Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Mart/March 2024, 21(2)
Başvuru/Received: 30/03/23
Kabul/Accepted: 13/11/23
DOI: 10.33462/jotaf.1273664

http://dergipark.gov.tr/jotaf
http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Observance of Agronomic and Nutritive Profile of Some Silage Corn Hybrids in Central Anatolian Region of Turkey

Türkiye'nin Orta Anadolu Bölgesinde Bazı Silajlık Mısır Hibritlerinin Tarımsal ve Besin Profilinin Gözlenmesi

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Abstract

The silage corn (SC) production and yield per area in Turkey have increased over the last decade owing to their high economic importance. The first objective of the current study was to determine the agronomic and nutritive profiles of SC hybrids in the Central Anatolian region of Ankara, Turkey. The other objective was to determine the relationship between silage maturity and corn heat unit (CHU) and growing degree day (GDD) ratings. The current study was set up as a randomized complete block design with three replications. Certified seeds of five dissimilar SC hybrids (*cv* PL 712, *cv* TORRO, *cv* CHAMP, *cv* MACHA, *cv* RANGER) (n=5) were established in the field. SC hybrids showed variation among themselves. Differences were also detected in all parameters, except dry matter (DM) content and crude protein (CP) yield. *Cv* "MACHA" had the highest nutritive profile [CP: 9.60%; acid detergent fiber (ADF): 30.02%; neutral detergent fiber (NDF): 51.62%; acid detergent lignin (ADL): 3.72%; total digestible nutrient (TDN): 62.60%; metabolic energy (ME): 2.34 Mcal kg^{-1} DM; net energy production (NE_p): 1.50 Mcal kg^{-1} DM]. One of the other hybrids, *Cv* "CHAMP" had the highest yield components [silage yield: 104.20 t ha^{-1}; dry matter yield: 35.4 t ha^{-1}; TDN yield: 21.10 t ha^{-1}; ME yield: 77880.00 Mcal ha^{-1}; NE_p yield: 49914.00 Mcal $ha-^1$]. There was a significant correlation between silage maturity and CHU and GDD ratings [CHU_{seed} (r = 0.84, P= 0.001), CHU_{silk} (r = 0.90, P<0.001), and GDD (r = 0.89, P<0.001). Based on these results, it was determined that the low-CHU SC hybrid had higher yield values and nutrient profiles in Ankara. In addition to this, SC hybrids; "*cv* CHAMP" and "*cv* MACHA" could be recommended for their agronomic profile, nutritive profile, and yield components in the Central Anatolian regions, Ankara, Turkey.

Keywords: Agronomy, Maturity, Cultivar selection, Yield, Quality

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Atıf: Ozkan, U. (2024). Türkiye'nin Orta Anadolu Bölgesinde bazı silajlık mısır hibritlerinin tarımsal ve besin profilinin gözlenmesi. *Tekirdağ Ziraat Fakültesi Dergisi*, 21(2): 393-403.
Citation: Ozkan, U. (2024). Observance of variance in agronomic and nutritive profile of silage corn hybrids in Central Anatolian Prairies of Turkey. *Journal of Tekirdag Agricultural Faculty*, 21(2): 393-403.

Öz

Türkiye'de silajlık mısır (SM) üretimi ve alan başına verim, ekonomik öneminin fazlalığı nedeniyle son on yılda artmıştır. Bu çalışmanın ilk amacı, Türkiye-Ankara'da Orta Anadolu bölgesinde SM hibritlerinin agronomik ve besleyici profilini belirlemektir. Çalışmanın diğer amacı, silaj olgunluğu ile mısır ısı birimi (CHU) ve yetiştirme derecesi günleri (GDD) arasındaki ilişkiyi göstermektir. Bu araştırma, tesadüf blokları deneme desenine göre üç tekrarlamalı olarak kurulmuştur. Sertifikalı beş farklı SM hibriti (*cv* PL 712, *cv* TORRO, *cv* CHAMP, *cv* MACHA, *cv* RANGER) (n=5) tarlaya kurulmuştur. SM hibritleri kendi aralarında farklılıklar göstermiştir. Kuru madde (KM) içeriği ve ham protein (HP) verimi hariç tüm parametrelerde de farklılıklar tespit edilmiştir. *Cv* "MACHA" en yüksek besleyici profile sahip olmuştur [HP: 9.60%; asit deterjan lifi (ADF): 30.02%; nötr deterjan lifi (NDF): %51.62; asit deterjan lignin (ADL): 3.72%; toplam sindirilebilir besin (TSB): 62.60%; metabolik enerji (ME): 2.34 Mcal kg^{-1} KM; net enerji üretimi (NE$_p$):1.50 Mcal kg^{-1} KM]. Diğer hibritlerden biri olan, *Cv* "CHAMP" ise en yüksek verim bileşenlerine sahiptir [Silaj verimi: 104.20 t ha^{-1}; KM verimi: 35.4 t ha^{-1}; TSB verimi: 21.10 t ha^{-1}; ME verimi: 77880.00 Mcal ha^{-1}; NE$_p$ verimi: 49914.00 Mcal ha^{-1}]. Silaj olgunluğu ile CHU ve GDD dereceleri arasındaki ilişki, önemli derecede korelasyon göstermiştir [CHU$_{seed}$ (r = 0.84, P= 0.001), CHU$_{silk}$ (r = 0.90, P<0.001) ve GDD (r = 0.89, P<0.001)]. Yukarıdaki sonuçlara dayanarak, Ankara'da düşük CHU değerlerine sahip olan SM hibritlerinin daha yüksek verim ve kaliteye sahip oldukları belirlendi. Buna ek olarak; Türkiye'nin Orta Anadolu bölgesindeki Ankara'da agronomik profil, besleyici profil ve verim bileşenleri için SM hibritlerinden "*cv* CHAMP" ve "*cv* MACHA" önerilebilmektedir.

Anahtar Kelimeler: Agronomi, Olgunluk, Çeşit seçimi, Verim, Kalite

1. Introduction

Quality forage deficits and their related costs are major problems for the livestock sector in Turkey. Production of silage corn (SC) has the main role to close this deficit. Silage corn has also been used globally as ensiled forage, particularly in Europe, the United States, China, Canada, and other developing countries. SC production in Turkey increased by 74% between 2011 and 2021 (from 300.797 ha to 524.842 ha) (showing an increase of 300%, 156%, 63%, and 63% in Konya, Ankara, Aydın, and Balıkesir, sequence), and with the greatest percentile in Turkey by approximately 45% of the total forage crop production in 2021 (Anonymous, 2021). This increment in SC production has been achieved through government support, which has exceeded 100% in the last ten years in Turkey. Expanding SC production is due to its potential for high yield and digestibility compared to small grains such as barley and oats (Baron et al., 2000). Owing to limiting digestible energy intake by beef and dairy cattle production, SC gives an opportunity to increase meat and milk production (Guyader et al., 2018).

The current market shows the great diversity of SC hybrids, with specific characteristics to attempt regional requirements, taking into account the environmental conditions (Zopollato and Sarturi, 2009). Also, the forage yield and nutritive profile of SC are influenced by soil nutrients, plant species, genotype within species, and stage of harvest. (Baron et al., 2012). Livestock producers expect higher productivity and higher dry matter content for meeting their total mixed rations. Several researchers have documented that agronomic profile, nutritive profile, and yield components were affected by SC hybrids (Singh et al., 2020; Gunes and Oner, 2019; Ileri et al., 2018; Ahmad et al., 2012). Cultivar selection based on weather conditions and growing period longevity is an important application for achieving sustainable yields (Ileri et al., 2018). SC growth pattern in Turkish prairies is known to generally warm climatic conditions. Thus, SC has a high potential as the second crop under irrigated conditions of dry environments with at least 3 months of extra growing period (Ileri et al., 2018). SC growth parameters of the cultivars are influenced by weather conditions and growing period longevity. These changes lead to changes in plant length, stem strength, leaf size, cob size, seed count, and storage of compounds in the plant nutrient composition of silages (Mahanna, 2010a, b).

Evaluating the economical production of the SC depends on silage dry matter (DM) yield and nutritive profile. Silage maturity and yield are correlated positively with Corn Heat Unit (CHU) accumulation. Therefore, cultivar maturity affects nutritive profile (Lardner et al., 2017; Guyader et al., 2018). CHU system proposed by Brown (1963) is used as a way to categorize SC hybrids for maturity. The CHU system determines regions with suitable air temperatures for SC production, and within regions of adaptation, it is used by farmers to select hybrids based on their maturity rating. The CHU system uses a growing-degree-day algorithm, in which daily air temperatures are accumulated over the growing season (Major et al., 2021). Many corn cultivars require 2000 or more CHU to reach the silage harvest stage (Abeysekara et al., 2013). Additionally, western Canada require ≥ 2300 CHU for ensiling corn (Lardner et al., 2017). SC's agronomic and nutritive profile of SC with CHU's correlated relationship needs to be better understood in one of the Central Anatolian Prairies, Ankara. Therefore, the first objective of this study was to determine the agronomic and nutritive profiles of SC hybrids. The second objective was to identify the relationship between silage maturity and CHU and GDD ratings.

2. Materials and Methods

2.1. Experimental Design and Agronomic Practices

The experimental area was established at Ankara University, Faculty of Agriculture, Field Crops Department. Ankara Province has a temperate, dry, and hot summer climate (C*sa*), according to the updated Köppen-Geiger climate classification (Rahimi et al., 2020) (*Table 1*). The soil in the experimental area is clay-sandy with 8.02 pH. The organic matter content was low, particularly in the layers below the given depth. The samples were rich in potassium (582 ppm), medium in phosphorus (13.28 ppm), and low in nitrogen (0.074%).

SC hybrids were planted using 65000 seeds ha^{-1}; with row spacing of 70 cm; mean plot size of 10.5 m^2 keeping a distance of 1m gap among three replications in a randomized complete block design. Certified seeds of 5 SC hybrids (*cv* PL 712, *cv* TORRO, *cv* CHAMP, *cv* MACHA, *cv* RANGER) (n=5) were established in the experimental area. All SC hybrids were planted on May 23, 2022 and harvested between 16-21 September, 2022. The harvest decision was made according to the level of achieving milk stage. The cobs in the plots that were in between 1/3 to 2/3 milk stage, were considered mature for silage (Bal et al., 1997, Johnson et al., 2002). Phosphorus (in the form of 46% diammonium phosphate) (80 kg ha^{-1}) and nitrogen (in the form of 18% ammonium sulfate) (200 kg ha^{-1}) were applied to the soil with planting, except nitrogen. Nitrogen was divided into two parts, half of it applied during the planting and second part was applied when the plants reached up to 40-50 cm length. Weeding was picked out mechanically when the plants were at 30-40 cm length. Silking date (days), cobs' emergence (days), silage maturity (days), plant length (cm), were measured for obtaining agronomic profile. Plant length was measured for ten corn plants, and followed by taking an average for each plot. Upon harvesting, all plants per replicate were weighed to determine silage yield on as hectare basis (t ha^{-1}). The dry matter yield (t ha^{-1}) was recorded for all respective plot by multiplying the dry matter (%) and silage yield.

***Table 1**. Location, soil description, and climatic information of Ankara in 2022* **(Anonymous, 2022)**

Latidute	Longitude	Elevation (m)	Texture	Mean Temperature (°C)	Precipitation (mm)	Acc. dCHU	GDD
39° 97' N	32° 86' E	891	Clay sandy	22.90	184.70*	3150.23	2108.55

Acc. dCHU: Accumulated daily CHU, GDD: Growing degree days, * May- end of the September total rainfall

The CHU accumulated between seeding and harvesting was calculated for Ankara province. Also, CHU between seedling to harvest (CHU_{seed}), silking to harvest (CHU_{silk}) and growing degree days (GDD) were calculated for each plant as the sum of daily CHU, as provided by the Turkish State Meteorological Service. Corn heat unit (CHU) were calculated on a daily basis, using the maximum (T_{max}) and minimum (T_{min}) daily air temperatures, measured from midnight to midnight, in °C. The following equation was used to calculate daily CHU, also it is presented below;

$$\text{Daily CHU} = (Y_{max} + Y_{min}) / 2 \quad \text{(Eq.1).}$$

$$Y_{max} = [3.33 \times (T_{max}\text{-}10)] - [0.084 \times (T_{max}\text{-}10)2] \ (\text{if } Y_{max} < 0, \text{ set } Y_{max} = 0) \quad \text{(Eq.2).}$$

$$Y_{min} = [1.8 \times (T_{min} - 4.4)] \ (\text{if } Y_{min} < 0, \text{ set } Y_{max} = 0) \quad \text{(Eq.3).}$$

Growing degree days (GDD) are calculated using the following equation below;

$$GDD = [(T_{max}, °C + T_{min}, °C) / 2 - 5] \quad \text{(Eq.4).}$$

For each SC hybrid, CHU_{seed}, CHU_{silk}, GDD values, and important dates are presented in *Table 2*.

Table 2. Selected corn hybrids with corn heat unit (CHU) and growing degree days (GDD) ratings for Ankara

Silage Corn Hybrids	Sowing date	Seedling emergence	Silking date	CHU_{seed}	CHU_{silk}	GDD	FAO Maturity Groups
PL 712	May 23	May 31	July 31	2969	1315	1972	700-712
TORRO	May 23	June 1	August 1	2875	1209	1910	680
CHAMP	May 23	June 1	August 3	2798	1072	1879	700
MACHA	May 23	June 1	July 30	2855	1280	1917	550-580
RANGER	May 23	June 1	July 29	2937	1371	1969	600

2.2. Sampling and Nutritive Profile Analysis

A total of 500 g representative samples were retained to determine the DM content and nutritive profiles for all plots. The samples were dried at 70 °C for 48 h. Dried samples were ground to pass through a 1-mm screen in a mill. All collected samples were analyzed for DM, CP, ADF, NDF, ADL, and TDN. DM was analyzed from the collected sample (10 g) (135 °C for 2 hours) (AOAC, 2005a). Nitrogen was analyzed by traditional Kjeldahl acid digestion, converting nitrogenous compounds to ammonia, which was distilled and titrated (AOAC, 2005b), and CP was calculated as N × 6.25. ADF and NDF were determined by a sequential procedure (Van Soest et al., 1991) with an ANKOM200 Fiber Analyzer (Ankom Technology Corp, Macedon, NY, USA) after pre-treatment with sodium sulfite and α-amylase, and expressed inclusive of residual ash. ADL was analyzed using ADF residues with the direct sulfuric acid (72%) method (Robertson et al., 1981). TDN was calculated by Horrocks and Valentine (1999) [(TDN = (-1.291 × ADF %) + 101.35)]. The estimated energy values are ME and NE_p, which were calculated following NRC (1989). After determining DM, CP, TDN, ME, and NE_p, the yield values of these parameters were converted on a hectare basis (t ha^{-1}) after multiplying the dry matter yield.

2.3. Statistical Analysis

The data obtained from the measurements and observations were subjected to analysis of variance according to randomized complete block design (5% significance level) with three replications using "JMP" v.13 computer software (SAS, 2017). For each hybrid, agronomic profile (the silking date, cobs' emergence, silage maturity, plant length), nutritive profiles (DM, CP, ADF, NDF, TDN, ME, and NE), yield components (silage yield, dry matter yield, CP yield, TDN yield, ME yield, and NE_p yield), CHU ratings and GDD were analyzed from each plot. Data for DM, CP, ADF, NDF, ADL, and TDN were arcsine transformed before statistical analysis to stabilize variances and normalize proportional data. Probabilities equal to or less than 0.05 were considered significant (* P<0.05, ** P<0.01). If ANOVA indicated differences between treatment means, a LSD test was performed to separate them. Correlations (r) between agronomic profile, nutritive profile, yield components, and CHU ratings, GDD were determined for all SC hybrids (data not shown). Examining the relationship between CHU's, GDD and silage maturity, nutritive profile; correlation (r) and regression (r^2) were performed with "JMP" v.13 (SAS, 2017). The dependent variables of the observation were CHU_{seed}, CHU_{silk}, and GDD.

3. Results and Discussion

3.1 Agronomic Profile

The effects of the SC hybrids on agronomic profile; silking date, cobs' emergence, silage maturity, and plant length are presented in *Table 3*, and differences (P<0.01) were detected in all agronomic traits, excluding cobs' emergence (P<0.05), in accordance with one-way ANOVA. "CHAMP" matured early for silage (109.00 days) in comparison with other hybrids. It also had the highest plant length (348.40 cm), latest silking date (72.67 days), and cobs' emergence (73.67 days). Silage maturity of "CHAMP" were 3% lower than the mean silage maturity value. The earliest silking date (67.33 days) and cobs' emergence (71.00 days) were observed in "RANGER." This hybrid also matured late for silage (115.67 days) compared to the other hybrids. The plant length of these hybrids were lined as "CHAMP" (348.40 cm), "MACHA" (330.10 cm), "PL 712" (306.71 cm), "RANGER" (298.35 cm), and "TORRO" (277.31 cm), respectively (*Table 3*).

Table 3. Agronomic and Nutritive Profile of SC hybrids

	SC Hybrids						
	"PL 712"	**"TORRO"**	**"CHAMP"**	**"MACHA"**	**"RANGER"**	**Mean**	**SE**
Agronomic Profile							
Silking date (day)**	69.00**bc**	70.00**b**	72.67**a**	67.67**c**	67.33**c**	69.33	0.54
Cobs' emergence (day)*	72.67**ab**	71.67**ab**	73.67**a**	72.00**ab**	71.00**b**	72.20	0.30
Silage maturity (day)**	114.67**a**	111.33**ab**	109.00**b**	111.33**ab**	115.67**a**	112.40	0.75
Plant length (cm)**	306.71**bc**	277.31**c**	348.40**a**	330.10**ab**	298.35**bc**	312.18	7.18
Nutritive profile							
DM % (ns)	29.00	30.00	34.00	34.00	31.00	31.6	0.01
CP (% DM)**	6.40**d**	7.32**c**	7.52**c**	9.60**a**	8.45**b**	7.86	0.30
ADF (% DM)**	36.95**a**	37.09**a**	32.38**b**	30.02**b**	31.18**b**	33.52	0.88
NDF (% DM)**	59.32**a**	57.73**ab**	56.59**abc**	51.62**c**	52.99**bc**	55.65	0.92
ADL (% DM)*	4.67**a**	4.46**ab**	3.91**bc**	3.72**c**	4.03**bc**	4.16	0.11
TDN (% DM)**	53.65**b**	53.46**b**	59.55**a**	62.60**a**	61.10**a**	58.07	1.14
ME (Mcal kg^{-1} DM)**	1.94**b**	1.93**b**	2.20**a**	2.34**a**	2.27**a**	2.14	0.05
NE_p (Mcal kg^{-1} DM)**	1.24**b**	1.23**b**	1.41**a**	1.50**a**	1.45**a**	1.37	0.28
Yield							
Silage yield (t ha^{-1})**	89.60**a**	81.20**a**	104.20**a**	96.10**a**	87.00**a**	91.60	2.51
Dry matter yield (t ha^{-1})*	26.20**bc**	24.20**c**	35.40**a**	31.80**ab**	26.70**bc**	28.80	1.43
CP yield (t ha^{-1}) (ns)	1.90	2.00	2.80	2.90	2.40	2.40	0.15
TDN yield (t ha^{-1})*	14.00**b**	12.90**b**	21.10**a**	19.80**a**	16.20**ab**	16.80	1.01
ME yield (Mcal ha^{-1})*	50828.00**b**	46706.00**b**	77880.00**a**	74412.00**a**	60382.00**ab**	62041.60	4118.30
NE_p yield (Mcal ha^{-1})*	32488.00**b**	29766.00**b**	49914.00**a**	47700.00**a**	38715.00**ab**	39716.60	2590.63

Values within rows with different letters are significantly different (* P<0.05; ** P<0.01; ns: non-significant, SE: standart error).

The variation in the agronomic profile of SC hybrids affected silage yield and nutritional value of silages (Jiang et al., 2022). The silking dates of SC hybrids ranged as 67.33 cm to 72.67 cm in the current study; showed lower variation and early silking, compared to the findings of Bulut (2016), Kir and Yavuz (2019). Cobs' emergence ranged from 71.00-73.67 days among the SC hybrids. Similar to silking date, cobs' emergence in the current study showed earliness over the findings of Bulut (2016), and Kir and Yavuz (2019). Although "CHAMP" had the latest silking date and cobs' emergence, it matured earlier for silage in comparison to other hybrids. All SC hybrids in the current study matured earlier than the maturity values findings of Bulut (2016), and Kir and Yavuz (2019). Corn plant length is a very important parameter for biomass yield and nutritional quality of silages. It also reflects crop growth attained during the growing period (Jiang et al., 2022). The plant length of SC hybrids ranged 277.31-348.40 cm. These findings in the current study were higher compared to the findings of Jiang et al. (2022), Singh et al. (2020), Kir and Yavuz (2019), Ileri et al. (2018), Bulut (2016). The variation observed in agronomic profile among the SC hybrids could be related to differences in genetic makeup such as days to germination, nitrogen uptake capacity, adaptation to a certain soil and sowing temperature, and maturity period of these SC hybrids (Jiang et al., 2022). "CHAMP", which was an early-maturing hybrid (109.00 days), reached a higher plant length compared to those having late maturity like "PL 712" and "TORRO", which had the earliest silking and cobs' emergence respectively in the current study. The plant lengths of "PL 712" and "TORRO" also were below the mean plant length.

3.2 Nutritive profile

The effect of the SC hybrids on nutritive profile; DM, CP, ADF, NDF, ADL, TDN, ME, and NE values are presented in *Table 3*. In accordance with one-way ANOVA, differences (P<0.01) were detected in all nutritive profile, excluding DM (ns). "MACHA" had the best nutritive profile values with DM (34%), CP (9.60%), ADF (30.02%), NDF (51.62%), ADL (3.72%), TDN (62.60%), ME (2.34 Mcal kg^{-1} DM), NE$_p$ (1.50 Mcal kg^{-1} DM). The lowest DM (29%), CP (6.40%) and TDN (53.46%), ME (1.93 Mcal kg^{-1} DM), NE$_{\mathbf{p}}$ (1.23 Mcal kg^{-1} DM) values were determined in "PL 712" and "TORRO", in the same vein (*Table 3, Figure 1*). Also, the highest NDF (59.32%) and ADF (37.09%) values were observed again in "PL 712" and "TORRO", respectively (*Table 3*). The nutritive profile of "MACHA" was greater than the mean nutritive profile values, especially 18% more CP, 11% ADL and 10% ADF.

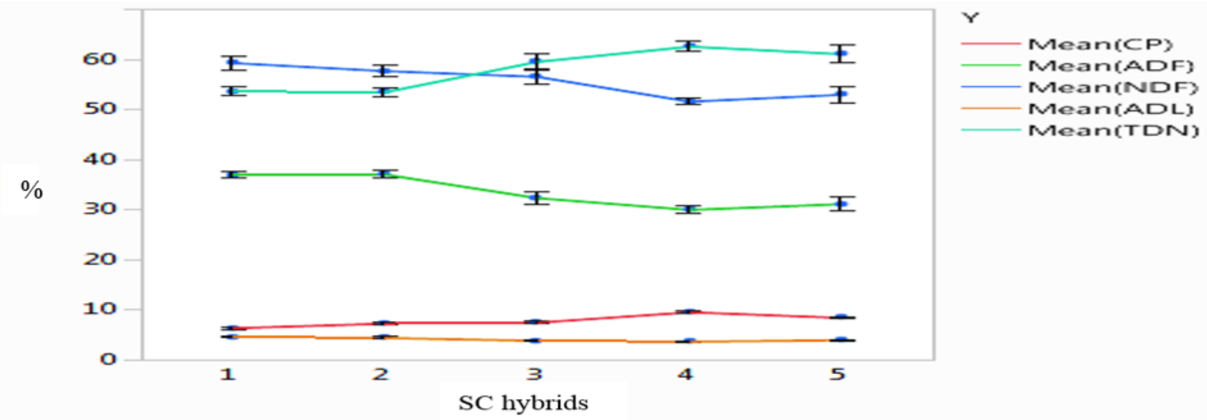

Figure 1. Nutritive profile of SC hybrids (1: "PL 712"; 2: "TORRO"; 3: "CHAMP"; 4: "MACHA"; 5: "RANGER")

Harvesting the crop at optimum DM content optimizes silage quality (Guyader et al., 2018) and increases the uptake availability of dry matter for ruminant animals. Bal et al. (2000), Ileri et al. (2018), Singh et al. (2020) have noted that DM content of silage corn 32.00- 40.00%, 20.57- 23.35%, 24.77- 27.57%, respectively. Wet silage material (<28% DM) lead to seepage from the silo and decrease the DM intake of ruminants, just like dry silage material (>40% DM) is difficult in making the packets which are hard to ferment in the silo (Allen et al., 2003; Mahanna, 2017). All SC hybrids had more than 30% DM content, excluding "PL 712", which was a late-maturing hybrid. In the current study, the mean CP content (7.86%) was greater compared to the findings of Ileri et al. (2018) (6.91%). On the other hand, the mean CP content of the SC hybrids was lower compared to the findings of Jiang et al. (2022) (8.06%), and Singh et al. (2020) (9.65%). Two of the SC hybrids – "MACHA" (9.60%) and

"RANGER" (8.45%), was higher than the mean CP content in the current study. In agreement with current study's findings (6.4-9.6%), previous studies have reported different CP contents ranging 6.4 - 8.0% among different corn genotypes (Guyader et al., 2018; Loučka et al., 2018; Kung et al., 2015; Opsi et al., 2013).

Digestibility is defined as the percentage of silage that is absorbed in the animal digestive tract (Barrière et al., 2003). Additionally; ADF, NDF, and ADL which are related to cell wall composition show a significant correlation with whole plant and cell wall digestibility (Truntzler et al., 2010). The CHU ratings and digestibility parameters of nutritive profile's relationship did not show significant differences. Just ADL content had a very weak correlation with CHU_{seed} ($r = 0.37$, $P = 0.16$). The mean ADF and NDF concentration was 33.52% and 55.65% in the current study. ADF and NDF concentrations of "MACHA" (30.02%) (51.62%), "RANGER" (31.18%) (52.99%), "CHAMP" (32.38%) (56.59%) were lower than the mean ADF and NDF. It is determined that "MACHA" is more digestible SC hybrid in comparison with other hybrids. ADF and NDF values obtained by Kir (2020) and Ileri et al. (2018) were as 24.26%, 49.78% and 22.23%, 39.20%, in the same vein. NDF values of Guyader et al. (2018) (53.00%), Opsi et al. (2013) (44.4-46.8%), Schwab et al. (2003) (45.00%) were much lower than current study which means their hybrids are more digestible. Khan et al. (2011) stated that ADF, NDF, and ADL values as 37.73-39.70%, 66.60-71.40%, and 3.0-5.45% according to different cutting stages, which are less digestible values compared to the current study's hybrids. TDN defines the available nutrients for livestock and the energy content of forages (Sayar et al., 2014; Posada et al., 2012); therefore, the highest TDN (62.60%), the highest estimated energy values with ME of 2.34 Mcal kg^{-1} DM, and NE_p of 1.50 Mcal kg^{-1} DM observed in "MACHA". In agreement with the current study, similar results were noted by Hundal et al. (2019), Sayar et al. (2014), Khan et al. (2011) for TDN and estimated energy values. TDN values of 57.2-62.6% were noted in 18 binary legume-grass mixtures by Bélanger et al. (2017) in agreement with the current study with mean value of 58.07%.

3.3 Yield Components

The effect of SC hybrids on yield components; silage yield, dry matter yield, CP yield, TDN yield, ME yield and NE_p yield values are presented in *Table 3*. In accordance with one-way ANOVA, differences ($P<0.01$) were detected in all yield components, excluding CP yield (ns). "CHAMP" had maximum silage yield (104.20 t ha^{-1}), dry matter yield (35.40 t ha^{-1}), TDN yield (21.10 t ha^{-1}), ME yield (77880.00 Mcal ha^{-1}) and NE_p yield (49914.00 Mcal ha^{-1}). The lowest silage yield (81.20 t ha^{-1}), dry matter yield (24.20 t ha^{-1}), TDN yield (12.90 t ha^{-1}), ME yield (46706.00 Mcal ha^{-1}) and NE_p yield (29766.00 Mcal ha^{-1}) was noted in "TORRO" (*Table 3*, *Figure 2*). The highest CP yield (2.90 t ha^{-1}) was documented in "MACHA" (*Table 3*). All yield components of "CHAMP" were at least 12% higher than the mean yield values, especially in TDN yield (20%), dry matter yield (18%).

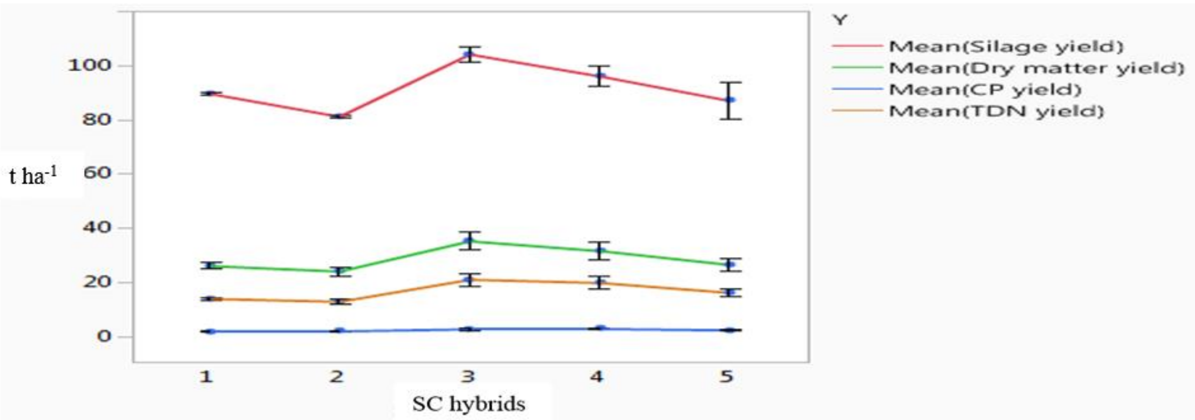

Figure 2. Yield components of SC hybrids (1: "PL 712"; 2: "TORRO"; 3: "CHAMP"; 4: "MACHA"; 5: "RANGER")

The mean of silage yield, dry matter yield, CP yield, and TDN yield was 91.60 t ha^{-1}, 28.80 t ha^{-1}, 2.40 t ha^{-1}, and 16.80 t ha^{-1} in the current study. "CHAMP" and "MACHA" that became early-matured hybrids were higher than the mean yield components. Silage yield values obtained by Kir (2020) (67.10 t ha^{-1}), Ileri et al. (2018) (77.00 t ha^{-1}), Malasli et al. (2017) (42.00-52.00 t ha^{-1}), and Carpici et al. (2010) (18.70 t ha^{-1}) were lower compared to the current study. Similarly, Kir (2020) and Malasli et al. (2017) also determined that dry matter yield was 26.20 t ha^{-1} and 12.10 t ha^{-1}. Different morphological and physiological traits of the SC hybrids may result in different yields of silage and dry matter. These differences arose from the hybrids' genetic structure. These traits also affected the plant length and dry matter content of the SC hybrids. Due to its highest CP contents (9.6%), "MACHA" was the hybrid that had the highest CP yield (2.90 t ha^{-1}). Kir (2020) and Carpici et al. (2010) indicated CP yield in Kirsehir (2.10-2.30 t ha^{-1}) and Bursa (0.90-1.50 t ha^{-1}) conditions. Mean CP yield in the current study was higher (2.40 t ha^{-1}) compared to these studies. The mean TDN yield was 16.80 t ha^{-1}. "CHAMP" (21.10 t ha^{-1}) and "MACHA" (19.80 t ha^{-1}) were higher than mean TDN yield. Agnew et al. (2022), Song et al. (2021), Kim et al. (2018) indicated that TDN yield was 10.00 t ha^{-1} for sole corn, 10.40 t ha^{-1} for corn + lablab (*cv*. "Rangai"), 9.80 t ha^{-1} for corn + soybean intercropping. Burken et al. (2017)'s TDN yield (17.90 t ha^{-1}) had a similar trend with the current study. TDN yield differences between these studies in the current study could have arisen from DM content and silage yield. Lardner et al. (2017) has mentioned that ME yield of silage corn was 31126.00 Mcal ha^{-1} which had lower ME yield compared to the current study.

3.4 Corn Growing Environment and Influence on Maturity

The range of the hybrids CHU_{seed}, CHU_{silk}, and GDD in the current study are presented in *Table 2*. The differences were detected in CHU_{seed}, CHU_{silk}, and GDD (P<0.001) by SC hybrids in accordance with one-way ANOVA. CHU_{seed}, CHU_{silk}, and GDD values of SC hybrids varied from 2798 to 2969, 1072 to 1315, and 1879 to 1972, in the same order (*Table 2*, *Figure 4*). Silage maturity had a positive strong correlation with CHU_{seed} (r = 0.84, p = 0.001), CHU_{silk} (r = 0.90, P<0.001), and GDD (r = 0.89, P<0.001) (data now shown). Silage maturity was reasonably predictable from CHU_{seed}, CHU_{silk}, and GDD measured. Their expression of regressions and their Rsquare values of silage maturity by CHU_{seed} (r^2 = 0.70), CHU_{silk} (r^2 = 0.81), and GDD (r^2 = 0.79) are presented in *Figure 3*.

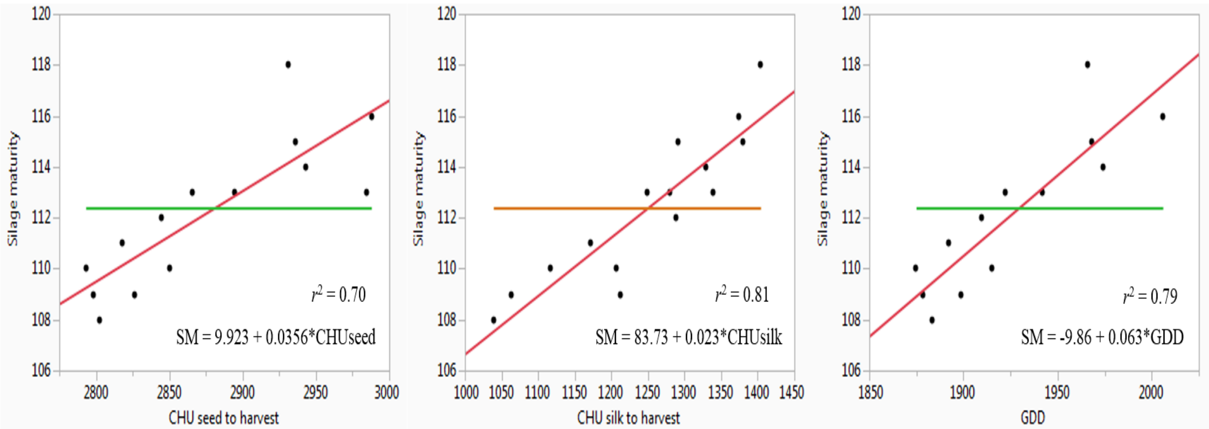

Figure 3. Expression of regression between CHUseed, CHUsilk, GDD and silage maturity

The range of the hybrids' CHU ratings (CHU_{seed}, CHU_{silk}) and GDD ratings showed narrow variation (*Table 2*). Successful growth of SC hybrids depends on the availability of CHU, and SC is considered more suitable to the areas with a minimum of 2000-2100 CHU's, in the western Canada that require ≥ 2300 CHU's for ensiling corn (Lardner et al., 2017; McCartney et al., 2009). Guyader et al. (2018) detected a significant weak correlation (r = 0.42) between yield and CHU ratings (2000-2600). They also indicated that late-maturing hybrids had higher biomass yield. But, these hybrids had less than desired DM content (≤ 30%). Lardner et al. (2017) noted a non-significant weak correlation between DM content (P>0.05) and forage yield to CHU's (r = 0.31, P = 0.06) respectively, which had similar trend with the current study. A significant correlation between yield and nutritive profile to CHU and GDD ratings was not detected in the current study. But, the SC hybrids used in the current study had higher CHU ratings compared to Guyader et al. (2018). Additionally, the SC hybrids had more than desired DM content (≥ 30%), excluding "Pl 712".

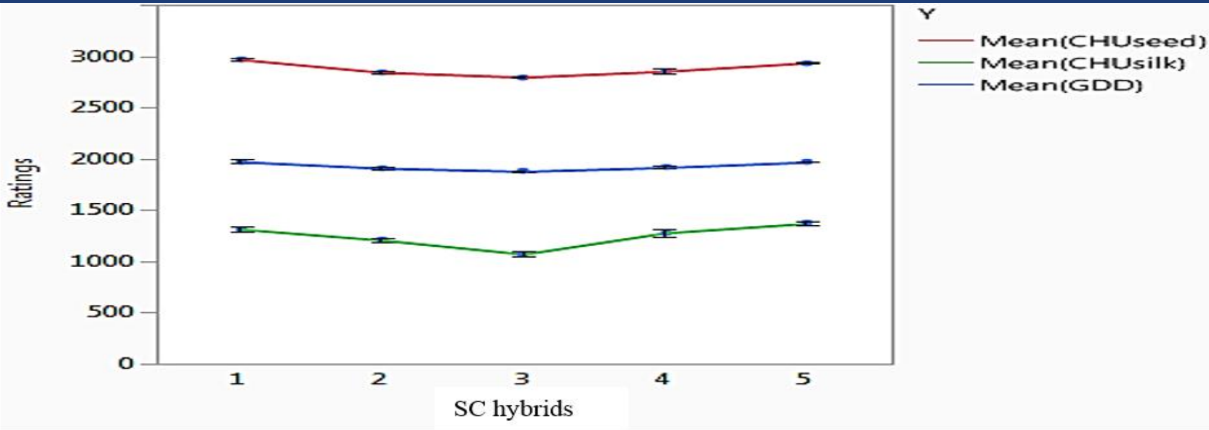

Figure 4. CHU and GDD ratings of SC hybrids (1: "PL 712"; 2: "TORRO"; 3: "CHAMP"; 4: "MACHA"; 5: "RANGER")

4. Conclusion

Based on the above results, "CHAMP" and "MACHA" could be recommended for their agronomic profile, nutritive profile, and yield components. "MACHA" had more quality and digestible forage, and "CHAMP" had more yield potential, which is very near to the nutritive profile of "MACHA". "CHAMP", and "MACHA" had more adaptation capability to the Central Anatolian region among all hybrids used in the current study. These hybrids had very few differences in yield components and nutritive profiles. Although there was a relationship between silage maturity with CHU and GDD ratings, the CHU rating system used for selecting SC hybrids might be challenging due to the annual variation of climatic conditions. The current study showed that low CHU SC hybrid had higher yield values and nutritive profile. In the Central Anatolian region like Ankara, early-maturing SC hybrids (as much as 2850 CHU_{seed}) would be ideal due to their optimum DM content for ensilaging and their desired yield levels and nutritive profiles.

Conflicts of Interest

The author declares that there is no conflict of interest.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Authorship Contribution Statement

Concept: Ozkan, U.; Design: Ozkan, U.; Data Collection or Processing: Ozkan, U.; Statistical Analyses: Ozkan, U.; Literature Search: Ozkan, U.; Writing, Review and Editing: Ozkan, U.

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