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Research Article

Yields and Nutritive Values of Different Corn Cultivars

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ABSTRACT

Corn is essential for both humans and animals. The crop is the third most important food crop after rice and wheat. A rise in farming is resulting in a lack of self-sufficiency of high quality forages. Therefore, corn cultivars in Korea must be optimized to increase productivity and yield. A study was conducted in Pyeongchang, South Korea between 2021-2022 to evaluate the characteristics and productivity of three corn cultivars: Kwangpyeongok, AGR 41, and Nero IT. Different varieties of corn were sown in Pyeongchang on April 29 and April 27 of 2021 and 2022, respectively. The productivity and characteristics of the cultivars Kwangpyeongok, AGR 41, and Nero IT were evaluated during the yellowing ripening stage. The characteristics included the leaves, stems, grain, and stover content. Across different corn cultivars, there was no significant difference in stem height, diameter, forage or grain quantity based on an average of two years. Yet, significant differences were noted in the stem heights of all cultivars between 2021 and 2022 (p<0.05). There was a significant difference in the diameters of Kwangpyeongok and Nero IT between 2021 and 2022. A significant difference in forage yield was observed for Nero IT between 2021 and 2022. The yield of grains and forages was higher in 2021 than in 2022, which could be attributed to temperature and precipitation variations. We can conclude from these data that all cultivars in Pyeongchang showed significant productivity and yield, which could be useful to produce nutrient rich silage for livestock.

(Key words: Corn cultivars, Pyeongchang, Productivity, High-quality silage)

Ⅰ. INTRODUCTION

Corn is the third important food crop in the world after rice and wheat and is one of the most essential food sources for humans and animals (FAO, 2020). The demand for these crops is projected to increase by over 3.3 billion tons by 2050. There are 182 million hectares of agricultural land in the world. It is one of the most widely cultivated and utilized cereal crops in the world, with 1.1 billion tons in 2019 (OECD/FAO, 2020). Among other feed crops, corn has the highest total digestible nutrients (TDN) and is called the silver crop. Dairy farms mainly cultivate this crop because of its higher yields and sugar content, making it more suitable for making silage. Korea uses 60% of its total feedstock as whole crop corn and soybeans, and its self-sufficiency rate is only 1%. Therefore, a large proportion of feedstock ingredients must be imported every year (Morgan et al., 1994). According to annual statistics of forage supply for the Rural Development Administration (RDA), corn cultivation area is 13,000 ha in Korea and 228,200 tons of silage was produced in 2018. Due to an increase in farming and a weak base of forage production, the self-sufficiency rate for high quality forage is not enough. Korea is therefore highly dependent on forage imports (MAFRA, 2018). In order to ensure flexibility between domestic production and imports, a key strategy must be developed. Hence, Korean corn varieties were developed in the 1960s. As a beginning, they developed and distributed synthetic varieties. Since the 1970s, hybrid varieties such as waxy corn for snacks (Lee et al., 2018), Topaz' for seeds (Son et al., 2017) and Dacheongok for silage production (Son et al., 2018) have been developed and distributed to farmers. Since then, corn varieties have been developed steadily to meet consumer and producer needs. According to changes in the times and social environment, the priorities of improved traits have changed. A total of 110 corn

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varieties have been registered in the National Seed Resources (KSVS, 2019). Increasing productivity has been achieved by improving resistance to biotic stress, such as diseases and pets, and environmental stress, such as temperature and precipitation.

Over the past three decades (1981-2010), temperatures on the Korean peninsula have increased by plus 1.2℃ and precipitation by 77.6 mm (KMA, 2018). The Representative concentration pathway-8.5 RCP indicates temperatures will rise by 4.7℃ and precipitation will increase by 13.1%, respectively. Increased temperatures have also altered precipitation levels, resulting in abnormal climate conditions that affect all sectors of agriculture (FAO, 2016). Crop failures and variability in yield have already been linked to heat waves, droughts, and heavy precipitation. Researchers have reported the impact of climate change on crop cultivation (Peng et al., 2015; Peichl et al., 2019). A study conducted by Chung et al. (2019) assessed the vulnerability of corn cultivation in the central region of South Korea to climate change. The aim of this study was to determine the characteristics and productivity of three corn cultivars in Pyeongchang region, Korea, which has a slightly lower temperature than middle and south regions.

Ⅱ. MATERIALS AND METHODS

1. Climate conditions of the study area

In Pyeongchang, the most popular city in Gangwon-Do, daily average temperatures range from 10.7℃ to 15.9℃ and from 24.7℃ to 27.3℃ between May and September. In Pyeongchang, August is the hottest month of the year, with average temperatures of 24.7 and 28.3℃ in 2021 and 2022, respectively. The minimum average temperature was 16.4℃ in 2021 and 15.9℃ in 2022, respectively. The cold season started on December 1 and will last until February 28. Throughout the year, Pyeongchang experiences significant precipitation variations. An average precipitation level in April (Sown month) was 60 mm and 48.5 mm in 2021 and 2022, respectively. An average precipitation level in August was 345 mm and 512 mm in April 2021 and 2022, respectively.

2. Experimental design

An experiment was conducted in Pyeongchang, South Korea. The corn was sown in Pyeongchang on April 29 and April 27 of 2021 and 2022, respectively, and harvested on 21 August and 22 September of 2021 and 2022, respectively. Plot size was 12 m^2 (3×4). Planting density for corn was two seeds per rigid row with a space between rows of 75 cm × 20 cm. After the seventh or eighth leaf, the superior plant was kept and the remainder was removed. A plot of 12 m^2 was sown with four rows of 4 M length, each row 75 cm apart from the other. As basal fertilizer, nitrogen (200 kg/ha), phosphorus (150 kg/ha), and potassium (150 kg/ha) were applied per hectare. When the crop was growing between four and six leaves, additional fertilizer nitrogen was applied (Soundharrajan et al., 2023).

3. Data analysis

A variety of corn growth characteristics were evaluated at the yellow-ripening stage using the research analysis criteria for agriculture and science and technology (RDA, 2012) including stem height, stem diameter, ear height, dry matter yield, and total dry matter yield. Climate data, including average temperatures (C), maximum temperatures (Tmax) and minimum temperatures (Tmin), and precipitation, were obtained from Korea Meterological Administration (kma.go.kr). The content of acid detergent fiber (ADF) and neutral detergent fiber (NDF) in forage and grain was determined (Van Soest et al., 1991). The crude protein was determined by the method of AOAC in 1990.

4. Statistical analysis

The experimental data were analyzed using IBM SPSS 27 software. A t-test was used to determine whether there was a statistically significant difference between cultivars. A level of p-value of 0.05 was considered statistically significant.

Ⅲ. RESULTS

1. Meteorological information during 2021 and 2022 in Pyeongchang

Tables 1 and 2 illustrate the temperature and precipitation levels in Pyeongchang for the years 2021 and 2022. Temperatures and precipitation maximums and minimums during the corn sowing and harvesting seasons were recorded. Pyeongchang

Table 1. Meteorological data in Pyeongchang during 2021and 2022

Years	Maximum Average Temperature (℃)					Minimum Average Temperature (℃)				
	April	May	June	July	August	April	May	June	July	August
2021	13.9	17.9	22.5	26.3	25.4	4.3	9.2	14.5	20.1	20.3
2022	10.1	14.3	18.9	23.1	22.2	2.5	2.3	10.1	16.7	15.1

Table 2. Precipitation level in Pyeongchang during 2021and 2022

Year	Precipitation (mm)				
	April	May	June	July	August
2021	60.0	112.5	148.0	247.5	345.0
2022	48.5	8.0	236.0	188.5	512.0

minimum average temperature during the sown period was 4.3 degrees in April 2021 and 2.5 degrees in April 2022. During the sown period, the maximum temperature reached 13.9℃ in April 2021 and 10.1℃ in April 2022. In the years 2021 and 2022, high temperatures were recorded in July (26.3℃ and 23.1℃) and August (25.4℃ and 22.2℃), respectively (Table 1). In 2021 and 2022, the precipitation level during the sown month of April was 60 millimeters and 48.5 millimeters, respectively. August precipitation levels were significantly higher in both years than in previous months (Table 2).

2. Growth characteristic and productivity of different corn cultivars in Pyeongchang region

Different types of corn cultivars, including Kwangpyeongok, AGR-1, and Nero-IT, were sown on April 29 and April 27 in 2021 and 2022. At the ripening stage, stem diameter and height, ear and forage yield, and overall dry matter content were measured on corn cultivars. In the past two years, Kwangpyeongok had an average stem height and diameter of 300 ±7.4 cm and 22.8 ± 2.1 mm, respectively. Kwangpyeongok produced an average of 11,373 ± 3,437 kg of forage yield per hectare and 10,877 ± 3,426 kg of grains per hectare. Kwangpyeongok's total dry matter content was 22,251 ± 1,970 kg/ha (Table 3). The average stem height and diameter for AGR-1 were 295 ± 56 mm and 21.8 ± 2.1 mm over the past two years. AGR-1 yielded an average of 11,592 ± 2,548 kg/ha and 10,938 ± 237 kg/ha. AGR-1 produced a total dry matter content of 22,530 ± 1,970 kg/ha (Table 3). Nero-IT stem height and diameter over the past two years were 281 ± 70 mm and 21.5 ± 1.7 mm, respectively. Nero-IT forage and grain yields

Table 3. Yield of corn of Kwangpyeongok cultivar at the different regions between 2020 and 2021

Cultivars	Year	Height (CM)	Diameter (mm)	Dry matter content (kg/ha)		
				Forage Yield	Grains	Total
Kok	2021	334 ± 20$^{\#}$	24.3 ±2.9	13,804 ± 4,223	13,300 ± 853	27,104±3,566
	2022	267 ± 27	27.5 ±3.2$^{\#}$	8,943 ±2,775	8,454 ± 4,045	17,397±244
	Mean	300 ±7.4^{a}	22.8 ±2.1^{a}	11,373 ± 3,437^{a}	10,877±3,426^{a}	22,251±4,853^{a}
AGR-1	2021	335 ±4.7$^{\#}$	22.1±2.3	13,394±3,909	11,106 ±769	24,500±1,617
	2022	255 ±29	21.6±3.5	9,790 ±1,921	10,770±3,861	20,560± 489
	Mean	295±56^{a}	21.8±0.4^{a}	11,592 ±2,548^{a}	10,938±237^{a}	22,530±1,970^{a}
Nero IT	2021	331±20$^{\#}$	22.8±2.3$^{\#}$	14,966 ±4,803$^{\#}$	11,976±2,522	26,942±2,114
	2022	231±23	20.3±1.9	6,335 ±1,917	5,963 ±1,946	12,298±1,986
	Mean	281±70^{a}	21.5±1.7^{a}	10,651 ±6,102^{a}	8,969 ±4251^{a}	19,620±7,322^{a}

Kok: Kwangpyeongok: the symbol # in the column indicates significant differences between cultivars in 2021 and 2022. Alphabets in the column indicate significant differences in yield over two years between the cultivars.

Table 4. Nutrient content grain with forage of different cultivars at the Pyeongchang

Cultivars	Year	Plant Nutrient (%)			Grain Nutrient (%)		
		NDF	ADF	CP	NDF	ADF	CP
Kok	2021	61.0 ± 3.7	35.4 ± 1.7	7.60 ± 1.5	29.8 ± 3.8	10.8 ± 1.1	9.46 ± 0.8
	2022	66.5 ± 4.3	35.5 ± 1.4	5.20 ± 1.1	27.1 ± 0.6	5.96 ± 0.6	7.92 ± 0.3
	Mean	63.8 ± 3.8[a]	35.5 ± 0.1[a]	6.40 ± 1.7[a]	28.5 ± 1.9[a]	8.38 ± 3.4[a]	8.70 ± 1.0[a]
AGR-1	2021	65.8 ± 2.7	38.2 ± 2.2	6.26 ± 0.8	29.7 ± 4.3	8.80 ± 1.0	8.24 ± 1.0
	2022	68.5 ± 3.6	37.3 ± 1.0	5.85 ± 0.9	25.6 ± 4.3	6.07 ± 0.9	8.14 ± 0.4
	Mean	67.1 ± 2.8[a]	37.7 ± 2.2[a]	6.06 ± 0.8[a]	27.6 ± 2.9[a]	7.50 ± 1.9[a]	8.19 ± 0.1[a]
Nero IT	2021	63.3 ± 4.4	34.9 ± 3.6	7.9 ± 0.8	33.9 ± 3.3	7.30 ± 0.5	8.16 ± 0.4
	2022	70.9 ± 2.3	37.9 ± 1.7	5.88 ± 0.8	19.6 ± 2.8	6.50 ± 0.5	7.59 ± 0.6
	Mean	67.1 ± 5.3[a]	36.4 ± 2.2[a]	6.9 ± 2.1[a]	26.8± 0.1[a]	6.90 ± 0.5[a]	7.88 ± 0.4[a]

Kok: Kwangpyeongok: Alphabets in the column indicate significant differences in yield over two years between the cultivars.

were 10,651 ± 6,102 kg/ha and 8,969 ± 4,251 kg/ha, respectively. The total dry matter content of Nero-IT was 19,620 ± 7,322 kg/ha (Table 3).

3. The nutrients content of Kwangpyeongok, AGR-1, and Nero-IT cultivars

We quantified the nutrient content of Kwangpyeongok, AGR-1, and Nero-IT cultivars such as acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP). The average NDF content of Kwangpyeongok, AGR-1, and Nero-IT forages was 63.8 ± 3.8%, 67.1 ± 2.8%, and 67.1 ± 5.3%, respectively. The NDF content of Kwangpyeongok grain, the AGR-1 grain, and the Nero-IT grain was 28.5 ± 1.9%, 27.6 ± 2.9%, and 26.8 ± 10.1%, respectively. The average ADF content of Kwangpyeongok, AGR-1, and Nero-IT forage was 35.5 ± 0.1%, 37.7 ± 2.2%, and 36.4 ± 2.2%, respectively. As for Kwangpyeongok, AGR-1, and Nero-IT grain, the ADF content was 8.38 ± 3.4%, 7.50 ±1.9%, and 6.90 ± 0.5%, respectively. As for the CP content of Kwangpyeongok, AGR-1, and Nero-IT forage, the averages were 6.40 ±1.7%, 6.06 ± 0.8% and 6.9 ± 2.1%, respectively. The ADF content of Kwangpyeongok, AGR-1, and Nero-IT grain was 8.70 ± 1.0, 8.19 ± 0.1, and 7.88 ± 0.4, respectively (Table 4).

Ⅳ. DISCUSSION

Corn and soybean whole crops have accounted for 60% of total feedstock production. Seoul forecasts corn production in Korea to remain unchanged at 90,000 tons in 2023-2024. The total consumption of corn in 2023/2024 is expected to remain flat at 11.3 million metric tons (MMT). The total consumption of corn in 2022/2023 remained at 11.1 MMT as increased feed consumption more than offset reduced food, seed, and industrial consumption. However, corn production in Korea has been reduced and accounts for less than 1% of total consumption (Yoona and Neil, 2023). As reported by the Rural Development Administration (RDA), the self-sufficiency rate of high quality forage is insufficient due to an increase in the number of farms and a weak base of forage production. As a result, Korea is highly dependent on imports of forage (MAFRA, 2018). It is important to identify a key strategy for ensuring flexibility between domestic production and importation. The development of new corn varieties and the optimization of their growth in different regions are therefore important criteria for improving the growth productivity and characteristics of corn. In this study, Kwangpyeongok, AGR-1, and Nero-IT cultivars were sown in Pyeongchang area on April 29 and 27 of 2021 and 2022 and harvested on 21 August and 22 September of 2021 and 2022, respectively. The characteristics and growth productivities of different cultivars were evaluated, such as stem height and diameter, ear and forage yield, and total dry matter content. Kwangpyeongok, AGR-1, and Nero-IT showed significant differences in stem heights in 2021. Cultivars cultivated in 2021 had higher stem heights than those cultivated in 2022. The stem diameter of Kwangpyeongok and Nero-IT were higher in 2021 as compared to corn grown in 2022 (p<0.05). In contrast, stem height and diameter between cultivars were not significantly different over two years. The grain quantity of Nero-IT was

significantly different between 2021 and 2022 (p<0.05). However, the average grain quantity, forage yield and total dry matter content were the same for all cultivars. According to these data, the corn cultivars cultivated in 2021 had slightly higher height, diameter, grain, and total dry matter yields than those cultivated in 2022. Growth and productivity of corn for all cultivars are slightly higher in 2021 due to higher precipitation and temperature levels than in 2022. The average maximum temperature at the time of seeding in 2021 was 13.9 degrees Celsius, while in 2022 it was 10.1 degrees Celsius. A temperature increase of at least three degrees Celsius was observed for all months until harvest period compared to 2022. Furthermore, the precipitation level was also higher in April, May, and July, 2021, which may be the main reason for the higher production of all cultivars in 2021, suggesting that the climate conditions may have an effect on corn yields. In addition, the nutrient contents, such as ADF, NDF, and CP, did not change significantly between years or between two years' averages. Our previous study reported that Gwangpyeongok, AGR-1, and Nero-IT have been grown in different regions with different climatic conditions, including Cheonan and Jeju. The data indicated that the total dry matter content of the Kwangpyeongok cultivar was slightly higher in Cheonan, while the total dry matter content of AGR-1 and Nero IT were slightly higher in Jeju (Soundharrajan et al., 2023). In the present study, it was found that Pyeongchang had a higher total dry matter yield than Cheonan and Jeju. Pyeongchang had a slightly lower total yield of AGR-1 and Nero-IT than Cheonan and Jeju (Soundharrajan et al., 2023). A productivity evaluation of different corn varieties in Pyeongchang was carried out by Kim et al. (2017) suggesting that there were not significant differences in productivity among certified varieties of imported silage corn. The varieties of Kwangpyeongok 32W86 and 32P75 might be suitable for cultivation in Pyeongchang for stable production. A report claimed that corn variety P2105 produced higher dry matter yields than other varieties. Further, the grain ratio was excellent for the P1543 and P1345 varieties at Pyeongchang (Kim et al., 2020). In the current study, characteristics and productivity levels of corn varieties such as Gwangpyeongok, AGR-1, and Nero-IT were observed in the Pyeongchang region. However, Gwangpyeongok and AGR-1 varieties produce a slightly greater amount of dry matter than Nero-IT varieties. Therefore, Gwangpyeongok, AGR-1 may be more suitable for stable cultivation in Pyeongchang for the production of corn forage for livestock.

Ⅴ. CONCLUSIONS

The study suggested that different corn cultivars such as Gwangpyeongok, AGR-1, and Nero-IT cultivated in Pyeongchang region showed significant variation stem height and diameter between the years. But, there is no significant variation in an average of two years stem height and diameter, grain-quantity and forage yield for all cultivars. In 2021 the corn characteristics and growth productivity were higher for all cultivars, it may due to moderately higher temperature and precipitation level compared to year of 2022. Over data suggested that Gwangpyeongok, AGR-1, and Nero-I are produced same amounts of productivity which could be very useful for livestock feed production.

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