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ORIGINAL RESEARCH ARTICLE

Changes in growth parameters and forage quantity and quality of corn harvested at different developmental stages

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ABSTRACT

Due to the different agricultural practices such as second cropping or more for the increase product obtained from the areas of suitable climate, some differences in harvesting stages of plants have been occurred. The study was carried out in the Menemem location of Izmir in the coastal Aegean region of Turkey under Mediterranean climate in 2018 and 2019 to determine the performance of corn cultivars in different maturity stages. Seven varieties of corn (Everest, Aga, Kilowatt, Burak, Samada-07, P30B74 and P31Y43) were harvested at 3 different growth stages (silking, end of milk and dough stages) to determine the changes in some parameters of growing, forage quantity and quality. The highest average of dry forage yield (24159 kg ha^{-1} average of years) was determined at the third harvest date. The maximum cob rate was also measured at the third harvest date, but the maximum leaf and stalk rates were measured at the first harvest date. The average protein rate decreased throughout the growing period while ADF and NDF increased. Almost all of the varieties were found to have large leaf areas. The Burak variety came to the fore due to its long length and relatively thick stalk features and high green and dry yields. Moreover, P31Y43 was determined to have a high quality in addition to high green and dry grass yields. Therefore, the Burak and P31Y43 can be suggested in terms of high parameters both quantity and quality under different crop conditions for increase production.

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INTRODUCTION

Currently, it is necessary to meet the feed needs of livestock culture to in turn meet the food needs of the rapidly increasing human population (Odegard and Voet, 2014). The most important need for sustainable livestock production is feed. Feed also constitutes the greatest expense of ruminant production systems (Charmley, 2001). Some affordable agricultural products (corn and cake of soybean or sunflower, etc.), which are also used as livestock feed, could be purchased from abroad until recently (Anonymous, 2019); today (during the pandemic), these items may not be as cheap and readily available as they used to be (Elleby *et al*., 2020). Moreover, it is predicted that the shortage and scarcity of some products may increase with the continuation of the pandemic. These events have already increased feed cost, which was already one of the biggest expenses in production (Vinnari and Tapio, 2009) and continues to increase. Satisfying demand without increasing costs can only be possible by increasing our own agricultural production. However, it does not seem possible to increase the agricultural area for many reasons, such as unplanned construction and erosion. By the most optimistic estimate, even if the agricultural areas are stable (not changing), this increase in production can only be achieved by agricultural practices such as production planning (two or more products) that increase productivity and provide higher production per unit area (Koca and Erekul, 2016).

Because it provides higher quality and especially has higher energy feed for livestock in addition to high yield performance, corn silage contributes significantly to ruminant rations (Tas, 2020). For these reasons, corn is the top crop in the world in terms of production amount, and its use in livestock nutrition is increasing daily (Kusaksız, 2010). The crop can be included in many different production plans. In particular, the Mediterranean climate prevailing in some regions allows effective utilization of corn in these agricultural areas. The existence of a long and hot production period in the coastal regions dominated by the Mediterranean climate allows the number of products to be increased as far as irrigation water allows. Some producers in zones that require high levels of feed for livestock production can produce corn as the second crop after winter fodder crops. Then, corn can be produced again as the third product and used as silage or green grass.

In general, it is known that approximately 50% of the dry matter yield of corn for silage comes from green parts and 50% from cobs (Geren, 2014). Growing corn for forage in combination with other crops in agricultural areas with suitable conditions means that the corn harvest can be done at different growth stages of the plants. This situation may be considered important in terms of the amount of feed in the beginning. However, the presence of fully developed cobs in the feed mixture is important in terms of the quality and quantity of feed (Oliveira *et al*., 2017). For many years, corn varieties with high grass yield capacity have been used for higher grass yield regardless of the grain yield capacity or the feed quality. The aim of this study was to exhaustively determine the changes in growth parameters and not only forage quantity but also the quality of corn silage at different harvest dates that may occur as a result of different cultivation systems, such as second crops or various cropping conditions, for increasing production.

MATERIALS AND METHODS

Production conditions

This study was carried out under standard crop production conditions in a typical Mediterranean climate with warm and dry summers and warm and rainy winters at the Aegean Agricultural Research Institute location of Izmir, Turkey throughout 2018 and 2019. The trial area, 11 m above sea level, consisted of alluvial soils deposited by rivers at the Aegean Agricultural Research Institute, Menemen Izmir, Turkey (38°56' N 27°05' E). The physical and chemical properties determined by the analysis of soil samples taken from the 0-20 cm and 20-40 cm depths are given in Table 1. The soil was alkaline with a sandy clay structure and low organic matter content, as shown in Table 1.

Climate data (temperature and precipitation values) for the main crop growing seasons throughout 2018 and 2019 are given in Table 2. In addition, long-term averages over the period are given.

Table 2 shows that the monthly average temperature values were close to the long-term average temperatures in 2018 and 2019. Moreover, it was noteworthy that the amount of precipitation in April and May was much lower than the average of many years. During the study (both 2018 and 2019), the average rainfall in June was much higher than the average of many years. Although there was a remarkably high precipitation rate in July 2019, rainfall was almost nonexistent in July 2018. Seven hybrid corn varieties named Kilowatt, AGA, Burak, Samada-07, Everest, P31Y43 and P30B74 (FAO 700-750) were used as materials for the experiment. These corn varieties are highly adapted to Mediterranean climate conditions from multiple aspects. Moreover, the varieties present relative tolerance to extremely hot and dry conditions.

The field experiment was conducted in a randomized block design with 3 repetitions under the main crop production conditions. Trial parcels consisted of 8 rows that were 7 m long, and the plant number of the parcels was determined to be 8 in m2. For data measurements (plant height, stalk thickness, forage yield and dry matter of stalks, cobs and leaves) performed in the study, the first and eighth rows were left out of the trial in all parcels consisting of 8 rows. The planting and emergence dates were recorded as April 5, 2018 and April 7, 2019 and as April 13, 2018 and April 15, 2019. Corn cultivars were harvested throughout various plant growth stages. The first harvest was made during the silking period after tasseling (17.06.2018 - 20.06.2019). The second harvest was performed near the end of the milk stage of corn (08.07.2018 - 10.07.2019), and the last harvest was performed (24.07.2018 - 29.07.2019) near the end of the dough stage (1/2 milk line).

Fertilization included 250 kg ha^{-1} pure nitrogen (N), 100 kg ha^{-1} pure phosphate (P) and 100 kg ha^{-1} pure potassium (K) throughout the vegetation period of corn. Before planting, 100 kg ha^{-1} pure N, P and K was provided by applying 15-15-15 composite fertilizer (approximately 667 kg ha^{-1}). The other half of the nitrogen fertilizer (remaining from fertilizer application before planting) was applied as calcium-amended ammonium nitrate (approximately 577 kg ha^{-1}) when corn plants ranged from the six- to eight-leaf growth period. Irrigation was performed with the drip irrigation method. Irrigation frequencies were determined by considering information such as the plant growth stage, soil moisture content, soil capacity and soil permeability. Under conventional agricultural conditions, standard spraying was performed to combat diseases, pests and weeds.

Table 1. Physical and chemical properties of trial soils.

Soil depth (cm)	Sand (%)	Clay (%)	pH	Total salt (%)	Lime (%)	Organic matter (%)
0-20	36.40	16.0	7.7	0.046	4.7	1.28
20-40	38.22	16.6	7.8	0.050	4.8	0.90

Table 2. Temperature and precipitation values of the years and long years average.

Months	Temperature (°C)		Precipitation (mm)		Long term	
	2018	2019	2018	2019	Temperature	Precipitation
April	18.3	15.1	3.8	57.6	15.0	42.4
May	21.7	20.5	16.0	3.6	20.0	27.4
June	23.1	26.3	74.4	27.6	24.7	8.6
July	25.1	27.0	0.0	20.6	27.0	2.4
August	27.9	28.6	0.8	0.0	26.5	2.7

Measurements

Plant height and stalk thickness: At all three harvest times (silking, late milk and late dough stages), plant height values were measured (cm) from the soil surface to the top of the plants (to the top of the corn tassel). Similarly, stalk thickness was measured (in internode under cob) with an electronic caliper at the harvest times.

Forage and dry grass yields: A row of each of the corn varieties was harvested by cutting from the soil surface (removed from the beginning and the end) during every harvest time. The obtained plants were immediately weighed, and the forage yield value was determined. Subsequently, samples taken from these plants were dried in an oven (48 hours or until completely dry at 70°C, Perry and Compton, 1977). The dried samples were weighed and considered the total yield. Then, the dry grass yield was calculated.

Protein rate, acid detergent fiber (ADF) and neutral detergent fiber (NDF): Silage quality analyses (protein, ADF and NDF) were performed in samples from parcels of different varieties at the three harvest times with an NIRS-FT (Bruker MPA) instrument. Samples with a depth of 2.8 cm, approximately 9 cm in diameter, were placed in the chamber of the instrument for measurements, and analyses were performed (Gislum *et al*., 2004).

Growth parameters

Total biomass and dry matter of plant parts: Three plants were randomly selected from the rows and taken as samples for forage and dry grass yield measurement at each harvest time and were weighed by shredding (stalk, leaf and cob). The weight of the tassel was included in the weight of the stalk; similarly, the weight of the cob leaves was also included in the weight of the leaves. Therefore, the average total biomass of the plant parts was determined at each harvest time. Then, the samples (plant parts) were dried in an oven (48 hours at 70°C, Perry and Compton, 1977). Thus, the dry weight averages of the plant parts were determined based on the results obtained.

Leaf area index (LAI): The LAI has been defined as the rate of the total area of leaves present in the vertical projection of the unit soil surface to the soil area (Maddoni and Otegui, 1996; Colomb *et al*., 2000). LAI values were calculated with the third formula (Loecke *et al*., 2004) after the leaf areas of the plants were measured in accordance with the formula mentioned in the literature (first and second) at each harvest date (Birch *et al*., 2003).

Leaf area rate (LAR): The LAR can be defined as the leaf area per unit plant weight (Loecke *et al*., 2004). LAR calculations were made with the formula mentioned in the literature.

Net assimilation rate (NAR): NAR was defined as a value that shows the capacity of the plant to produce new dry matter from its own leaf area. The NAR was calculated using the formula mentioned in the literature (Hunt *et al*., 2002).

Relative growth rate (RGR): The RGR can be defined as the dry matter increase of the plant per unit time. It has been reported that the RGR can be calculated according to the formula mentioned in the literature (South, 1995).

Statistical analysis

To determine the effects of the different harvest dates on the forage and dry grass yields, quality parameters and morphological features of the corn hybrids, the values obtained from the study were analyzed statistically with a randomized block design with three replications. ANOVA was applied to examine the differences among harvest dates, cultivars and the interactions between the dates and study years. Significant differences between the means of the replications were tested using Fisher's least squares difference (LSD) method (Steel and Torrie, 1980). Plant growth parameters (total biomass and dry matter of plant parts and LAR, NAR and RGR) were also evaluated as shown in the Figures 1-5.

RESULTS AND DISCUSSIONS

Plant height and stalk thickness

During the silking period, the P30B74 and burak varieties had plant heights above the average of years (277.8 cm and 275.6 cm in the first year and 277.4 cm and 265.0 cm in the second year, respectively). Samada-07 and Aga were also added to this group in the late milk stage (288.0 cm, 295.0 cm, 289.9 cm, 291.5 cm in the first year and 280.5 cm, 292.3 cm, 289.2 cm, 290.9 cm in the second year, respectively). Burak, Samada-07 and Aga had heights above the averages of the years in the late dough period, which was determined at silage harvest maturity (280.4 cm, 280.8 cm, 279.1 cm in the first year and 272.2 cm, 282.0 cm, 277.3 cm in the second year, respectively). The Burak variety stood out for its high plant height at all three harvest times of the study.

Table 3. Plant height, stalk thickness, forage yield and dry-grass yield obtained from varieties at growth stages (harvest dates).

Growth stages	Varieties	Plant Height (cm)		Stalk Thickness (mm)		Forage yield (kgha^{-1})		Dry-grass yield (kgha^{-1})	
		2018	2019	2018	2019	2018	2019	2018	2019
Silking	Kilowat	245.4	256.3	26.2	25.9	43964	59717	8019	8504
	P31Y43	256.6	255.2	25.1	25.8	44116	58537	7543	9992
	P30B74	277.8	277.4	24.8	24.7	41431	55166	10112	10239
	Everest	238.3	231.9	27.6	27.2	42771	53448	7622	9277
	Burak	275.6	265.0	25.6	25.7	62511	62550	11930	10641
	Samada-07	260.7	256.5	25.3	24.4	46163	48873	8614	8393
	Aga	256.8	254.1	25.6	25.1	56263	54540	10237	10033
	Average	258.7	256.6	25.7	25.5	48174	56119	9154	9583
Late milk stage	Kilowat	266.6	279.1	24.3	25.0	54031	59579	15210	17858
	P31Y43	277.5	279.8	23.2	23.6	65632	68253	18445	18686
	P30B74	288.0	280.5	22.9	23.4	72341	57408	20904	17587
	Everest	249.1	240.8	26.0	26.7	59763	72322	15764	37663
	Burak	295.0	292.3	25.3	28.7	73388	86410	19979	22583
	Samada-07	289.9	289.2	24.6	24.5	61150	67145	18715	17456
	Aga	291.5	290.9	24.1	24.9	71030	77006	19441	17335
	Average	279.7	278.9	24.3	25.3	65334	69732	18351	21310
Late dough stage	Kilowat	260.7	275.2	23.1	26.2	59238	65429	19933	21952
	P31Y43	268,4	274.2	22.4	22.5	68667	66476	24208	23280
	P30B74	266.5	268.3	22.1	21.0	71143	63714	23925	21086
	Everest	247.7	242.7	24.3	25.1	66096	62762	22115	22258
	Burak	280.4	272.2	23.9	24.1	71333	68571	23602	36521
	Samada-07	280.8	282.0	24.0	22.5	58667	61238	21494	33601
	Aga	279.1	277.3	23.1	22.4	71076	61048	23196	21054
	Average	269.1	270.3	23.3	23.4	66603	64177	22639	25679
LSD Cul. (0.05)		ns		ns		6492		ns	
LSD H.D. (0.05)		ns		ns		4250		ns	
LSD Cul.*H.D. (0.05)		9.09		1.14		ns		3669	

*: 0.05, **: 0.01 significant, ns: no significant, Cul.: cultivar, H.D.: harvest date.

It was determined that the average stalk thickness decreased throughout the developing period in both years, as shown in Table 3. Kilowatt and Everest varieties (26.2 mm and 27.6 mm in the first year and 25.9 mm and 27.2 mm in the second year, respectively) showed values above the yearly averages on the first harvest date according to stalk thickness analysis. However, the plant height averages of the cultivars were not as high as expected (relatively short). Everest and Burak varieties (26.0 mm and 25.3 mm in the first year and 26.7 mm and 28.7 mm in the second year, respectively) came to the forefront at the second harvest time of the study. Moreover, these varieties also gave the highest averages (24.3 mm and 23.9 mm in the first year and 25.1 mm and 24.1 mm in the second year, respectively) in the late dough stage of both years. In particular, the Burak variety can be defined as both being tall and having thick stalks. It has been emphasized that plant height and stalk thickness are important yield parameters (Ilker, 2011). Tall plant height is a desirable feature in silage varieties for a high green grass yield. Thinner stalks are expected as the plants grow longer. Therefore, high plant height may cause thinning of plant stalks. As a result, tall varieties may sometimes have difficulty standing upright because they do not have sufficient stalk thickness, and they might fallen over in the field before harvest (Dahiya *et al*., 2018). The Burak variety showed promising results with high values for both features.

Forage and dry grass yields

The average forage yield increased almost throughout the growing period (first, second and third harvests). Forage yield increased from the first harvest to the second in both years. However, yields did not increase similarly in the late dough period. Although the average in the third harvest showed a limited increase in the first year of the study, there was a significant decrease in the second year. Burak gave higher values (62511 kg ha^{-1} in the first year and 62550 kg ha^{-1} in the second year) than the average of the silking stage in both years. While the Aga variety showed high forage yield values in the first year, the Kilowatt and P31Y43 varieties showed the second highest values at the first harvest date. Burak and Aga (73388 kg ha^{-1} and 71030 kg ha^{-1} in the first year and 86410 kg ha^{-1} and 77006 kg ha^{-1} in the second year, respectively) showed above average values in the late milk stage. Furthermore, Burak and P31Y43 showed (68667 kg ha^{-1} and 71333 kg ha^{-1} in the first year and 66476 kg ha^{-1} and 68571 kg ha^{-1} in the second year, respectively) high values in the late dough period.

The average dry grass increased throughout the growing period. In both years, P30B74, Burak and Aga (10113 kg ha^{-1}, 11930 kg ha^{-1}, 10237 kg ha^{-1} in the first year and 10239 kg ha^{-1}, 10641 kg ha^{-1}, 10033 kg ha^{-1} in the second year, respectively) showed high averages at the first harvest. Moreover, Burak also gave high averages at the second and last harvest dates of both years (19979 kg ha^{-1} and 23602 kg ha^{-1} in the first year and 22583 kg ha^{-1} and 36521 kg ha^{-1} in the second year, respectively). The cost of obtaining feed is one of the most important expenses in ruminant production systems (Siddque *et al*., 2015). Therefore, the feed cost can sometimes account for more than 60 or even 70

Table 4. Leaf area index, protein, ADF and NDF obtained from varieties at growth stages (harvest dates).

Growth stages	Varieties	Leaf Area Index ($m^2 m^{-2}$)		Protein (%)		ADF (%)		NDF (%)	
		2018	2019	2018	2019	2018	2019	2018	2019
Silking	Kilowat	3.90	3.85	12.8	12.6	35.4	34.9	36.3	35.3
	P31Y43	3.76	4.42	12.5	11.9	35.1	33.3	38.0	33.4
	P30B74	5.13	5.75	10.9	9.7	35.4	31.6	46.7	46.7
	Everest	4.12	4.74	12.7	12.9	35.3	35.7	35.7	35.9
	Burak	5.61	5.06	11.7	11.3	35.1	33.9	44.0	44.0
	Samada-07	4.88	4.77	12.3	12.1	34.9	34.4	41.2	41.6
	Aga	5.22	5.22	12.5	12.6	35.5	35.7	42.6	43.2
	Average	4.66	4.83	12.2	11.9	35.2	34.2	40.6	40.0
Late milk stage	Kilowat	3.99	4.25	8.9	9.1	37.0	37.8	46.1	40.0
	P31Y43	5.30	4.54	9.3	9.3	36.8	36.7	42.8	37.6
	P30B74	5.86	5.63	8.9	9.0	36.7	36.9	47.8	47.8
	Everest	5.16	5.24	9.2	9.2	37.1	37.3	40.6	40.3
	Burak	5.13	5.90	8.8	7.9	37.1	33.0	46.5	46.5
	Samada-07	5.14	4.97	9.2	9.3	36.7	37.2	44.6	45.0
	Aga	6.06	5.25	8.9	8.9	36.6	36.5	45.9	46.6
	Average	5.23	5.11	9.0	9.0	36.9	36.5	44.2	43.4
Late dough stage	Kilowat	3.86	3.85	8.8	9.2	37.1	38.9	52.5	51.1
	P31Y43	4.96	4.30	9.0	8.7	36.7	35.5	52.9	46.6
	P30B74	5.95	5.17	8.5	8.4	36.8	36.2	58.0	58.0
	Everest	5.47	4.86	8.6	8.6	37.1	37.2	50.7	50.3
	Burak	4.68	5.23	8.6	8.7	36.8	37.0	54.3	54.3
	Samada-07	4.95	4.42	8.7	8.8	36.8	37.0	52.3	52.8
	Aga	4.36	4.41	8.6	8.9	36.8	38.0	53.7	54.5
	Average	4.89	4.61	8.7	8.8	36.9	37.1	53.5	52.5
LSD Cul. (0.05)		0.37		ns		0.7		ns	
LSD H.D. (0.05)		0.24		ns		0.5		ns	
LSD Cul.*H.D. (0.05)		0.64		0.4		ns		2.2	

*: 0.05, **: 0.01 significant, ns: no significant, Cul.: cultivar, H.D.: harvest date.

percent of the annual expenses of the business. For this reason, regular feeding of livestock and ensuring profitability is only possible with the production of forage plants with high dry matter contents (Chia *et al*., 2019). In this study, the Burak variety stood out due to its highest dry grass yield among all three varieties. Although Burak variety gave the highest green grass yield with P31Y43 (the difference between varieties was insignificant), Burak did not show high dry grass yields in either year. The P31Y43 variety displayed high dry grass values in the second and third harvests in the first year of the experiment, while it did not show the expected performance in the second year.

Protein rate, ADF and NDF

Protein rate values decreased throughout the growing period. At the beginning of sampling (first harvest), high protein rate averages of Kilowatt, Everest and Aga were noticeable in both years (12.8%, 12.7%, 12.5% in the first year and 12.6%, 12.9%, 12.6% in the second year, respectively). At the second harvest (late milk stage), P31Y43, Everest and Samada-07 gave high protein rate averages (9.3%, 9.2%, and 9.2% in the first year and 9.3%, 9.2%, and 9.3% in the second year, respectively). Finally, at the silage harvest (late dough stage), the Kilowatt variety (8.8% in the first year and 9.2% in the second year) yielded a higher protein content than the average of both years as in the first harvest. The protein rate is an important feed quality parameter (Demira *et al*., 2021). Protein sources can increase production through increased intake of protein supplies (Mahmud and Rahouma, 2021). The Kilowatt cultivar showed the highest protein rate values at both the first and third harvests in both years. Although the rate decreases proportionally as the harvest time is delayed, its amount can be expected to increase. In addition, it is associated with digestibility (Caetano *et al*., 2011; Ferreira and Teets, 2017). Therefore, together with a higher dry matter rate, the protein rate will mean a higher protein amount. It would be appropriate to evaluate this parameter in parallel with dry matter and digestibility in the future.

As shown in Table 4, the ADF and NDF averages almost continuously increased throughout the growing period in both years. The ADF averages of the second and third harvests were equal in the first year. The ADF values of the kilowatt and Everest varieties (35.4%, 35.3% at the first stage, 37.0%, 36.7% at the second stage, 37.1%, 36.8% at the last stage in the first year and 34.9%, 35.7% at the first stage, 37.8%, 37.3% at the second stage, 38.9%, 37.2% at the last sampling stage in the second year, respectively) were higher than the average harvest time at the three growing stages. The NDF values of P30B74, Burak, Samada-07 and Aga (46.7%, 44.0%, 41.2%, 42.6% at the first stage, 47.8%, 46.5%, 44.6%, 45.9% at the second stage, 58.0%, 54.3%, 53.7% at the last sampling stage in the first year and 46.7%, 44.0%, 41.6%, 43.2% at the first stage, 47.8%, 46.5%, 45.0%, 46.6% at the second stage, 58.0%, 54.3%, 52.8%, 54.5% at the last sampling stage in the second year, respectively) were higher at almost all harvest times in both years (except Samada-07 at the last sampling stage in the first year). The quality of corn silage depends on its availability in the rumen, which can be assessed by the energy content or the content of digestible nutrients (Powell *et al*., 2013). The ADF and NDF values, which provide information about structural carbohydrates in plants and about the approximate energy level of the feed, increase feed injury by promoting dry matter consumption in ruminants. Moreover, these parameters protect livestock against metabolic diseases by increasing the pH. The ADF and NDF values should be within certain limits for corn silage (ADF 25% - 35%, NDF 35% - 45%), since excessive amounts may cause digestive problems (Keles and Cıbık, 2014). The ADF and NDF values of almost all varieties (except P30B74 and Aga) in the first harvest period were within the quality limits in both years of the study. The values measured in the second and third harvest periods were slightly above the limits. The values of P31Y43, Everest and Samada-07 in the second harvest and only P31Y43 in the third (late dough stage) were as promising. The high-quality values (protein rate, ADF and NDF), which were consistent with and above the general averages obtained from P31Y43 and Kilowatt, can be explained by the high rate of cobs on a single plant.

Growth parameters

Total biomass and dry matter of plant parts: The total biomass and dry weight of corn plants measured at harvest times and the values of plant parts (leaves, cobs and stalks) are given in Figure 4 and Figure 5. From the total biomass graph (Figure 4), clearly the stalk weight of the plants was generally high during the silking period. In the same sampling period, while the cob weights of the cultivars were almost nonexistent, leaf weight values ranked second. Burak had the highest biomass which was different (942.7 g) than that of the other varieties. Moreover, the Aga variety (824.4 g) had the second highest value of total biomass, and the difference was also significant. All other varieties gave close values to each other. Throughout the milk stage, the first noticeable response was the rapidly increasing cob weights in all varieties. On the other hand, it can be said that the leaf and stalk values decreased proportionally. Burak and Aga gave the highest biomass values (1217.7 g and 1105.2 g, respectively) at the second harvest time and at the first harvest time, respectively. Moreover, other varieties also showed close values to each other. While the weight of the cobs continued to increase at the late dough stage, it was determined that the stalk and leaf weight values decreased proportionally. The high rate of cobs per plant of the corn varieties must have resulted in high quality values (Onal Ascı and Acar, 2018). Moreover, there were some differences in terms of the biomass increase in the last harvest time compared to that of the first and second harvests. P30B74 gave the highest biomass value (1101.5 g), and that of kilowatt (1094.4 g) was second by a small margin. Burak and Aga, which gave high values in the first and second harvests, did not stand out much in the late dough stage (1062.2 g and 995.1 g, respectively). The biomass weights of both varieties were reduced in this period. This result suggested that these varieties may have completed their vegetation period earlier than others.

The total dry matter graph (Figure 5) shows that the stalk and leaf weights of the plants were high on the first harvest date (silking). In fact, it was determined that almost all varieties (except P30B74) did not have significant cob dry matter data at the silking stage. P30B74 and Burak (173.2 g and 169.7 g, respectively) gave the highest and significantly different values. On the other hand, the Aga variety, which ranked third in total dry weight (151.5 g), was identified as the only variety with no cob weight. Similar to the biomass values, the rapidly increasing cob weights in all varieties at the second harvest time (late milk stage) was noteworthy. P30B74 and Burak gave the highest dry matter values (320.4 g and 325.5 g, respectively). Although Everest showed a proportionally increased highest cob dry weight, it had the lowest total dry weight (262.8 g) in the late milk stage. At the late dough stage, the weight of the cobs continued to increase. Burak and Samada-07 gave the highest and significantly different dry matter values (456.3 g and 413.9 g, respectively). It can be said that as the stalk weight of the varieties increases, the leaf weight values also increase. Other varieties (except kilowatt) gave similar values to each other. This could be attributed to the high dry matter accumulation carried out by the high number of leaves in the case of tall plants.

Leaf area index (LAI): The LAI is given in Table 4. Initially, LAI averages were approximately 4.74 m^2 m^{-2}. The average LAI increased from the first harvest to the second harvest (approximately 5.20 m^2 m^{-2}) and then dropped to approximately 4.75 m^2 m^{-2} at the last harvest date in both years. P30B74, Burak and Aga had high LAI averages (5.13 m^2 m^{-2}, 5.60 m^2 m^{-2}, and 5.22 m^2 m^{-2} in the first year and 5.75 m^2 m^{-2}, 5.06 m^2 m^{-2}, and 5.22 m^2 m^{-2} in the second year, respectively) at the first harvest time, which can be defined as the beginning of the generative period. In both years, P30B74, Everest and Aga were determined to have high LAIs (5.86 m^2 m^{-2}, 5.16 m^2 m^{-2}, and 6.06 m^2 m^{-2} in the first year and 5.63 m^2 m^{-2}, 5.24 m^2 m^{-2}, and 5.25 m^2 m^{-2} in the second year, respectively) at the second harvest time. At the last harvest (late dough stage), the P30B74 and Everest varieties gave the highest averages (5.95 m^2 m^{-2} and 5.47 m^2 m^{-2} in the first year and 5.17 m^2 m^{-2} and 4.86 m^2 m^{-2} in the second year, respectively) in both years. LAI is an important parameter because it gives the size of the leaves (the organ with the highest photosynthetic ability) per unit area (m^2). In general, the P30B74 variety showed high values at all three harvests, while the Everest variety showed high averages at the second and third harvests. For this reason, the varieties were considered. However, a high LAI value does not always indicate that high yields (seed or grass) can be obtained due to the shading effect. In previous a study, it was reported that the LAI value should be between 3.5 m^2 m^{-2} - 4 m^2 m^{-2} and that some negative outcomes may occur at values above these numbers (Konuskan and Kilinc, 2019). At the last harvest time, only the Aga variety was determined to give values (4.36 m^2 m^{-2} in the first year and 4.41 m^2 m^{-2} in the second year) within these approximate limits, and there were values below the limit, such as those of Kilowatt (3.86 m^2 m^{-2} in the first year and 3.85 m^2 m^{-2} in the second year). In light of this information, it is not possible to make a variety recommendation by only comparing the LAI values.

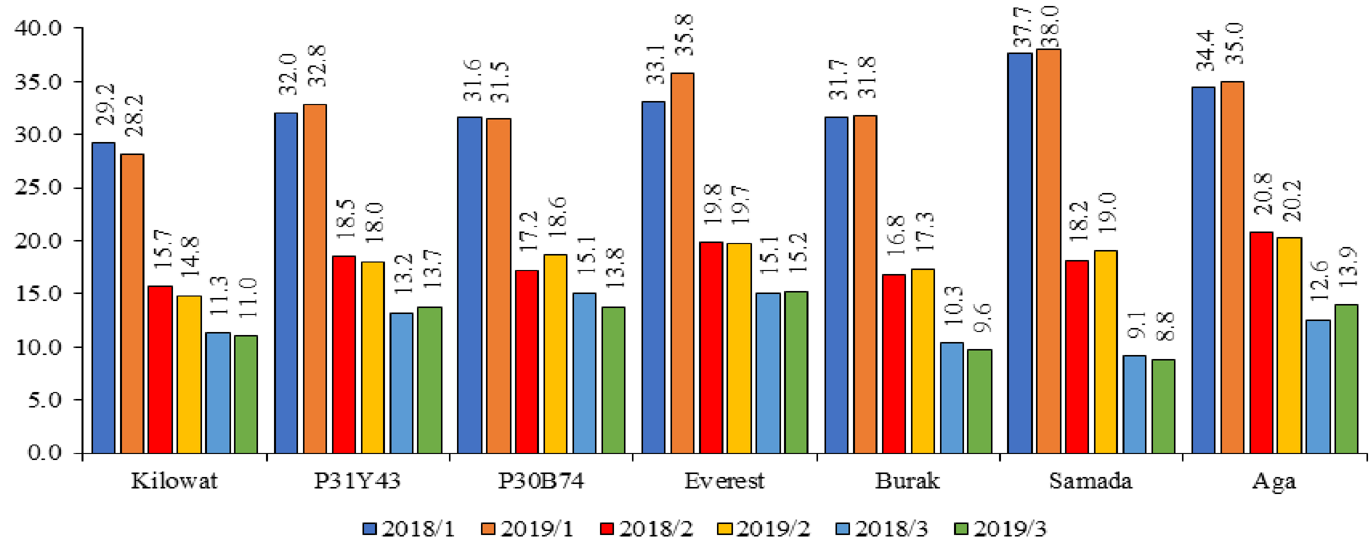

Figure 1. *Leaf Area Rate (m^2 g^{-1}); 2018/1 and 2019/1: silking stage, 2018/2 and 2019/2: late milk stage, 2018/3 and 2019/3: late dough stage.*

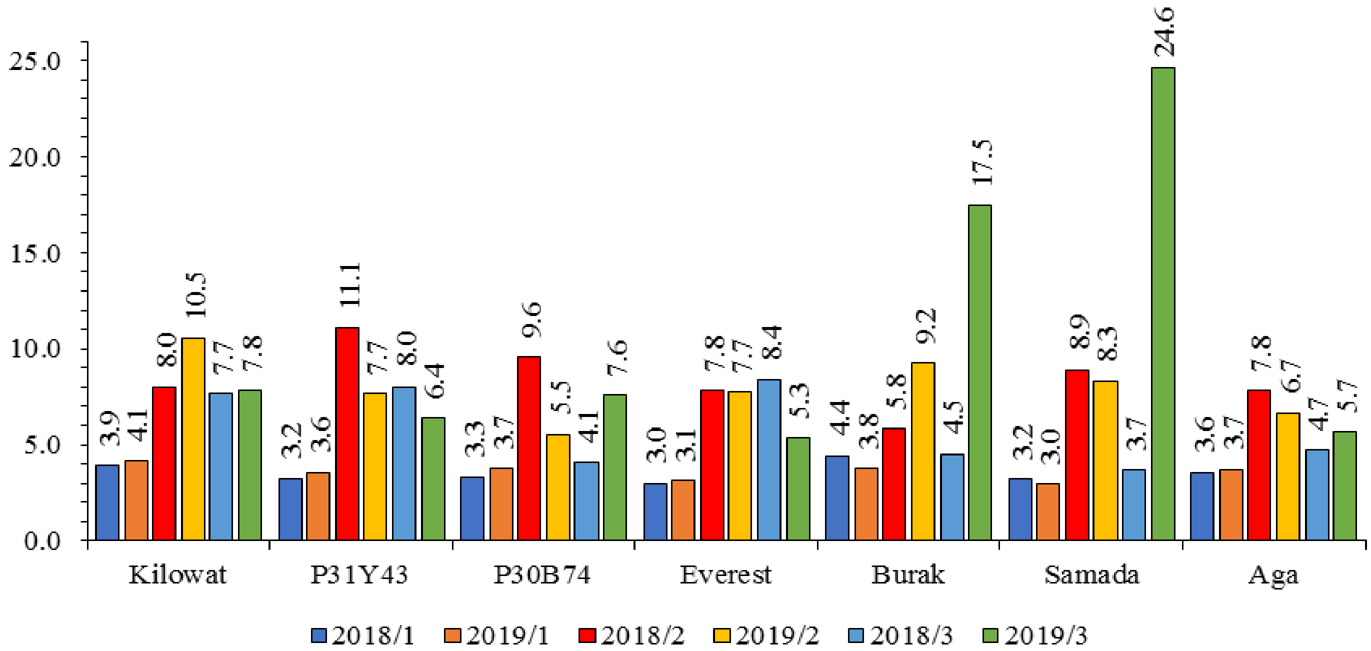

Figure 2. *Net Assimilation Rate (g m^{-2}) $day^{-1;}$ 2018/1 and 2019/1: silking stage, 2018/2 and 2019/2: late milk stage, 2018/3 and 2019/3: late dough stage.*

Leaf area rate (LAR): The calculated LAR values from the varieties in two years of the study are shown in Figure 1. The values decreased throughout the growing period. Everest, Samada-07 and Aga showed high averages (33.1 m^2 g^{-1}, 37.7 m^2 g^{-1}, 34,4 m^2 g^{-1} in the first year and 35.8 m^2 g^{-1}, 38.0 m^2 g^{-1}, 35.0 m^2 g^{-1}, respectively) during the silking period. The cultivars also gave high average LAR values (19.8 m^2 g^{-1}, 18.2 m^2 g^{-1}, and 20.8 m^2 g^{-1} in the first year and 19.7 m^2 g^{-1}, 19.0 m^2 g^{-1}, and 20.2 m^2 g^{-1}, respectively) at the second harvest time (late milk stage). In the late dough stage, high averages were calculated for the P31Y43, P30B74, Everest and Aga varieties (13.2 m^2 g^{-1}, 15.1 m^2 g^{-1}, 15.1 m^2 g^{-1}, 12.6 m^2 g^{-1} in the first year and 13.7 m^2 g^{-1}, 13.7 m^2 g^{-1}, 15.2 m^2 g^{-1}, 13.9 m^2 g^{-1}, respectively). The Everest and Aga varieties stood out on all three harvest dates in terms of the LAR. Moreover, P31Y43 and P30B74 also showed noteworthy values at the silage harvest date (late dough stage). LAR can be defined as the leaf area per unit plant weight (Loecke *et al*., 2004). From another aspect, the LAR value can be used to evaluate the amount of dry matter that the leaves will be able to assimilate (Koca, 2009). As a result, the varieties had higher dry matter increases than leaf areas, especially for the period from the late milk stage to the late dough stage.

Net assimilation rate (NAR): The NAR averages throughout the study are shown in Figure 2. The averages varied between years. NAR averages throughout sampling stages increased continuously in the first year. However, in the second years of the study, the NAR value, which increased from the silking period to the late milk period, decreased in the late dough period. High NAR averages of the Kilowatt, Burak and Aga varieties were determined in both years at the silking stage (4.0 g m^{-2} day-1, 4.4 g m^{-2} day^{-1}, 3.6 g m^{-2} day^{-1}, and 3.6 g m^{-2} day^{-1} in the first and 4.2 g m^{-2} day^{-1}, 3.8 g m^{-2} day^{-1}, and 3.7 g m^{-2} day^{-1} in the second year respectively). Moreover, only Samada-07 gave high NAR values (8.9 g m^{-2} day^{-1} in the first year and 8.3 g m^{-2} day^{-1} in the second year) every two years at the late milk stage. Unlike other sampling stages, large differences were observed in NAR figures obtained from varieties between years in the last sampling period (Figure 2).

The Kilowatt, P31Y43 and Everest varieties (7.7 g m^{-2} day^{-1}, 8.0 g m^{-2} day^{-1}, and 8.4 g m^{-2} day^{-1}, respectively) showed well above average NAR values in the first year. In the second year the varieties showed low NAR values. In contrast, the Burak and Samada-07 varieties showed NAR values (17.5 g m^{-2} day^{-1} and 24.6 g m^{-2} day^{-1}, respectively) almost twice the general average in the second year. NAR reflects how efficient the plant is in producing new dry matter from its own leaf area (Hunt *et al*., 2002). The fluctuation in NAR values determined in the last harvest period between the years may have been due to the unexpectedly high precipitation in June 2019 (Table 2). Moreover, after rainfall in June, higher average temperatures were determined in July and August than the averages of the same months in the first year. Leaf area and dry matter values that directly affected the NAR value were heavily affected by climatic factors. Therefore, this situation is like that described in previous studies, in which the climate parameters changed with different sowing times, locations and multiple years (Popović *et al*., 2018; Singh *et al*., 2020).

Relative growth rate (RGR): The RGR averages throughout the study are shown in Figure 3. The calculated RGR in both years of the study increased from the first sampling period to the second sampling period. However, in both years, the RGR averages decreased on the third sample date (late dough stage). The varieties showed very close values (0.017 g g^{-1} day^{-1} in the first year and 0.016 g g^{-1} day^{-1} in the second year) on the first harvest date (silking) in both years. Everest and Samada-07 had high averages (0.022 g g^{-1} day^{-1} in the first year and 0.021 g g^{-1} day^{-1} and 0.022 g g^{-1} day^{-1} in the second year, respectively) at the late milk stage in two years. RGR values obtained in the late dough stage fluctuated between years, similar to the NAR values calculated in the same stage. The Kilowatt, P31Y43 and Everest varieties had high RGR values (0.012 g g^{-1} day^{-1}, 0.013 g g^{-1} day^{-1}, and 0.015 g g^{-1} day^{-1}, respectively) in the first year, while Burak and Samada-07 had high values in the second year (0.023 g g^{-1} day^{-1} and 0.030 g g^{-1} day^{-1}, respectively). RGR can be defined as the plant dry matter increase per unit time (South, 1995). It was determined that Everest and Samada-07, which came to the fore in the second harvest period, showed high performances in different years during the last harvest period (Everest in the first year and Samada-07 in the second year). It was thought that the differences between years might be due to the different climate conditions of those years (for example, unexpectedly high precipitation in June 2019). The result was in line with some previous studies in which different growth values were measured in different environmental conditions (Goergen *et al*., 2018; Goergen *et al*., 2019).

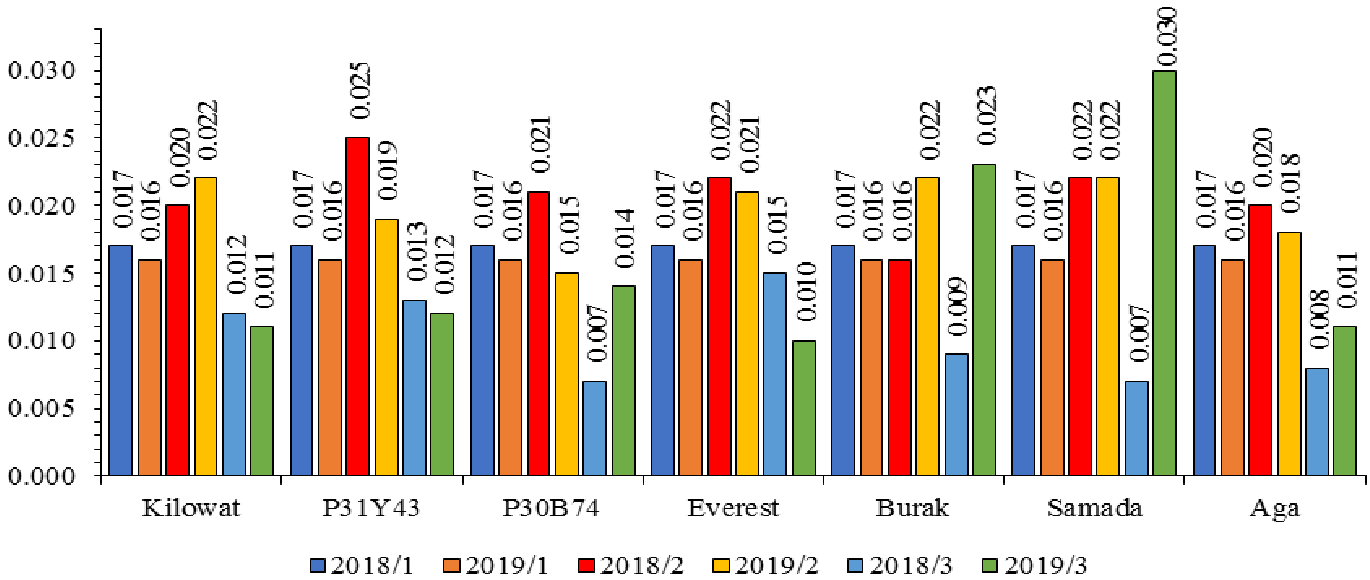

Figure 3. *Relative Growth Rate (g g^{-1}) day^{-1}; 2018/1 and 2019/1: silking stage, 2018/2 and 2019/2: late milk stage, 2018/3 and 2019/3: late dough stage.*

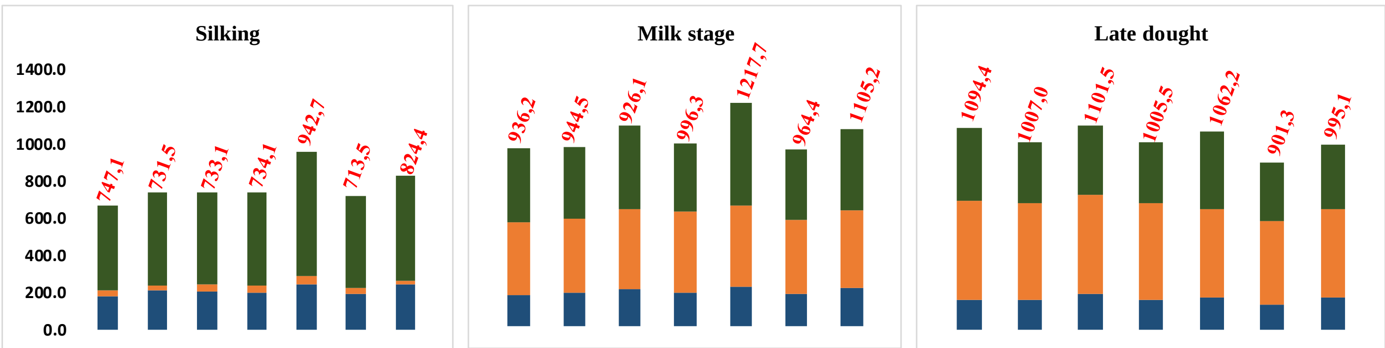

Figure 4. *Total biomass values (g) of corn and plant parts (stalk, cob and leaf) weights from different growing stages (average of 2018 and 2019).*

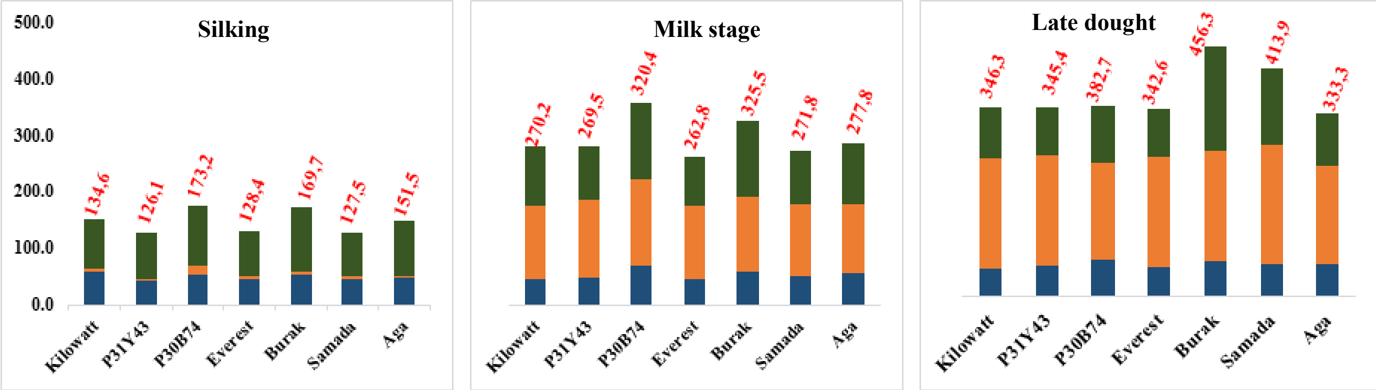

Figure 5. *Total dry matter values (g) of corn and plant parts (stalk, cob and leaf) weights from different growing stages (average of 2018 and 2019).*

Conclusion

The results obtained from the two-year of the study were interpreted in detail.

- According to plant height and stalk thickness averages of the study, we can say that the Burak variety has both tall and thick stalks.
- Burak and P31Y43 varieties stood out in terms of green grass and dry grass yields. While the Burak variety had the maximum dry grass and green grass yields at harvest dates in both years, the P31Y43 variety showed above average values.
- According to the feed quality results examined in the study, the average protein rate decreased during plant growth. The Kilowatt variety came to the fore at the three harvest dates both years (with the rate only declining for the first-year late milk stage). In terms of ADF and NDF values, the P31Y43 variety showed values within the limits required for corn silage. The high-quality values obtained from P31Y43 and Kilowatt may have been due to the high rate of cobs per plant.
- In both years, fluctuations were observed in the total biomass per plant values obtained from the varieties among the harvest dates. The dry weight averages of per plant were not as unbalanced as the biomass values. The Burak variety came to the fore at the three different harvest times, which may have occurred due to the different crop conditions applied to increase production.
- Almost all of the varieties included in the study were found to have large leaf areas. Thus, even in the first harvest period, averages above the desired values were obtained. This situation continued for the later harvest dates. A high leaf area index may cause shading effects.
- The LAR, NAR and RGR values varied greatly over the years. Changes in climate parameters over the years (especially varying monthly precipitation) had a significant impact on the growth parameters. Considering growing parameters at the three harvest dates in both years, the Samada-07 variety performed the best.

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