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PERFORMANCE OF SOME DIFFERENT HYBRID DENT CORN (*Zea mays* L. *indentata* S.) VARIETIES UNDER CENTRAL ANATOLIAN CONDITIONS

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ABSTRACT

This study was conducted under Cumra ecological conditions between 2019 and 2020 in order to determine the performance of some KWS hybrid corn varieties (V1; Kerbanis, V2; Kefieros, V3; Kontigos, V4; Kefrancos, V5; 2572) belonging to different maturity groups. When the results obtained in both years of the study were evaluated together, it was seen that the highest leaf number, grain protein content, and the lowest stalk lodging values were obtained from the V3 variety. The highest first ear height and thousand grain weight values were obtained from the V2, V4, and V5 varieties. The highest ear weight and grain weight per ear values were obtained from the V2 and V5 varieties. The highest grain ear ratio, hectoliter, and the lowest grain moisture values were obtained from the V1 variety. The highest plant height, number of grains per ear, tasseling stage, ear length, ear diameter, stalk lodging, and grain moisture values were obtained from the V5 variety. However, obtaining the highest stalk lodging and grain moisture values from this variety in both research years eliminated the other positive characteristics of this variety. The highest grain yield values were obtained from the V2 variety. When the evaluation is done by taking into account the highest grain yield, lowest grain moisture, and stalk lodging values together, it is seen that the V3 variety is of a nature that can be recommended for Cumra-Konya ecological conditions.

Keywords: Corn, variety, yield components

INTRODUCTION

Corn is the most widely produced grain in the world with the highest yield obtained from a unit area. In 2020, there were 691 thousand 632 hectares of cultivation area, 9410 kg ha^{-1} yield, and 6.5 million tons of corn production in Turkey. Konya province ranks first in the country with a total grain corn production of 1 million 70 thousand tons (TURKSTAT, 2021).

In crop production, the yield is determined by the genetic potential of the variety, environmental factors (soil, climate), and cultivation techniques (Karasahin, 2021). The new hybrid grain corn varieties developed have a genetic yield potential of about 4 tons da^{-1}. The emergence of this potential varies depending on environmental stress factors, such as climate, planting time, plant density, soil structure and texture, amount of organic matter, pH, EC, water management, fertilization, weed control, and disease and pest presence (GRDC, 2017).

Theoretically, the ratio of C3 plants to convert solar energy into biomass under 30 °C and 380 ppm CO_2 conditions is 4.6%, while this ratio is 6% in C4 plants. In practice, the maximum rate reached is 2.4% for C3 plants and 3.7% for C4 plants. Within the total sunlight band, the photosynthetically active band (400-740nm) ratio is 48.7% (Zhu et al., 2008). The main function of the corn canopy is to absorb sunlight. If light falls on the soil instead of the corn canopy, it is absorbed by soil and lost, thereby a decrease in photosynthesis and yield is experienced. The use of this absorbed light as efficiently as possible is closely related to the leaf angle. Flat and horizontal leaves capture light best but use it quite inefficiently. Vertical leaves are quite unsuccessful in capturing light, but they use it most efficiently. For this reason, the ideal plant type is those that have horizontal lower leaves and vertical upper leaves. After the tasseling stage, the top 5 leaves of the corn canopy account for 26% of the total leaf area and realize 40% of dry matter production (Liu et al., 2020). More than 90% of the grain weight is obtained from photosynthesis, which takes place during the grain filling period, and during this period the photosynthetic products are transferred directly to the grains. Therefore, the production of dry matter after the emergence of the corn silk is very important for grain yield. It has been reported that shading practices in the silking period and before and after this period have different effects on varieties and cause a 12-50% reduction in grain yield (Liu, 2008; Kim et al., 2016).

Corn varieties mature at different times depending on their total temperature requirements. For this reason, by taking into account the dates of the last frost of spring and the first frost of autumn in the region where planting will be done, knowing the average total temperature values for many years during this vegetation period is one of the main elements that should be considered in the selection of varieties (Karasahin, 2021). Although late varieties are high in yield potential due to the length of maturation time, they even may not form ears if the total temperature requirements cannot be met. The ear kernels they form may not arrive at harvest maturity. Harvest becomes difficult due to high grain moisture, and because there will be problems with storing corn grains at high humidity, an obligation to sell the product at fairly low prices occurs due to high drying costs. Even, due to frost damage, low yield problems can be experienced. For these reasons, in the selection of varieties for growing the same varieties in different regions, the differences in maturation times must necessarily be taken into account.

Although the number of ears per unit area increases as the plant density increases, a decrease in ear weight occurs. For this reason, to be able to obtain high-yield varieties at high plant densities, the length of grain-filling time is important. The fact that grain-filling periods of varieties with a long maturation time are longer leads to high yield potential. As the maturation period increases, corn will receive more solar radiation and store more energy, and as a result of this, grain yield will increase (Sangoi, 2000). In addition, many studies conducted in our country and around the world have revealed that corn varieties with a long maturation period have higher yields (Tollenaar and Wu, 1999; Sangoi, 2000; Kocer, 2004). While the number of corn varieties registered in Turkey is approximately 307, this number increases to 938 along with registered corn lines. In addition, the number of production-permitted varieties that are at the stage of registration is 57 (TTSMM, 2021).

Today, on the one hand, new hybrid-corn varieties are being improved and released to the market, on the other hand, new varieties that have not been farmed before in our region are being brought and seeds are being sold to our farmers. Determining the suitability of registered varieties to their own ecology is of great importance. Problems of high grain moisture and low yield in harvest depending on the maturation period take place at the top of the most important problems in grain corn production in Konya region, where continental climate prevails. These problems will be solved by planting corn varieties with appropriate vegetation time at an appropriate density and applying cultural methods such as optimal irrigation and fertilization on site and on time (Karasahin and Sade, 2012).

In this study, it was aimed to determine the performance of some KWS hybrid corn (*Zea mays* L. *indentata* S.) varieties belonging to different maturity groups under the environmental conditions of Cumra.

MATERIALS AND METHODS

The research was carried out in the experimental fields of S.U. Cumra School of Applied Sciences between 2019 and 2020 under the ecological conditions of Cumra District of Konya province. Hybrid corn varieties (*Zea mays* L. *indentata* S.) belonging to V1 (Kerbanis; FAO 550), V2 (Kefieros; FAO 580), V3 (Kontigos; FAO 600), V4 (Kefrancos; FAO 650), V5 (2572; FAO 700) maturity groups were used as material.

Çumra-Konya district, where the research was conducted, has a typical Central Anatolian climate with cold and limited rainfall winters and hot and dry summers. Some meteorological data recorded in 2019 and in 2020 in Cumra-Konya district where the research was carried out and their average values for many years are given in Table 1. In order to determine the physical and chemical properties of the soil in which the study was conducted, samples were taken from depths of 0-30 cm and 30-60 cm and analyzed. Results of the analysis showed that they were in the clay structure class and poor in organic matter (Table 2).

Table 1. Some meteorological data of Cumra-Konya district

Months	Precipitation (mm)			Mean Temperature (°C)			Mean Relative Humidity (%)		
	2019	2020	1972-2019	2019	2020	1972-2019	2019	2020	1972-2019
May	2.0	13.8	37.3	18.4	17.0	15.7	44.7	49.0	57.5
June	36.2	6.8	20.3	21.5	20.7	19.8	54.5	47.4	53.5
July	6.4	10.0	6.8	22.3	24.6	22.9	47.7	43.3	48.2
August	4.6	0.0	4.5	22.7	23.1	22.4	48.9	39.2	49.1
September	6.4	12.2	10.2	19.1	22.0	18.3	47.8	48.0	52.1
October	9.2	6.2	31.1	15.5	17.1	12.6	56.4	49.2	62.8
November	43.0	10.0	35.8	8.8	6.0	6.2	71.6	69.8	71.2
Mean	-	-	-	18.3	18.6	16.8	53.1	49.4	56.3
Total	107.8	59.0	146	-	-	-	-	-	-

Table 2. Physical and chemical soil properties of the research field

Properties	Depth (0-30cm)	Depth (0-60 cm)	Properties	Depth (0-30 cm) (ppm)	Depth (0-60 cm) (ppm)
Organic matter (%)	1.24	0.62	Total N (%)	0.11	0.07
pH	7.58	8.14	P	49.6	6
EC (mS cm^{-1})	0.55	0.45	K	416	160
Lime ($CaCO_3$) (%)	19.8	19.0	Ca	6023	5960
Sand (%)	14.9	12.3	Mg	1193	1631
Silt (%)	26.0	26.7	Fe	4.22	3.38
Clay (%)	59.1	60.1	Zn	0.50	0.18
Texture class	Clay	Clay	B	0.64	0.31
Bulk density (g cm^{-3})	1.28	1.46	Mn	2.81	3.29
Field capacity (% v v^{-1})	34.43	35.98	Cu	1.69	1.63
Wilting point (%v v^{-1})	17.42	17.55	Na (meq l^{-1})	1.28	1.59
Infiltration rate (mm h^{-1})	4.4	5.0	SO_4 (meq l^{-1})	0.11	0.51

The water used in the research as irrigation water was T2 (medium salt) A1 (low sodium) irrigation water (Table 3). The dynamic fertigation approach was used in fertilization. In this approach, plant nutrient uptake is associated with water intake. Plant nutrients are applied at a certain concentration of the applied irrigation water (Voogt et al., 2000). Based on this approach, TDR was used in the preparation of a soil-based irrigation program, and after determining the need for irrigation water, the amount of pure N amount required to reach the target product (20 tons ha^{-1}) was calculated by taking into account soil analysis. The determined amount (300 kg ha^{-1}) was proportionated to the total amount of water consumption of corn (7500 mm ha^{-1}) according to the average for many years, then the obtained result was multiplied by the amount of water to be applied per hour, and the amount of fertilizer to be given per hour was found. The amount of fertilizer to be required during the irrigation period was injected into the drip irrigation system through the venturi type dosing pump in the form of a solution to be prepared in a 1-ton water tank. A portion of nitrogen and all phosphorus and potassium were given with the base fertilizer. 500 kg ha^{-1} composite 13.24.12.10.1.1 (13% N, 24% P_2O_5, 12% K_2O, 10% SO_3, 1% Zn, and 1% Fe) fertilizer was used as the base fertilizer. The remaining amount of nitrogen (265 kg) was applied in each irrigation in the form of urea as described above (46% N). Above-ground drip irrigation method was used for irrigation of research plots. In this process, drip irrigation pipes of Akona Company, which have 22 mm diameter drippers with a 1.6 lt h^{-1} flow rate (dripping one at each 30 cm) were used.

Table 3. Irrigation water analysis report

Parameters	Results	Parameters	Results (ppm)
pH	7.3	Calcium	68
EC (mS cm^{-1})	0.58	Magnesium	17.99
Total hardness (Ca + Mg) (°F)	24.46	Bicarbonate	275.15
SAR	0.35	Chloride	25.17
Salinity and Alkalinity Class	T2-A1	Sulfate	28.80
Sodium (ppm)	12.65	Boron	0.14
Potassium (ppm)	2.73	Iron	0.18

The research was carried out as three replications based on the “randomized complete block design”. In the experiment, the plots were arranged as 5 x 2.8 m = 14.0 m^2 and in such a way that there are 4 rows in each plot. All plots were arranged in such a way that between rows and above rows were 70 x 15 cm (95238 plant ha^{-1}). The previous crop was dry bean. Planting was carried out with a pneumatic sowing machine on 25 May 2019 in the first year, and on 10 May 2020 in the second year. After the plants came out and the rows were clear, above-ground drip irrigation pipes were placed on the plots in such a way that they were in the middle of both rows.

In the research, full irrigation management was used. TDR (time domain reflectometry) device was used to measure soil moisture in the preparation of the irrigation program. For the first periods, by taking the average TDR readings for soil depth of 0 - 15 and 15 - 30 cm, irrigation was started when 40% of the soil useful moisture was used (TDR value 40), and the amount of water enough for bringing it to the field-capacity with a soil depth of 30 cm was applied by calculating. After the stem elongation period, irrigation was started by taking the averages of TDR readings for soil depth of 0 - 15, 15 – 30, 30 – 45 and 45 - 60 cm, and the amount of water enough for bringing it to the field-capacity with a soil depth of 60 cm was applied by calculating. The accuracy of the irrigation amount was checked by TDR measurements made 24 h after irrigation.

After physiological maturation, a row of edges was discarded from the edges of the plots as an edge effect.

The harvest was carried out on the remaining 7 m^2 area by manually collecting the cobs from the plants. Plant-based measurements were made on five plants randomly selected from each plot. Characteristics and methods studied in the research are as follows: stem diameter (mm), number of leaves, first ear height (cm), plant height (cm), number of grains per ear (piece ear^{-1}), tasseling stage (days), ear length (cm), ear diameter (mm), ear weight (g), grain weight per ear (g), grain ear ratio (%), stalk lodging (number), hectoliter weight (kg hl^{-1}), thousand grain weight (g), harvest grain moisture (%), and grain yield per unit area (kg ha^{-1}) (TTSMM, 2018). Analysis of raw protein content in grain (%) was done in an external laboratory according to AACC (2000). The obtained data was subjected to analysis of variance and the F test was performed (Steel and Torrie, 1980). The average values of the operations whose differences were detected were grouped according to the "HSD" importance test (JMP, 2007).

RESULTS AND DISCUSSION

Stem diameter, leaf number and first ear height

When the means of the two years were examined, it was observed that the highest stem diameter values (21.8 mm) were obtained from the V4 variety, while the lowest values were obtained from the V1 and V5 varieties (20.1 and 20.3 mm, respectively, $P<0.01$) and they took place in the same statistical group (b) (Table 4). Effects of the "year x variety interactions" were significant on stem diameter; the highest values were obtained from the first year x V4, second year x V4, and second year x V5 interactions (21.7, 21.9, and 20.0 mm respectively, $P<0.01$) and they took place in the same statistical group (a) (Table 4). It has been noted that varieties with a high stem diameter are more resistant to stalk lodging (Hondroyianni et al., 2000; Ma et al., 2014; Robertson et al., 2016).

Table 4. Means of stem diameter, leaf number and first ear height of varieties measured in the field trial run in 2019 and 2020

Varieties	Stem Diameter (mm)**			Leaf Number**			First Ear Height (cm)**		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
V1	19.2 bc	21.0 ab	20.1b	17.1 a	16.4 bc	16.8 ab	96.5 d	119.0 a-d	107.7 b
V2	21.2 ab	19.5abc	20.4 ab	16.3 c	16.6 abc	16.4 bc	135.4 ab	124.4 abc	129.9 a
V3	20.8 abc	18.6 c	19.7 b	17.0 ab	16.9 abc	16.9 a	124.5 abc	117.3 bcd	120.9 ab
V4	21.7 a	21.9 a	21.8 a	16.4 bc	16.3 c	16.3 c	139.5 ab	124.6 abc	132.1 a
V5	20.7 abc	20.0 a	20.3 b	16.6 abc	16.5 abc	16.6 abc	140,8 a	110.2 cd	125.5 a
Mean	**20.7**	**20.2**		**16.7**	**16.5**		**127.3 a**	**119.1 b**	
CV (%)		9.8			3.5			15.9	
V		**			**			**	
Y		Ns			Ns			*	
V*Y Int.		**			**			**	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year
** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

Regarding the mean of the two years, it was determined that the highest leaf number values (16.9) were obtained from the V3 variety ($P<0.01$). The year x variety interactions had significant effects on leaf number, and the highest values (17.1) were obtained from the first year x V1 interaction. On the other hand, the lowest values (16.3) were obtained from the second year x V4 interaction ($P<0.01$), (Table 4). There is a positive relationship between the number of leaves and the plant height. In general, the number of leaves decreases in short varieties, and this is largely affected by genetic factors (Hallauer and Miranda, 1987; Ozata et al., 2013).

In terms of the first ear height values, as the mean of the varieties, the difference between the years was statistically significant ($P<0.05$). The values of the first research year were obtained greater than the second year (127.3 and 119.1 cm, respectively). The highest first ear height values were obtained from the V2, V4, and V5 varieties in terms of the two-year mean data (129.9, 132.1, and 125.5 cm, respectively, $P<0.01$) and they took place in the same statistical group (a) (Table 4). Effects of year x variety interactions were significant on the first ear height values and the highest values (140.8 cm) were obtained from the first year x V5 interaction ($P<0.01$) (Table 4). Previous research has shown that the first ear height is a morphological character formed under the influence of ecological factors and the characteristic of the variety (Karasahin, 2008; Amanolahi-Baharvand et al., 2014). It has been reported that as the maturity group moves from early to late, the first ear height gradually increases in relation to this (Karasahin and Sade, 2012). Whereas the first ear height values of tall genotypes were found to be high, the first ear height values of short genotypes were found to be lower (Hallauer and Miranda, 1987).

Plant height, number of grains per ear, and tasseling stage

In terms of two-year data, the highest plant height values (321.5 cm) were obtained from the V5 variety ($P<0.01$). Year x variety interactions had significant effects on plant height values, and the highest values (334.6 cm) were obtained from the first year x V5 interaction ($P<0.01$). On the other hand, the lowest values (284.0 cm) were obtained from the second year x V3 interaction (Table 5). Although plant height in corn is largely under the influence of genetic factors, it is known to be widely affected by cultivation techniques and environmental conditions (Hallauer and Miranda, 1987; Koca, 2009). There is a positive relationship between plant height and first ear height, and the first ear heights of varieties with high plant height are also longer (Karasahin and Sade, 2012).

Table 5. Means of plant height, number of kernels ear^{-1} and tasselling stage of varieties measured in the field trial run in 2019 and 2020

Varieties	Plant Height (cm)**			Number of Grains Ear^{-1}**			Tasselling Stage (Days)**		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
V1	294.1 bc	295.8 bc	294.9 c	480.2 ef	552.7 cd	516.4 d	65	75	70 e
V2	292.3 bc	302.6 bc	297.4 bc	520.6 de	641.6 ab	581.1 b	68	78	73 d
V3	295.3 bc	284.0 c	289.6 c	503.4 def	618.3 ab	560.8 bc	70	80	75 c
V4	307.9 b	308.6 b	308.3 b	462.3 f	599.2 bc	530.7 cd	75	85	80 b
V5	334.6 a	308.5 b	321.5 a	623.5 ab	662.1 a	642.8 a	80	90	85 a
Mean	**304.8**	**299.9**		**518.0 b**	**614.8 a**		**71.6 b**	**81.6 a**	
CV (%)		5.5			8.0			0.001	
V		**			**			**	
Y		Ns			**			**	
V*Y Int.		**			**			Ns	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year
** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

Considering the means of varieties, it is seen that the number of grains per ear values were obtained more in the second research year compared to the first year (614.8 and 518.0 respectively, P<0.01). The highest number of grains per ear values (642.8) were obtained from the V5 variety in terms of the mean of the two-year data (P<0.01). Effects of year x variety interactions were significant on number of grains per ear values, and the highest values (662.1) were obtained from the second year x V5 interaction (P<0.01). On the other hand, the lowest values (462.3) were obtained from the first year x V4 interaction (Table 5). There is a positive relationship between the number of grains per ear and grain yield, which are among the corn yield elements (Tollenear et al., 1992; Kara, 2001).

Considering the means of the varieties, it is seen that higher tasseling stage values were obtained in the second research year compared to the first year (81.6 and 71.6 respectively, P<0.01). In terms of the means of the two years, the highest tasseling stage values (85) were obtained from the V5 variety (P<0.01), (Table 5). The tasseling period in corn depends on genotype and environmental conditions, especially air temperature (Daughtry et al., 1984). Tasseling and maturation are delayed if factors such as moisture, nitrogen, and lighting are negative during the tasseling period (Shaw, 1988; Ozata et al., 2013).

Ear length, ear diameter and ear weight

In terms of the mean data of the varieties, higher ear length values were obtained in the second research year compared to the first year (18.0 and 16.7 respectively, P<0.01). Considering the two-year mean values, the highest ear length values (18.9 cm) were obtained from the V5 variety (P<0.01). Year x variety interactions had significant effects on ear length values, and whereas the highest values were obtained from almost all interactions (P<0.01), the lowest values (13.3 cm) were obtained only from the first year x V1 interaction (Table 6).

Table 6. Means of ear length, diameter and weight of varieties measured in the field trial run in 2019 and 2020

Varieties	Ear Length (cm)**			Ear Diameter (mm)**			Ear Weight (g)**		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
V1	13.3 b	18.1 a	15.7 c	51.1 bcd	50.5 cd	50.8 c	209.5 d	315.6 abc	262.6 b
V2	17.6 a	18.9 a	18.3 ab	52.3 abc	51.9 abc	52.1 ab	312.5 bc	374.0 a	343.3 a
V3	17.1 a	16.9 a	17.0 bc	52.4 abc	49.1 d	50.8 c	279.3 c	282.0 c	280.6 b
V4	16.7 a	17.1 a	16.9 bc	52.6 ab	49.7 d	51.1 bc	285.5 c	307.5 bc	296.5 b
V5	18.8 a	19.0 a	18.9 a	53.9 a	51.0 bcd	52.4 a	330.9 abc	356.1 ab	343.5 a
Mean	**16.7 b**	**18.0 a**		**52.5 a**	**50.4 b**		**283.5 b**	**327.0 a**	
CV (%)		11.9			3.4			16.9	
V		**			**			**	
Y		**			**			**	
V*Y Int.		**			**			**	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year
** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

Regarding the means of the varieties, higher ear diameter values were obtained in the first research year compared to the second year (52.5 and 50.4 mm respectively, P<0.01). The highest ear diameter values (52.4 mm) were obtained from the V5 variety in terms of the two-year means (P<0.01) (Table 6). Effects of year x variety interactions were significant on ear diameter values, and the highest values were obtained from the first year x V5 interaction (P<0.01). On the other hand, the lowest values were obtained from the second year x V3 and second year x V4 interactions (49.1 and 49.7 mm, respectively), and they took place in the same statistical group (d) (Table 6). Ear length, which is an important yield element in corn, is under the influence of environmental and genetic factors. Variation among genotypes for ear diameter could be related to the genetic background of cultivars (Kusaksiz and Kutlu Kusaksiz, 2018). In general, it has been observed that the ear lengths and diameters of high-yielding varieties are also high. This indicates that there is a strong relationship between the length and diameter of the ear (Tekkanat and Soylu, 2005).

Considering the means of the varieties, it is seen that higher ear weight values were obtained in the second research year compared to the first year (327.0 and 283.5 g respectively, P<0.01). Regarding the means of the both years, the highest ear weight values were obtained from the V2 and V5 varieties (343.3 and 343.5 g respectively, P<0.01). Year x variety interactions had significant effects on ear weight values, and the highest values (374.0 g) were obtained from the second year x V2 interaction (P<0.01) (Table 6).

Grain weight per ear, grain ear ratio, and stalk lodging

In terms of the mean data of the varieties, higher grain weight per ear values were obtained in the second research year compared to the first year (282.1 and 236.8 g respectively, P<0.01). Considering the means of the both years, it is seen that the highest grain weight per ear values were obtained from the V2 and V5 varieties (288.9 and 292.2 g respectively, P<0.01). Year x variety interactions had significant effects on grain weight per ear values, and the highest values (317.9 g) were obtained from the second year x V2 interaction (P<0.01) (Table 7). There is high positive correlation between grain yield with ear length, ear diameter, number of kernel per ear, ear weight and thousand grain weight (Kokten and Akcura, 2017).

Table 7. Means of grain weight ear^{-1}, grain ear ratio and stalk lodging of varieties measured in the field trial run in 2019 and 2020

Varieties	Grain Weight Ear^{-1} (g)**			Grain Ear Ratio (%)**			Stalk Lodging (number)**		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
V1	182.5 d	275.1 abc	228.8 b	87.1 a	87.2 a	87.1 a	1.3 b	5.0 b	3.2 b
V2	259.9 bc	317.9 a	288.9 a	83.2 c	85.0 b	84.1 c	1.7 b	5.5 ab	3.6 b
V3	233.4 cd	244.1 c	238.8 b	83.5 c	86.6 a	85.1 b	0.0 c	2.0 c	1.0 c
V4	231.0 cd	265.8 bc	248.4 b	80.9 d	86.4 a	83.7 c	2.0 b	5.5 ab	3.8 b
V5	277.0 abc	307.3 ab	292.2 a	83.8 c	86.3 a	85.0 b	4.3 a	6.5 a	5.4 a
Mean	**236.8 b**	**282.1 a**		**83.7 b**	**86.3 a**		**1.9 b**	**4.9 a**	
CV (%)		16.9			1.2			12.4	
V		**			**			**	
Y		**			**			**	
V*Y Int.		**			**			**	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year
** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

Regarding the means of the varieties, it is observed that higher grain ear ratio values were obtained in the second research year compared to the first year (86.3 and 83.7 % respectively, P<0.01). The highest grain ear ratio values (87.1 mm) were obtained from the V1 variety in terms of the two-year means (P<0.01) (Table 7). Effects of year x variety interactions were significant on grain ear ratio values, and the highest values were obtained from the first year x V1, second year x V1, second year x V3, second year x V4, and second year x V5 interactions, and they took place in the same statistical group (a) (87.1, 87.2, 86.6, 86.4, and 86.3 % respectively, P<0.01) (Table 7).

According to the means of the varieties, higher stalk lodging values were obtained in the second research year compared to the first year (4.9 and 1.9 respectively, P<0.01). When the means of the two years are considered, it is seen that whereas the highest stalk lodging values (5.4) were obtained from the V5 variety (P<0.01), the lowest stalk lodging values (1.0) were obtained from the V3 variety. Year x variety interactions had significant effects on stalk lodging values, and the highest values were obtained from the first year x V5 and second year x V5 interactions, and they took place in the same statistical group (a) (4.3 and 6.5 respectively, P<0.01). In both research years, the lowest stalk lodging values were obtained from the first year x V3 and second year x V3 interactions, and they took place in the same statistical group (c) (0.0 and 2.0 respectively) (Table 7). Genetic characters of varieties are the most important factor on stalk lodging rates (Butzen, 2013). Since plant stems are weaker at high plant densities, the rate of stalk lodging increases (Echezona, 2007). It has been observed that tall varieties are more prone to have stalk lodging under the influence of gravity (Ransom, 2005). In late varieties, the mechanical strength of the stalk is weaker due to the fact that they have high humidity. Therefore, more stalk lodging is observed in this type of varieties. Elements such as drought, low light intensity, and disease and harmful presence negatively affect photosynthesis, and since the carbohydrate needs of corn grains that develop in such cases cannot be met by photosynthetic activities, these needs are provided from carbohydrates accumulated in the root and stalk. For this reason, the mechanical strength of the stalk reduced and lodging occurs. Loses between 5 and 50% are experienced in grain yield due to the stalk lodging (Li et al., 2015; Xue et al., 2020; Wang et al., 2020).

Hectoliter, grain protein content and thousand grain weight

In terms of the means of the varieties, higher hectoliter values were obtained in the first research year compared to the second year (77.3 and 76.2 kg hl^{-1} respectively, P<0.01). The highest hectoliter values (78.5 kg hl^{-1}) were obtained from the V1 variety in terms of the two-year means (P<0.05) (Table 8). Year x variety interactions had significant effects on hectoliter values. The highest values were obtained from the second year x V1 and the first year x V2 interactions and they took place in the same statistical group (a) (79.9 and 79.4 kg hl^{-1} respectively, P<0.01) (Table 8). Ozmen (2008) reported that effects of genotype and environmental interaction were significant on hectoliter weight.

Table 8. Means of hectoliter, grain protein and thousand grain weight of varieties measured in the field trial run in 2019 and 2020

Varieties	Hectoliter (kg hl^{-1})**			Grain Protein Content (%)**			Thousand Grain Weight (g)**		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
V1	77.1 ab	79.9 a	78.5 a	7.3 c	8.0 a	7.7 b	369.7 c	410.5 cd	390.1 b
V2	79.4 a	72.6 d	76.0 b	6.9 de	6.7 e	6.8 d	475.0 a	434.0 bc	454.5 a
V3	76.7 abc	78.7 ab	77.7 ab	7.5 bc	8.3 a	7.9 a	435.0 abc	378.0 d	406.5 b
V4	75.0 bcd	76.9 ab	75.9 b	6.8 de	7.7 b	7.2 c	448.0 abc	460.5 ab	454.3 a
V5	78.3 ab	73.0 cd	75.6 b	7.4 c	7.0 d	7.c c	434.0 bc	452.5 ab	443.3 a
Mean	**77.3 a**	**76.2 b**		**7.2 b**	**7.5 a**		**432.3**	**427.1**	
CV (%)		1.7			1.0			3.2	
V		**			**			**	
Y		*			**			Ns	
V*Y Int.		**			**			**	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year
** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

Considering the means of the varieties, it is seen that higher grain protein content values were obtained from the second research year compared to the first year (7.5 and 7.2 % respectively, P<0.01). In terms of two-year means, the highest grain protein content values (7.9 %) were obtained from the V3 variety (P<0.01). Year x variety interactions had significant effects on grain protein content values, and the highest values were obtained from the second year x V1 and second year x V3 interactions (8.0 and 8.3 % respectively, P<0.01) (Table 8).

In terms of the mean data of the two years, the highest thousand grain weight values were obtained from the V2, V4, and V5 varieties (454.5, 454.3, and 443.3 g respectively, P<0.01). Effects of year x variety interactions were significant on thousand grain weight values, and the highest values (475.0 g) were obtained from the first year x V2 interaction (P<0.01) (Table 8). Since multiplication of the number of grains obtained from the unit area and the thousand grain weight directly determine the grain yield, the number of grains and weight constitute the main yield elements (Battaglia et al., 2017).

Grain moisture and grain yield

In terms of the mean data of the varieties, higher grain moisture values were obtained in the first research year compared to the second year (22.8 and 22.3 % respectively, P<0.01). When the means of the two years were examined, it was seen that whereas the highest grain moisture values (27.6 %) were obtained from the V5 variety (P<0.01), the lowest grain moisture values (17.3) were obtained from the V1 variety. Effects of year x variety interactions were significant on grain moisture values, and the highest values (28.0 %) were obtained from the first year x V5 interaction (P<0.01). In both research years, the lowest grain moisture values were obtained from the first year x V1 and second year x V1 interactions, and they took place in the same statistical group (e) (17.6 and 17.0 respectively) (Table 9). When previous studies on grain moisture at harvest were examined, it was observed that in general, the harvest grain moisture in early varieties was found to be lower than in late varieties (Kapar and Oz, 2006; Vartanli and Emekliler, 2007). The decrease in moisture in the grain after physiological maturation is closely related to physical factors. Climate factors such as temperature, humidity, and wind speed affect the moisture decrease in the grain. Variety characteristics also play an important role in moisture loss after maturation. For example, characteristics such as the way corn ear husk wraps the ear, the size and number of ear husks, the permeability of the kernel shell, and the oblique or upright posture of the ear are important variety characteristics that affect moisture drop (Nielsen, 2006; Demirci, 2009). Due to the limited vegetation time of the Central Anatolia region, grain moisture in harvest is very important in terms of production costs. If grain moisture is high at harvest, the cost of drying will bring a serious burden and negatively affect producers today, when energy prices are increasing day by day (Karasahin and Sade, 2012; Karasahin, 2021).

Table 9. Means of grain moisture and grain yield of varieties measured in the field trial run in 2019 and 2020

Varieties	Grain Moisture (%)**			Grain Yield (kg ha^{-1})**		
	2019	2020	Mean	2019	2020	Mean
V1	17.6 e	17.0 e	17.3 d	15715 e	16650 d	16183 d
V2	21.9 c	26.5 b	24.2 b	19370 b	20410 a	19890 a
V3	20.0 d	19.5 d	19.8 c	17655 c	17925 c	17790 c
V4	26.6 b	21.2 c	23.9 b	17355 cd	17670 c	17513 c
V5	28.0 a	27.2 b	27.6 a	18070 c	19500 b	18785 b
Mean	**22.8 a**	**22.3 b**		**17633 b**	**18431 a**	
CV (%)		1.1			1.5	
V		**			**	
Y		**			**	
V*Y Int.		**			**	

CV; Coefficient of variation, *; P <0.05, **; P <0.01, Ns; Not significant, V; Varieties, Y; Year

** Different letters indicate significant differences based on the LSD test at the p<0.05 level.

When the means of the varieties were examined, it was observed that higher grain yield values were obtained in the second research year compared to the first year (18431 and 17633 kg ha^{-1} respectively, P<0.01). The highest grain yield values (19890 kg ha^{-1}) were obtained from the V2 variety in terms of the two-year means (P<0.01), (Table 9). Effects of year x variety interactions were significant on grain yield values, and the highest values (20410 kg ha^{-1}) were obtained from the second year x V2 interaction (P<0.01) (Table 9). Grain yield in the corn plant is genetic and a complex character that occurs from planting to harvest as a result of ecology and the common effects of cultivation techniques (Hallauer and Miranda, 1987). It has been stated that in variety preference, all parameters, such as grain yield, grain moisture, and the rate of moisture loss after physiological development should be evaluated together (Sade, 1999).

There are similarities and differences between the values obtained from the results of this research and the values obtained from other research studies related to the issue. It is considered that these similarities and differences stem from the type and dose of mineral fertilizers, the genetic characteristics of cultivated varieties, climate and soil properties, and applied cultivation techniques (soil preparation, the depth and density of planting, pest and weed control, irrigation, and fertilization).

CONCLUSIONS

When the results obtained in both years of the study are evaluated together, it is seen that the highest stem diameter values were obtained from the V4 variety. The highest leaf number, grain protein content and the lowest stalk lodging values were obtained from the V3 variety. The highest first ear height and thousand grain weight values were obtained from the V2, V4 and V5 varieties. The highest ear weight and grain weight per ear values were obtained from the V2 and V5 varieties. The highest grain ear ratio, hectoliter and the lowest grain moisture values were obtained from the V1 variety. The highest plant height, number of grains per ear, tasseling stage, ear length, ear diameter, stalk lodging and grain moisture values were obtained from the V5 variety. However, obtaining the highest stalk lodging and grain moisture values from this variety in both research years eliminated the other positive characteristics of this variety. The highest grain yield values were obtained from V2 variety. When the evaluation is done by taking into account the highest grain yield, lowest grain moisture, and stalk lodging values together, it is seen that the V3 variety is of a nature that can be recommended for Cumra-Konya ecological conditions.

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