EFFECTS OF HUMIC ACID DOSES ON FORAGE YIELD AND YIELD COMPONENTS OF SILAGE CORN (*Zea mays* L.) CULTIVARS

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Abstract. This study aims to determine the effect of humic acid fertilizer doses on forage yield a yield components and some quality characteristics of corn silage (*Zea mays* L.) cultivars (M17GS01, Hido, LG Turuva, and Pioneer PR31Y43) with four Humic Acid doses (Control, 2.5, 5.0, and 10 kg/ha^{-1}) in 2022 and 2023 years at Niğde. The field experiment was arranged in a randomized block design according to the split-plot; corn cultivars were located in the main plots, and humic acid doses were in the sub-plots. The forage yield, yield components, and quality parameters were measured. The highest yield of dry matter was determined in the LG Turuva cultivar. The highest fresh and dry matter yields were determined in 10 kg/ha^{-1} humic acid dose applications per hectare. This study recommends LG Turuva and humic acid (10 kg/ha^{-1}) for silage corn production in Niğde environmental conditions. The highest NDF (45.3%) and ADF (27.22%), recorded in cultivar Hido, while the highest starch (30.44%), dry matter (30.01%) and pH value (4.01) was determined in cultivar M17GS01. On the other hand, the highest crude protein content (7.58%), and ash value (4.25%) was determined in the cultivar PR 31Y43.
Keywords: *maize hybrids, organic fertilizer, fodder, fodder production, green forage*

Introduction

Corn (*Zea mays* L.) is ranked as third most essential cereal crop in the world and belongs to the poaceae family. It is a food source for human consumption, animal feeding material, fodder, biotic energy fuel, and other industrial products. Within a short period, achieving a greater yield perspective is one of the main characteristics of an increasingly fast and vigorous position in crop growing. Corn greatly contributes to seed production and maintains a special economic status for nations. The endless increase in the human population globally is increasing the threat to food security and energy. It can be recognized by the efficient use of present arable lands (Maruf, 2019).

In general, normal corn yield is more than 4 t/ha^{-1}. It has a high efficiency of nutrient element acquisition and multiple mechanisms in response to nutrient element deficiency. Likewise, it can be grown in many places, from lowlands to highlands, from sea level up to over 2600 m high (Stansluos, 2020). Corn is an important plant cultivated widely for silage production because of many benefits, such as great energy and effortless digestibility, and it can be mixed with other feeding plant materials. It is considered one of the great essential sources of roughage-succulent feeding material for animals. Corn silage is capable of high and stable silage production, with delicious and high nutrient contents. Turkey silage corn production was 18.563.390 tons in a 401591ha area. In the last ten years, cultivation and production have increased by approximately 210% due to advanced mechanization, easy storage by developing the silage package industry daily, and the best selection of high-yield corn silage cultivars. High productivity and qualified yield of developed new varieties are the most important ways to increase crop yield. Regarding quality yield, when choosing the best hybrid for silage, hybrid corn silage should have high dry matter content and high fresh forage yield potential, a long period of green color, be easily digestible, and have a high hybrid net energy value (Özata et al., 2018).

Corn is the crop that delivers the highest silage yield. The genetic potential of corn varieties and the application of fertitlzers play an essential role in determining and increasing yield potential. Humic acid has multi benneficial effects on soil fertilization and water-holding capacity, and due to its containing organic material, it increases the activities of microorganisms in the soil (Oktem and Oktem, 2020).

Due to high intensive and growing all year, the soils are endlessly stressed of organic carbon (Gao et al., 2022). Enhancing productivity alone or in mixture with chemical fertilizers is needed to improve soil fertility status when low soil organic matter on the one hand and a growing need for more nutrient elements (Daur and Bakhashwain, 2013). Chemical and nonchemical fertilizers used to support plants health, and to develop soil structure organic fertilizers can be applied (Rady et al., 2016; Nur Susilawati and Purba, 2021; Gao et al., 2022). Organic fertilizer application on soil improves the continuous crop obstacle by soil, improves soil fertility, reduces soil-borne diseases, and improves microbial flora structure (Li et al., 2019; Laftah and Alabdulla, 2022). Spraying organic fertilizer on the plant as humic acids can improve plant growth and production by increasing photosynthesis, cell membrane the permeability, absorption of nitrogen, phosphorous and potassium elements, and improving micronutrient elements uptake, especially Fe (Khan et al., 2014). Humic acid fertilizer has beneficial effects on corn development, providing mineral sustenance, enhancing germination of seed, growth of seedling, initiation of root, root system growth, boosting development of shoot system, and increasing the availability of macro and microelements. Humic acid reduces enviromental stress factors, e.g., un-optimal heat, high pH, and high salinity, increasing nutrient availability and decreasing some toxic elements absorption. Also, there is a lack of comprehensive studies on optimizing humic acid for some crops, especially corn silage production (Daur and Bakhashwain, 2013). Furthermore, humic acid fertilizer expands the composition of the aeration feature of the soil and provides better aeration of roots. The applications of humic acid doses to corn crops revealed a momentous increase in yield and yield characteristics. (Khan et al., 2014; Li et al., 2019; Oktem and Oktem, 2020).

Forage crops like corn are changing rapidly. In the last few years, near-infrared (NIR) techniques have been accepted as accurate techniques for feed quality analysis. They are fast and economical, and all features adequately meet fresh forage farm analysis demands. NIR can decrease the time and labour required for analysis. Moreover, NIR instruments decrease sample size and weight when evaluating the quality analysis of corn silage without any sample preparation (Berzaghi et al., 2005). Our study aimed to determine the effects of humic acid doses on forage yield, yield components and some quality characteristics of corn cultivars.

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Materials and methods

Location

Two field experiments had done at the research area Faculty of Agricultural Sciences and Technologies (N37° 94', E34° 96'), Niğde Ömer Halisdemir University, Turkey. The research was carried out in 2022 and 2023 in Niğde province, which is located at an altitude of 1299 m above sea level and has an average annual precipitation of 343 mm. Soil analysis results are represented in (*Table 1*).

Table 1. *Shows analysis results on some characteristics of Niğde soil chemical conditions*

EFFICIENCY ANALYSIS	ANALYSIS RESULT	EVALUATION
Saturation (%)	61	Clay – Loamy
pH	7.8	Slightly Alkaline
Total Salt (%)	0.01	Unsalted
Lime (%CaCo3)	22.1	Over
Organic Matter (%)	1.9	Less
Available Phosphorus (P2O5, Kg / Decare)	9.2	High
Available Potassium (K20, Kg/Decare)	240	High
MICRO-MACRO ELEMENT ANALYSIS		
Iron (Fe)	10.2	Very high
Copper (Cu)	1.0	Enough
Zinc (Zn)	1.68	Enough
Manganese (Mn)	23.5	Enough
Calcium (Ca)	5511.00	High
Magnesium (Mg)	1976.00	Very high
Sodium (Na)	-	-

Design

The experiment was established in accordance with the design of the split plot in randomized blocks with 4 replications. Treatments: Corn varieties were located in the main plots, and humic acid doses were located in the sub-plots. In the study, four corn cultivars M17GS01 (FAO 700), Hido (FAO 700), LG Turuva (FAO 650), and PR 31Y43 (FAO 700) and 4 humic acid doses (Control, 2.5, 5.0, and 10.0 kg/ha^{-1}) were used (*Table 2*). Seeds were planted with a four-row with 70 cm a row spacing and 15 cm within a row spacing. Every plot was 2.8 m width and 5.0 m long, and the total size of the plot was 14 m^2 and plant number required 33 in each row (Kır and Ünsal, 2020).

Cultural practices

The seeds were planted on May 10, 2022, and on May 7 in 2023. After land preparation, applied base fertilizers as NPK (15+15+15 (5.5 SO3) manually to the soil surface and mixed with a rotovator. During the growing season, urea fertilizer was applied to each plot in the study at a fixed rate of 10 kgha^{-1} pure nitrogen. The top dressing was applied in two separate periods. When the plants reached a height of approximately 60 cm, at stem elongation development stage (BBCH 30 – 39) half of the urea fertilizer was applied, and the other half was applied during the tasseling period (BBCH 50 – 59). The plots were irrigated with a drip irrigation system immediately after fertilizer applications.

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Table 2. *The detailed treatments*

Treatments	Details
T1	M17GS01 corn cultivar with 0 kg humic acid ha^{-1}
T2	Hido corn cultivar with 0 kg humic acid ha^{-1}
T3	LG Turuva corn cultivar with 0 kg humic acid ha^{-1}
T4	PR 31Y43 corn cultivar with 0 kg humic acid ha^{-1}
T5	M17GS01 corn cultivar with 2.5 kg humic acid ha^{-1}
T6	Hido corn cultivar with 2.5 kg humic acid ha^{-1}
T7	LG Turuva corn cultivar with 2.5 kg humic acid ha^{-1}
T8	PR 31Y43 corn cultivar with 2.5 kg humic acid ha^{-1}
T9	M17GS01 corn cultivar with 5 k humic acid ha^{-1}
T10	Hido corn cultivar with 5 kg humic acid ha^{-1}
T11	LG Turuva corn cultivar with 5 kg humic acid ha^{-1}
T12	PR 31Y43 corn cultivar with 5 kg humic acid ha^{-1}
T13	M17GS01 corn cultivar with 10 kg humic acid ha^{-1}
T14	Hido corn cultivar with 10 kg humic acid ha^{-1}
T15	LG Turuva corn cultivar with 10 kg humic acid ha^{-1}
T16	PR 31Y43 corn cultivar with 10 kg humic acid ha^{-1}

Humic acid doses application

Humic acid doses were applied in two equal doses during the growing process. The concerned dose was added to the five-liter sprayer, mixed with water, then sprayed around the root zone. The first dose was applied to the root zone of the plants when they reached 20-25 cm in height, at leaf development stage (BBCH 10 - 19), and the other half was applied to plants when they reached approximately 50 cm in height, at stem elongation stage (BBCH 30 – 39), according to the experiment. The plants were watered immediately after application. The characteristics examined in the research were arranged according to the Seed Registration and Certification Central Directorate Technical Instructions.

Data collection

Data of yield and yield components were collected from two middle plant lines from every plot and the rows on the edge of the plot were not harvested because of the edge effect. In the study, observations were taken from 10 plants representing the plots from the middle two rows in each plot. The observations and measurements taken in the study were as follows; Days of 50% flowering were counted from the sowing date. Then, ten plants from each plot were randomly selected to measure height of plant (cm), diameter of stem (mm), cob number, and leaf area index (cm^2). At harvest, early dough and dough stage (BBCH 83 – 85), the dry matter ratio %, yield of green forage kg/ha^{-1}, and yield of dry matter (kg/ha^{-1}) were determined in each plot becuase hectare is considered international measure (Karadağ and Akbay, 2013; Karadağ and Balmuk, 2013; Kuşvuran et al., 2015).

Leaf area for each leaf was determined following McKee's (1964) procedure: by measuring from their base to the leaf tip the length of leaf blades ($Leaf_L$) and the width of the leaf at its widest point ($Leaf_W$) and multiplying these values with a correction factor (0.75), as shown in the following equation.

$$\text{Individual Leaf Area} = \text{Leafl} \times \text{Leafw} \times 0.75 \qquad \text{(Eq.1)}$$

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To determine the harvesting time, the milk line of the grain on the cob was cut and checked in order to determine the silage maturity period and the harvest was made at the dough maturity period when it was 2/3 (Keleş and Türk, 2018). Harvesting was carried out during the dough maturity period, which is the best harvest time for corn silage (Geren et al., 2003). Fresh forage yield was determined in each of the two middle rows, and the values were transformed to kg/ha^{-1}. Yield of dry matter was determined using the of Daur et al. (2011) procedure, where taken three plants sample from every subplot, dried in an oven at 70^{o}c, and the values of the sample were transformed into kg/ha^{-1} based on the average covered area.

During harvesting time, corn fresh silage samples were collected and chopped in small particles, located in 1 kg plastic bags covered after removing air/oxygen delivered to quality analysis to measure Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), starch, Dry matter (DM), pH, Crude protein (CP), and ash by using AURA handled Near-infrared reflectance spectroscopy machine (Gao et al., 2022).

Data analysis

All data obtained in this research were subjected to analysis of variance (ANOVA) to evaluate the response of humic acid fertilizer applications on silage yield and yield components of corn cultivars in accordance with the experimental design using the software program MSTATC for statistical analysis. The comparison and differences between the means were tested according to Tukey tests at the probability level 5%.

Results and discussion

Flowering 50% (days)

High fresh yield, early dry matter yield, and low seed moisture content have been the main components of corn development researches, as well as high forage quality in recent years. Early flowering is essential for cultivar in the growth period and is the main principle for cultivating corn. Generally, in the incredible popularity of silage corn cultivation areas, early flowering is essential. Cultivars differ in terms of the period of days of 50% flowering considering investigated cultivars and standards flowered later than candidate cultivars in both years.

There were highly significant differences among cultivars, humic acid fertilizer doses, and the interactions between cultivars and humic acid doses application showed no significant differences for days of 50% flowering (*Table 3*). The earliest 50% flowering was 88.8 days recorded by the M17GS01 cultivar, and the latest 50% flowering was 94.8 days recorded by the PR 31Y43 cultivar. The earliest humic acid effect on 50% flowering was 88.8 days, recorded by 0.0 kg/ha^{-1}, and the latest 50% flowering was recorded by 5.0 kg/ha^{-1} (94.0 days) and 10.0 kg/ha^{-1} (94.0 days). The earliest day of 50% flowering was 87.3 days, recorded by the interaction between the M17GS01 cultivar and 0.0 kg/ha^{-1} combination. In comparison, the latest 50% flowering value of 99.3 days was recorded by the Hido cultivar and 10 kg/ha^{-1}. M17GS01 and LG Turuva were flowering at the earliest cultivars in both years. Some researchers under Samsun conditions (Öner et al., 2011) under Samsun conditions observed that the days of 50% flowering for cultivars were from 58 to 65 days in the study to select silage corn cultivars' yield. Similarly, in Samsun environmental conditions, Özata et al. (2012) found the days of 50% flowering were between 58 to 64 days in their study. Overall, in Antalya, the conditions

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were between 60 and 65 days (Erdal et al., 2009). In Konya environmental conditions, Sade et al. (2005) found 50% flowering arranged from 82 to 87 days in their research. Kuşvuran et al. (2015) found that average 50% flowering was 107 days, in Tokat was 77.3 and in Kocaeli was 78.13. Gençtürk (2007) found that average 50% flowering were between 109 and 127 days, in Erzurum was 79.30 to 94.70 days. Bulut et al. (2008) found that average 50% flowering 114 days. Yıldırım (2018) found between 62.66 to 69.0 days. Sivas region in summer season has a quit hot, quite low relative humidity, altitude, and length of the day resulting flowering in short time. Data obtained from our research agreed with the finding of Sade et al. (2005). In conclusion, the differences between cultivars used, climate conditions, and environmental factors lead to different results.

Table 3. *shows the effect of cultivars and humic acid doses on days of 50% flowering, plant height, stem diameter, and cobs number per plant average two years (2022/2023)*

Treatments	**50% flowering (days)**	**Plant height (cm)**	**Stem diameter (mm)**	**Cobs number/ plant**
Cultivars (C)				
C1: M17GS01	88.8 a	274.3 c	23.8 b	1.2 c
C2: Hido	93.8 c	260.9 d	22.3 c	1.7 a
C3: LG Turuva	91.3 b	302.6 a	25.5 a	1.5 b
C4: PR 31Y43	94.8 d	284.5 b	22.2 c	1.4 b
SD ±	0.6352	3.3447	0.0281	0.1095
Humic Acid Doses kg ha^{-1} (H.A.)				
H.A.1	88.8c	279.7 b	22.4 c	1.4
H.A.2	91.1b	271.3 c	22.8 b	1.4
H.A.3	94.0 a	285.0 a	23.8 b	1.5
H.A.4	94.7 a	286.2 a	24.7 a	1.4
SD ±	0.7766	3.7551	0.0282	0.0769
Interactions (C × H.A.)				
C1 × H.A.1	87.3	261.8 g	22.9 d	1.2
C2 × H.A.1	89.0	251.7 i	21.9 g	1.7
C3 × H.A.1	87.5	307.4 b	23.5 d	1.5
C4 × H.A.1	91.5	298.1 c	21.5 h	1.3
C1 × H.A.2	88.8	265.0 g	22.1 f	1.3
C2 × H.A.2	91.4	252.8 i	22.3 e	1.7
C3 × H.A.2	90.8	286.7 d	24.4 c	1.5
C4 × H.A.2	93.6	280.5 f	22.3 e	1.3
C1 × H.A.3	90.3	288.2 d	24.8 c	1.2
C2 × H.A.3	95.0	279.4 f	22.1 f	1.8
C3 × H.A.3	93.0	295.7 c	25.9 b	1.6
C4 × H.A.3	97.1	276.9 f	22.6 d	1.6
C1 × H.A.4	88.9	282.2 e	25.4 b	1.2
C2 × H.A.4	99.3	259.6 g-h	23.0 d	1.6
C3 × H.A.4	93.8	320.6 a	28.1a	1.6
C4 × H.A.4	97.0	282.5 e	22.3 e	1.5
SD ±	1.5532	7.5101	0.0564	0.1538
F value				
C	0.0000**	0.0000**	0.0000**	0.0493*
H.D	0.0000**	0.0254**	0.0000**	0.4954ns
C * H.A	0.3773ns	0.0103**	0.0077**	0.3119ns
C.V (%)	4.77	7.57	6.80	28.70

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Height of plant (cm)

The primary and interaction effects of cultivar and humic acid doses on height of plant were found to be highly significant (*Table 3*). The highest average plant height value recorded by the LG Tturuva cultivar 302.6 cm and lowest recorded by the Hido cultivar 260.9 cm. Humic acid showed highest plant height was 286.2 cm recorded by 10.0 kg/ha^{-1} and shortest plant height was 286.2 cm record by 0.0 kg/ha^{-1}. The interaction between LG Turuva and 10 kg/ha^{-1} was recorded with the highest plant height (320.6 cm) and shortest plant height between the Hido cultivar and 0.0 kg/ha^{-1} humic acid (251.7 cm) and Hido cultivar and 2.5 kg/ha^{-1} humic acid (252.8 cm).

Forage crops like corn cultivated to achieve high yield it considered that plant height has important and positive role on the yield (İptaş et al., 2002). Plentiful vegetative parts are the greatest preferred features in corn silage, and high plant length can contribute to obtain a huge amount of vegetative parts (Kuşvuran et al., 2015). Yılmaz et al. (2007) observed comparable findings on silage corn plant height. In some additional studies, silage corn plant height were found from 191.3 to 186 cm (Nur Susilawati and Purba, 2021), from 177 to 2001 cm under Saudi Arabia conditions (Daur and Bakhashwain, 2013), from 62.92 to 145.42 cm (Wulandari et al., 2019). In a research done under Bursa conditions the average plant heights ranged between 268.6 to 280.9 cm for cultivars (Karasu, 2012), between 221.1 to 202.0 cm in Iran conditions (Safdarian et al., 2014), and between 257.4 to 297.1 cm in Bursa conditions (Çarpici and Çel, 2010) and observed that the average plant height under Kayseri conditions was between 200.2 to 184.1 cm. Furthermore, their study conducted under Antalya conditions found the average plant height was between 277.6 to 308.4 cm, obtained in first year 234 cm and second year 273 cm in the for silage corn cultivars (Erdal et al., 2009); in the study under Samsun conditions found the silage corn cultivars plant height arranged from 235 to 284 cm (Özata et al., 2012), and in Adana conditions (Bolat et al., 2011) founded silage corn plant height observed from 270 to 283.3 cm under Adana conditions. Yürekli et al. (2021) found plant height in Tokat 258.7 cm and in Kocaeli 231 cm. Kuşvuran et al. (2015) found average plant height 246 cm. Some researchers showed varied differences in plant height values, İptaş et al. (2002) from 227 to 258 cm, Kuşaksız and Kuşaksız (2005) from 155 to 207 cm, Budak et al. (2005) from 256 to 298 cm, Boran (2007) average 215 cm, Gençtürk (2007) from 2005 to 245 cm, Gürel (2007) from 228 to 274 cm, Sade et al. (2007) from 235 to 273 cm, Erdal et al. (2009) from 235 to 277 cm, Kuşvuran et al. (2011) average 245 cm and Özata et al. (2012) 280 to 324 cm. Genetic variation, day light, irrigation, nutrient elements, and density of plants have significant effect on determination plant height (Uyanık, 1984). In conclusion, the differences between recorded plant height due to research conducted in various climate, ecological conditions, cultivars used, and cultural practices (Yürekli et al., 2021).

Stem diameter (mm)

Highly significant differences found among cultivars, humic acid doses, and interactions between cultivars and humic acid doses in terms of stem diameter (*Table 3*). The highest value of stem diameter was 25.5 mm, recorded by the LG Turuva cultivar, and the lowest value was 22.2 mm, recorded by the PR 31Y43 cultivar. The highest value was 24.7 mm, recorded by 10.0 kg ha^{-1} and the lowest value was 22.4 mm, recorded by 0.0 and 2.5 kg ha^{-1}. The highest interaction effects of cultivar and humic acid doses on stem diameter value 28.1 mm was recorded by LG Turuva cultivar and 10.0 kg ha^{-1}

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combination. In contrast, the lowest value, 21.5 mm, was recorded by Pioneer cultivar and 0.0 kg ha^{-1}.

Stem diameter is significantly important to prevent plant lodging especially inn corn because stem is tall. Stem thickness resulting from some cultural practices such as extreme irrigation and nitrogen fertilization, regular planting, and genetic factors with other ecological factors like winds, frequent heavy rains, lodging will become expected. Especially when cobs forming and grains filling stage, as moving toward advanced maturity stages occurs more lodging and this leads to losses during harvest then decrease yield. Instead, increament of stem diameter leads to increase stem ratio then has a negative effect on the silage quality (Kuşvuran et al., 2015; Wulandari et al., 2019). Under Indonesia conditions, the average stem diameter was between 28.5 to 19.0 mm. Çarpici and Çel (2010) observed under Bursa conditions, the average stem diameter was between 16.6 to 24.5 mm. Kaplan et al. (2016) observed under Kayseri conditions the average stem diameter between 19.3 to 22.3 mm. Sade et al. (2007) obtained stem diameter from 23.7 to 24.8 mm, Ergül (2008) from 22.9 to 29.6 mm, and Kusvuran et al. (2011) average stem diameter 20.8 mm. Obtained results are agreed with Sade et al. (2007), Ergül (2008), Çarpici and Çel (2010), Kaplan et al. (2016), and Wulandari et al. (2019). We can conclude that climate conditions and environmental factors, genetic variations used and cultural practices in cultivation are effective on stem diameter.

Cobs number per plant

There were a significant differences among cultivars but no significant differences between humic acid doses and the interactions in terms of cobs number (*Table 3*). The highest value of cobs number was 1.7, recorded by the Hido cultivar, and the lowest value was 1.2, recorded by the M17GS01 cultivar. The highest value was 1.5, recorded by 5.0 kg ha^{-1}, and the lowest value was 1.4, recorded by 0.0, 2.5, and 10 kg ha^{-1}. The highest interaction effects of cultivar and humic acid doses on cobs number value 1.8 was recorded by the Hido cultivar and 5.0 kg ha^{-1} combination. These results agreed with Gençtürk (2007) found between 0.6 to 1.6, Gürel (2007) from 1.0 to 1.8, Bulut et al. (2008) found 1.2, Kuşvuran et al. (2015) obtained from 1.2 to 1.9, and disagreed with Karasu (2012) found that ear number per plant values were arranged between 0.92 to 0.91.

Leaf area index (cm^2)

A highly significant differences among cultivars and humic acid doses, but there was no significant difference in the interactions among cultivars and humic acid doses in leaf area index (*Table 4*). Highest value 868.4 cm^2, recorded by the Hido cultivar, and the lowest value was 698.7 cm^2, recorded by the M17GS01 cultivar. The highest value was 801.1 cm^2, recorded by 10.0 kg ha^{-1}, and the lowest value was 744.0 cm^2, recorded by 2.5 kg ha^{-1}. The highest interaction effects of cultivar and humic acid doses on leaf area value 919.5 cm^2 were recorded by the Hido cultivar and 10.0 combination. In contrast, the lowest value, 665.8 cm, was recorded by the M17GS01 cultivar and 2.5 kg ha^{-1} (Daur and Bakhashwain, 2013). The average leaf area index between 578 to 802 cm^2 was found under Saudi Arabia (Safdarian et al., 2014). The average leaf area index found under Saudi Arabian conditions is between 390 and 560 cm^2 (Wulandari et al., 2019). The average leaf area index between 463.04 to 4029.09 cm^2 was found under Indonesia conditions. In conclusion, the obtained results were in harmony with Daur and Bakhashwain (2013) and higher from Wulandari et al. (2019) and Safdarian et al. (2014).

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***Table 4.** The effect of cultivars and humic acid doses on leaf area index, dry matter ratio, fresh forage yield, and dry matter yield average two years (2022/2023)*

Treatments	**Leaf area index (cm^2)**	**Dry matter ratio (%)**	**Fresh forage yield (kg/ha^{-1})**	**Dry matter yield (kg/ha^{-1})**
Cultivars (C)				
C1	698.7 d	33.8 a	7117 c	2088.1
C2	868.4 a	33.1 b	7366 b	1992.5
C3	722.1 c	32.7 c	7517 a	2101.3
C4	791.0 b	33.2 b	7177 c	2000.0
SD±	6.9974	0.3045	0.0823	0.3251
Humic Acid Doses kg ha^{-1} (H.A.)				
H.A.1	758.4 c	32.6	6240 d	1761.2
H.A.2	744.0 d	33.3	6998 c	1982.5
H.A.3	776.7 b	33.6	7572 b	2094.4
H.A.4	801.1 a	33.5	8366 a	2343.8
SD±	10.0994	0.2770	0.1106	0.3560
Interactions (C × H.A.)				
C1 × H.A.1	692.2	32.2	6005	1770.0 gf
C2 × H.A.1	855.5	31.6	6429	1725.0 h
C3 × H.A.1	719.7	34.3	6231	1690.0 h
C4 × H.A.1	766.3	32.6	6295	1860.0 f-h
C1 × H.A.2	665.8	33.2	6613	1887.5 e-h
C2 × H.A.2	807.0	33.3	7277	2065.0 c-f
C3 × H.A.2	724.0	34.1	7396	2187.5 b-d
C4 × H.A.2	779.2	32.6	6707	1790.0 gh
C1 × H.A.3	698.8	33.1	7746	2255.0 ac
C2 × H.A.3	891.6	33.6	7312	1980.0 d-g
C3 × H.A.3	728.3	34.1	7769	2087.5 b-e
C4 × H.A.3	788.2	33.6	7461	2055.0 c-f
C1 × H.A.4	738.1	34.0	8103	2440.0 a
C2 × H.A.4	919.5	32.5	8446	2200.0 b-d
C3 × H.A.4	919.5	33.5	8671	2440.0 a
C4 × H.A.4	716.3	34.2	8243	2295.0 ab
SD±	20.1989	0.5539	-	0.7120
F value				
C	0.0000**	0.0598*	0.0113*	0.0532*
H.D	0.0011**	0.0918ns	0.0000**	0.0000**
C * H.A	1.3251ns	0.1444ns	0.3553ns	0.0017**
C.V (%)	7.42	4.70	8.57	9.84

Dry matter percentage

Data revealed a significant differences between cultivars, no significant humic acid doses, and interactions between cultivars and humic acid doses in terms of dry matter percentage (*Table 4*). The highest value of dry matter was 33.8%, recorded by the M17GS01 cultivar, and the lowest value was 32.7%, recorded by the LG Turuva cultivar. The highest value was 33.6%, recorded by 5.0 kg ha^{-1}, and the lowest value was 32.6%, recorded by 0.0 kg ha^{-1}. The highest interaction effects of cultivar and humic acid doses on dry matter ratio value 34.3% was recorded by the LG Turuva cultivar and 0.0 kg ha^{-1}

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combination. The lowest value of 31.6% was recorded by the Hido cultivar with 0.0 kg ha^{-1}. Observed that the average dry matter ratio by Şimşek (2006) was from 19.0 to 20.9%, Gençtürk (2007) from 23.7 to 30.0%, Gürel (2007) from 30.8 to 37.9%, Sade et al. (2007) from 29.3 to 38.3%, Ergül (2008) from 24.4 to 32.1%, and Erdal et al. (2009) from 34 to 38%. Kuşvuran et al. (2015) reported the average was 32.7% lowest was 26.0% and the highest was 40.4%, and under Kayseri conditions was between 32.30 to 28.80% (Kaplan et al., 2016). In term of corn silage quality the ideal dry matter percentage should be 30 to 35% and among preferred characters. Despite the fact that higher dry matter percentage reduce quality features like digestibility, assimilability, and protein percentage. Lower dry matter percentage of silage materials cause yield and quality reduction as a result of high water content (Kuşvuran et al., 2015). Our obtained findings agreed with Ergül (2008), Erdal et al. (2009), Kuşvuran et al. (2015) and Kaplan et al. (2016). Researchers said that the corn feeding materials which will be ensiled should 30 to 35% dry matter content, in other hand, should be 65 to 70% water content, and also low content of carbohydrate during vegetation stages before milk stage (Orak and Iptas, 1999).

Fresh forage yield (kg/ha^{-1})

Obtained data were significant differences among cultivars, highly significant differences between humic acid doses, and no significant differences between interactions between cultivars and humic acid doses regarding fresh yield (*Table 4*). The highest result of fresh yield 7517 kg ha^{-1}, recorded by the LG Turuva cultivar, and the lowest yield 7117 kg ha^{-1}, recorded by the M17GS01 cultivar. The highest yield 8366 kg ha^{-1}, recorded by 10 kg/ha^{-1}, and the lowest value was 6240 kg ha^{-1}, obtained by 0.0 kg ha^{-1}. Interaction effects on cultivar and humic acid doses on fresh yield were highly significant, and the highest yield was 8671 kg ha^{-1}, was recorded by LG Turuva cultivar and 10.0 kg/ha^{-1} combination. In contrast, the lowest yield 6005 kg ha^{-1}, was recorded by the M17GS01 cultivar and was 0 kg/ha^{-1}. Yield (green forage) is one of the most essential standard selection characteristics for silage corn and corn breeding research.

Akdemir et al. (1997) their study under Bursa conditions recorded fresh yield was from 4834 to 6706 kg/ha^{-1} (İptas et al., 2002). In Tokat's ecological and main crop conditions, it was found that the fresh forage yield arranged between 6723 - 8799 kg/ha^{-1} on average in the experiment that they conducted was 1996.98 kg/ha^{-1}, and Kaplan et al. (2016) observed that the average fresh yield under Kayseri conditions was between 7520 – 6100 kg/ha^{-1}. Geren et al. (2003) from 7983 to 9013 kg/ha^{-1}, Akdeniz et al. (2004) from 3336 to 7842 kg/ha^{-1}, Kuşaksiz and Kuşaksiz (2005) from 5598 to 7297 kg/ha^{-1}, Budak et al. (2005) from 5871 to 7678 kg/ha^{-1}, Şimşek (2006) from 7774 to 13298 kg/ha^{-1}, Boran (2007) found 5872 kg/ha^{-1}, Gençtürk (2007) from 6100 to 7767 kg/ha^{-1}, Gürel (2007) from 6618 to 9525 kg/ha^{-1}, Sade et al. (2007) from 6868 to 7477 kg/ha^{-1}, and Ergül (2008) from 6795 to 10348 kg/ha^{-1} (Erdal et al., 2009). In their research under Antalya environmental conditions, the average fresh forage yield was observed to be between 6345 and 6504 kg/ha^{-1}, Erdal et al. (2009) from 5268 to 7867 kg/ha^{-1}, Kuşak and Kaya (2010) found 9011 kg/ha^{-1}, (Öner et al., 2011) in their research for registration new corn silage varieties in Samsun-Çarşamba location found that fresh forage yield arranged between 6075-7391 kg/ha^{-1}. Kusvuran et al. (2011) found 6458 kg/ha^{-1}, Özata et al. (2012) found fresh yield arranged from 3340.5 to 6297 kg/ha^{-1} in their work under Samsun environmental conditions, Daur and Bakhashwain (2013) obtained fresh forage yield arranged between 5999.6 - 6738.4 kg/ha^{-1}. Safdarian et al. (2014) obtained fresh forage

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yield arranged between 2490 to 1850 kg/ha^{-1}. Kuşvuran et al. (2015) from 8461 to 13190 kg/ha^{-1}, Bulut (2016) from 4611.1 to 8030.8 kg/ha^{-1}, Özata et al. (2018) the highest yield was obtained at 6187.9 kg/ha^{-1}, and the lowest at 4616.9 kg/ha^{-1}. Kır (2020) from 5450 to 7300 kg/ha^{-1}, and Yürekli et al. (2021) from 5756.1 to 12405 kg/ha^{-1}. In conclusion, the differences between our obtained findings from researchers as result of divers corn cultivars used, ecological and cultivation conditions.

Yield of dry matter (kg/ha^{-1})

There were significant differences between cultivars, highly significant differences between humic acid doses, and the interactions between cultivars and humic acid doses in terms yield of dry matter (*Table 4*). Highest value yield of dry matter was 2101.0 kg/ha^{-1}, recorded by the LG Turuva cultivar, and lowest was 1992.5 kg/ha^{-1}, recorded by the Hido cultivar. Also highest value was 2343.8 kg/ha^{-1}, recorded by 10 kg ha^{-1}, and lowest was 1761.2 kg/ha^{-1}, recorded by 0.0 kg ha^{-1}. The highest yield of combination between cultivar and humic acid doses on fresh yield was 2440.0 kg/ha^{-1}, recorded by the LG Turuva cultivar and 10.0 kg/ha^{-1} combination, while the lowest yield was 1690.0 kg/ha^{-1} was recorded by the LG Turuva cultivar and 0 kg ha^{-1}. Dry matter is one of corn silage production's most essential yield characteristics (Özata et al., 2018). The average dry matter yield was arranged between 1806 to 2278.7 kg/ha^{-1} (Daur and Bakhashwain, 2013). Average yield of dry matter was obtained between 10267 to1198.0 kg/ha^{-1}. (Çarpici and Çel, 2010) Found dry matter yields changed between 1871.9 to 23855 kg/ha^{-1}. (Özata et al., 2012) yield of dry matter differs between 1105-1867 kg/ha^{-1} in their study in Samsun environmental conditions, and Erdal et al. (2009) observed that the average dry matter yield was arranged between 2333 to 2227 kg/ha^{-1}. Iptas (2002) their experiment showed that the average yield of dry matter from 1513.9 to 2076.6 kg/ha^{-1} in Tokat environmental conditions. Öner et al. (2011) stated that yield of dry matter different between 1289 to 2132 kg/ha^{-1} in their experiment conducted with registered silage varieties in the Samsun-Carsamba location in 2010. Akdeniz (2004) found dry matter yield arranged between 683-1499 kg/ha^{-1} in the first year and between 7670-1723 kg/ha^{-1} in the second year in their two-year study under Van ecological conditions. While obtained data were in harmony with Özata et al. (2018), Çarpici and Çel (2010), Özata et al. (2012), and Iptas (2002), and higher than Öner et al. (2011) and Akdeniz (2004), generally, green fodder yield and dry matter yield, and other yield characteristics including plant height, leaves number plant, leaf area index showed improvement with increasing increment of humic acid fertilizer up to 25 kg/ha^{-1} however it was observed to have negative affect or ineffective beyond that dose. The increment in the yield characteristics of corn silage in the humic acid-adjusted doses was most probably due to the improvement of soil condition of the root zone, where the soil maintains humic acid to supply nutrient elements as compared with the control (Daur and Bakhashwain, 2013). Our results have great support by Suganya and Sivasamy (2006), Selim et al. (2009), Buyukkeskin and Akinci (2011), Çelik et al. (2011), Tahir et al. (2011), Kim et al. (2012) who have stated that humic acid increase crop growth and productivity. Nevertheless, Iptas et al. (2002) obtained dry matter yield 2370 kg/ha^{-1}, Geren et al. (2003) from 1884 to 2130 kg/da^{-1}, Akdeiz et al. (2004) from 725 to 1612 kg/da^{-1}, Kusaksiz and Kuşaksız (2005) from 1627 to 2314 kg/da^{-1}, Şimşek (2006) from 1498 to 2690 kg/da^{-1}, Boran (2007) found 1631 kg/da^{-1}, Gençtürk (2007) from 1642 to 2204 kg/da^{-1}, Gürel (2007) from 2211 to 3459 kg/da^{-1}, Sade et al. (2007) from 2040 to 2933 kg/da^{-1}, Ergül (2008) from 1998 to 3028 kg/da^{-1}, Erdal et al. (2009) from 1878 to

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2922 kg/da^{-1}, Kuşaksız and Kaya (2010) average 1756 kg/da^{-1}, Özata et al. (2012) from 1104 to 1815 kg/da^{-1}, and Kuşvuran et al. (2015) from 2838 to 4163 kg/da^{-1}.

Quality components

After years of forage yield improvement determination new cultivar, consideration has recently been targeted at developing or recognizing cultivars improved quality characters. In corn improvement beginning to select superior stem quality, staying green for long period of time, higher nutritional value of grains, etc. (Fulgueira et al., 2007).

Acid detergent fiber (ADF %)

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest ADF% was recorded by Hido cultivar (27.22%) and lowest NDF % was recorded by M17GS01cultivar (25.35%). Highest ADF% was recorded by humic acid dose 10 kg ha^{-1} (27.70%) and lowest NDF % was recorded by humic acid dose 2.5 kg ha^{-1} (25.36%) (*Table 5*). Safdarian et al. (2014) found that ADF were between 27 to 33%, Kaplan et al. (2016) found between 22.15 to 28.55%, and Özata et al. (2018) found between 27.1 to 35.0%. ADF and NDF are considered as good forage quality indicator (Çarpici and Çel, 2010). ADF and NDF differences as a result of plant part fiber content, species, fertility of soil, and experimental locations environmental conditions (Safdarian et al., 2014).

Neutral detergent fiber (NDF %)

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest NDF% was recorded by Hido cultivar (45.18%) and lowest NDF % was recorded by M17GS01cultivar (42.36%). Highest NDF% was recorded by humic acid dose 10 kg ha^{-1} (45.78%) and lowest NDF % was recorded by humic acid dose 0.0 kg ha^{-1} (42.05%) and 2.5 kg ha^{-1} (42.72%) (*Table 5*). Daur et al. (2013) found NDF were between 55.14 to 57.11%, Özata et al. (2018) found between 54. 4 to 67.0%, Kaplan et al. (2016) found between 46.08 to 49.85%, and Safdarian et al. (2014) found between 52.1 to 57.3%. Weather with low temperatures lead to crop leaves shrinking, cell walls thickening which increasing ADF and NDF ratios, a recess in growth and development (Galdamez-Cabrera et al., 2002; Mahajan and Tuteja, 2005) and plant cells change relevantly several times.

Starch %

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest Starch% was recorded by M17GS01 cultivar (30.44%) and lowest starch % was recorded by Hido cultivar (24.71%). Highest Starch% was recorded by humic acid dose 10 kg ha^{-1} (30.50%) and lowest starch % was recorded by humic acid dose 0.0 kg ha^{-1} (27.10%) (*Table 5*). Generally, dietary starch recommendations range between 23 and 30% of ration dry matter (DM), depending on the diet's forage content (Ferreira, 2002).

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Table 5. *Shows percentage of NDF, ADF, Starsh, DM, pH, CP, and Ash results of corn silage cultivars*

Cultivars	**NDF%**	**ADF%**	**Starch%**	**DM%**	**pH**	**CP %**	**Ash%**
C1	42.36 c	25.35 c	30.44 a	30.01 b	4.01 a	7.58 a	3.93 ab
C2	45.18 a	27.22 a	24.71 c	25.74 c	3.91 a	7.19 b	4.11 a
C3	43.09 c	25.61c	29.38 a	31.49 a	3.93 a	7.17 b	3.88 b
C4	44.13 b	26.18 b	27.67 b	30.02 b	3.98 a	7.48 a	4.14 a
SD±	0.8068	0.5075	1.1980	1.2809	0.4360	0.2621	0.2159
Humic Acid Doses kg ha^{-1} (H.A.)							
H.A.1	42.05 c	24.63 d	26.76 c	27.14 d	3.62 b	6.93 c	3.51 c
H.A.2	42.72 c	25.36 c	27.10 c	28.32 c	3.71 b	7.24 b	3.86 b
H.A.3	44.20 b 45.78	26.66 b	28.12 b	30.30 b	4.13 a	7.54 a	4.24 a
H.A.4	a	27.70 a	30.23 a	31.50 a	4.37 a	7.71 a	4.44 a
SD±	0.8743	0.7192	0.7669	1.0523	0.2384	0.2920	0.2648
Interactions (C × H.A.)							
C1 × H.A.1	40.30	23.74	29.17	27.87	3.61	7.46	3.07e
C1 × H.A.2	41.30	24.76	29.27	29.37	3.71	7.44	3.64cde
C1 × H.A.3	43.20	25.71	30.87	30.63	4.25	7.62	4.40ab
C1 × H.A.4	44.60	27.17	32.45	32.16	4.47	7.82	4.60a
C2 × H.A.1	43.70	25.73	23.87	23.74	3.62	6.41	3.83bcd
C2 × H.A.2	44.30	26.69	23.82	24.02	3.64	7.10	3.82bcd
C2 × H.A.3	45.92	27.77	24.80	26.95	3.98	7.52	4.27abc
C2 × H.A.4	46.77	28.70	26.37	28.26	4.39	7.74	4.52ab
C3 × H.A.1	40.97	24.71	27.99	28.97	3.56	6.69	3.31de
C3 × H.A.2	42.07	24.54	27.98	30.45	3.63	7.09	3.94abcd
C3 × H.A.3	43.70	26.01	29.41	32.55	4.22	7.52	4.08abc
C3 × H.A.4	45.62	27.17	32.16	34.00	4.32	7.39	4.19abc
C4 × H.A.1	43.17	24.33	32.4	28.00	3.70	7.19	3.83bcd
C4 × H.A.2	43.22	25.47	27.33	29.45	3.85	7.32	4.03abc
C4 × H.A.3	43.97	27.16	27.39	31.07	4.09	7.65	4.23abc
C4 × H.A.4	46.15	27.76	29.94	31.57	4.30	7.79	4.48ab
SD±	2.3852	1.9621	2.0920	2.8706	0.6502	0.7967	0.7224
F value							
C	0.0000**	0.0000**	0.0000**	0.0000**	0.8821**	0.0016ns	0.0092**
H.D	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
C * H.A	0.4107ns	0.6497ns	0.2647ns	0.7396ns	0.8079ns	0.1445ns	0.0166*
C.V (%)	2.10	2.98	3.87	3.77	6.32	4.16	6.92

Dry matter (DM) %

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest dry matter % was recorded by LG Turuva cultivar (31.49%) and lowest dry matter % was recorded by Hido cultivar (25.74%). Highest dry matter % was recorded by humic acid dose 10 kg ha^{-1} (31.50%) and lowest starch % was recorded by humic acid dose 0.0 kg ha^{-1} (27.14%) (*Table 5*). The moisture content of forage crops differs due to crop species, crop physiological and seasons of the year. Therefore, results expressed on a dry matter basis

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which is the most beneficial factor to perform assessments (Fulgueira et al., 2007). Dry matter ratios were between 28.80 to 32.30% (Kaplan et al., 2016) and from 28.54 to 33.47% which were somewhat near to expected ratios (about 30%) (Keady, 2005). Ball et al. (1996) mentioned that different varieties' dry matter and protein composition might vary due to plant genetics, the proportion of leaves, stems and stalks, maturity stage, temperature, and fertilization.

Silage pH

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest pH was recorded by M17GS01 cultivar (4.01) and lowest pH was recorded by LG Turuva cultivar (3.93). Highest pH was recorded by humic acid dose 10 kg ha^{-1} (4.37) and dose 5 kg ha^{-1} (4.13) and lowest pH was recorded by humic acid dose 0.0 kg ha^{-1} (3.62) ad dose 2.5 kg ha^{-1} (3.71) (*Table 5*). Kaplan et al. (2016) silage pH found were between 3.92 to 4.02 which were within the ideal value for corn silage. Low pH ranges show soluble sugars contain acidified atmosphere with fermentation (Islam et al., 2012). Low pH levels from 3.86 to 4.02 are considered as accumulation of lactic acid indicator provided that silage quality conservation and then leading the microbial activities (McDonald et al., 1991). Increasing water levels dissolved carbohydrates increase lactic acid production and decrease pH levels by increament of lactic acid (Bates, 2009).

Crude protein (CP %)

Statistical analysis revealed that there were a highly significant differences among cultivars, humic acid doses, and there were no significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest CP % was recorded by M17GS01 cultivar (7.58%) and PR 31Y43 cultivar (7.48%), lowest CP % was recorded by LG Turuva cultivar (7.17%) and Hido cultivar (7.19%). Highest CP % was recorded by humic acid dose 5 kg ha^{-1} (7.54%) and dose 10 kg ha^{-1} (7.71%) while lowest CP % was recorded by humic acid dose 0.0 kg ha^{-1} (6.93%) (*Table 5*). Safdarian et al. (2014) found CP% were between 4.2 to 7.2%, Kaplan et al. (2016) found between 6.41 to 7.70%, Karasu (2012) found between 10.13 to 12.5%, Özata et al. (2018) found between 6.8 to 7.9%, and Daur et al. (2013) found between 8.0 to 11.5%. ADF and NDF ratios increment could lead to crude protein decrease (Hargreaves et al., 2009). Additionally, ADF and NDF ratios increment make hard digestion of forage and result in crude protein decrease, production of gas, metabolic energy and content of digestible organic matter (Kamalak et al., 2011).

Ash %

Statistical analysis revealed that there were highly significant differences among cultivars, humic acid doses, and there were significant differences among the interactions of cultivars and humic acid doses (*Table 5*). Highest ash % was recorded by Hido cultivar (4.11%) and PR 31Y43 (4.14%) while the lowest ash % was recorded by LG Turuva cultivar (3.88%). Highest ash % was recorded by humic acid dose 10 kg ha^{-1} (4.44%) and dose 5 kg ha^{-1} (4.24%) while lowest ash % was recorded by humic acid dose 0.0 kg ha^{-1} (3.51%). Highest CP % interaction value was recordrd by M17GS01 cultivar with humoc acid dose 10 kg ha^{-1} (4.60%) and lowest CP % was recorded by M17GS01 cultivar with

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humic acid dose 0 kg ha^{-1} (3.07%) (*Table 5*). Safdarian et al. (2014) found ash % were between 1.5 to 2.2 % and Kaplan et al. (2016) found between 5.91 to 6.81 %. Our findings are within acceptable range and disagree with Safdarian et al. (2014) and Kaplan et al. (2016). Ash contains nutrient elements such as P and K (Baranauskiene et al., 2003).

Conclusion

The production and intake of corn fodder have commonly greater than before as a result of its great energy importance. Improving corn yield involves strategic conduct of agronomic practices and advanced plant improvement methodologies. To accomplish this, selecting cultivars with high yield, coupled with a keen focus on maximizing the genetic potential of cultivars under varying environmental conditions. Characters of plants breeding for silage corn are: flowering duration, green fodder yield, and dry matter yield at harvest are observed as determinants for the period of selection. The maturity period, green fodder yield, and yield of dry matter are significantly affected by environmental conditions. Our research aimed to determine the effect of humic acid doses application on forage yield and yield components of corn cultivars. LG Turuva cultivars were best for recording the highest fresh silage yield. LG Turuva and M17GS01 cultivars recorded the Highest dry matter yield and early flowering. Humic acid application of 10.0 kg/ha^{-1} affects green fodder yield, yield of dry matter, and control recorded earliness of flowering. The comparison of interaction between corn cultivars and humic acid fertilizer doses: M17GS01 and LG Turuva cultivars had a great response with 10.0 kg/ha^{-1}. Humic acid fertilizer doses recorded high fresh silage yield and dry matter yield. M17GS01 and LG Turuva cultivars with 0.0 kg/ha^{-1} humic acid fertilizer doses recorded the earliest flowering. Further research is required on application of humic acid fertilizer dose and associating it with doses and a wide range of corn cultivars. Therefore, its application is recommended for corn production.

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