain value (Table 7). Previous studies reported that oil content in grain, which varied between 3.33-4.00% (Kılınç et al., 2018), 3.80-5.45% (Erdoğan et al., 2019), 3.47-5.70% (Kahrıman et al., 2020), 3.10-8.27% (Taş, 2020), 2.30-3.62% (Ekinci and Duman, 2021). This is thought due to differences in plant materials and environmental conditions. Oil content in grain is largely attributed to the embryo, and varieties with larger embryos characterized as oil-bearing (Koca et al., 2009).

Table 7. Mean values of protein and oil content in grain of maize genotypes

Cultivars/ Genotypes	Seed protein contents (%)			Seed fat percent (%)		
	2016	2017	Mean	2016	2017	Mean
KALİPSO	12.23	10.65	11.44 ab	3.97	3.84	3.91 a
70MAY82	10.31	10.16	10.23 ab	3.39	3.37	3.38 abc
PR31D24	10.70	8.78	9.74 ab	3.52	3.28	3.40 abc
BOLSON	11.44	9.80	10.62 ab	3.49	3.28	3.39 abc
DKC6022	11.47	9.10	10.29 ab	3.78	3.40	3.59 ab
SAMADA-07	12.77	10.70	11.73 a*	4.03	3.92	3.98 a**
GM2901	10.97	8.78	9.87 ab	3.16	2.89	3.02 bcd
GM2902	10.86	8.48	9.67 ab	3.18	2.90	3.04 bcd
GM2903	10.70	7.74	9.22 b	3.03	2.66	2.85 cd
GM2904	10.24	8.98	9.61 ab	2.85	2.55	2.70 d
GM2905	10.16	8.56	9.36 ab	2.75	2.58	2.66 d
GM2806	10.40	8.41	9.41 ab	2.85	2.54	2.70 d
Mean	11.02 a**	9.18 b	10.10	3.33	3.10	3.22
LSD	Year:0.94, Cultivar: 2.50			Cultivar:0.63		
CV (%)	12.41			9.77		

There is no difference between the averages indicated with the same letter with *$p<0.05$, **$p<0.01$ probability.

Correlations between the studied traits

The combined correlation analysis of the data from the two years of the experiment was carried out to determine the correlations between the examined traits. According to the results of the correlation analysis, there were significant correlations between grain yield and first cob height (r=0.446**), cob diameter (r=0.505**), number of kernels per cob (r=0.638**), 1000-grain weight (r=0. 615**), hectoliter weight (r=0.536**), starch content in grain (r=0.558**), protein content in grain (r=0.457**), oil content in grain (r=0.721**) and cob length (r=0.268*). In addition, there were significant and positive correlations between 1000-grain weight and hectoliter weight (r=0.560**), protein content in grain (r=0.351**), oil content in grain (r=0.512**), and starch content in grain (r=0.259*) (Table 8). Öktem and Çölkesen (1997) reported significant and positive correlations (0.44*) between first cob height and grain yield. A significant and positive correlation was reported between grain yield and hectoliter weight (Barrios Sánchez et al., 2019; Yılmaz and Topal, 2021). Soylu et al. (2008) reported that the difference between varieties in terms of plant height was insignificant. Taş (2020) reported that there were positive and significant correlations between grain yield and starch content (r=0.7008**), while there were negative and significant negative correlations between oil content and grain yield (r=-0.7195**) and starch content (r=-0.8065**).

Table 8. Correlation coefficients and significance levels between the traits investigated in maize genotypes

Traits	FCH	CL	CD	NK	GY	TGW	HW	SC	PC	OC
PH	0.223	0.494**	0.103	0.186	0.222	0.278*	0.371**	0.124	0.471**	0.235*
FCH	1.000	0.281*	0.457**	0.339**	0.446**	0.342**	0.579**	0.425**	0.365**	0.498**
CL		1.000	0.377**	0.347**	0.268*	0.287*	0.498**	0.242*	0.468**	0.288*
CD			1.000	0.452**	0.505**	0.426**	0.548**	0.444**	0.247*	0.586**
NK				1.000	0.638**	0.415**	0.571**	0.328**	0.313**	0.616**
GY					1.000	0.615**	0.536**	0.558**	0.457**	0.721**
TGW						1.000	0.560**	0.259*	0.351**	0.512**
HW							1.000	0.368**	0.624**	0.657**
SC								1.000	0.409**	0.585**
PC									1.000	0.498**
OC										1.000

* Significant with probability at $p<0.05$ level, ** Significant with probability at $p<0.01$ level.
PH: Plant height (cm); FCH: First Cob Height (cm); CL: Cob length (cm); CD: Cob diameter (mm); NK: Number of kernels per cob (pcs); GY: Grain yield (kg ha^{-1}); TGW: 1000-grain weight (g); HW: Hectoliter weight (kg hl^{-1}); SC: Starch content in grain (%); PC: Protein content in grain (%); OC: Oil content in grain (%).

CONCLUSIONS

Except for cob length, statistically significant differences were observed among genotypes for plant height (cm), first cob height (cm), cob diameter (mm), number of kernels per cob (pcs cob^{-1}), grain yield (kg ha^{-1}), 1000-grain weight (g), hectoliter weight (kg hl^{-1}), starch content in grain (%), protein content in grain (%) and oil content in grain (%). The highest grain yield was recorded in KALİPSO (10693.9 kg ha^{-1}) and SAMADA-07 (10298.4 kg ha^{-1}) varieties, while the lowest yield were observed in value was obtained in GM2806 and GM2905. The 70MAY82 variety exhibited the maximum plant height and cob length, whereas KALİPSO and SAMADA-07 recorded the highest values for first cob height, cob diameter, grain yield, 1000-kernel weight, hectoliter weight, starch, protein, and oil content. According to these results, it can be recommended to grow KALİPSO, SAMADA-07, and 70MAY82 varieties as main crops in Gümüşhane, particulary under semi-arid climate conditions. Evaluating the performance of new maize genotypes developed through breeding programs under diverse environmental conditions and comparing their productivity with standard regional genotypes is essential for improving crop performance and adaptation.

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