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Research Article

Evaluation of Growth Characteristics and Forage Yield of Domestically Bred Silage Corn Varieties

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ABSTRACT

This experiment was conducted to evaluate the growth characteristics and productivity of silage corn varieties developed in Korea. Corn cultivation was carried out using the experimental field in the Pyeongchang campus of Seoul National University (550 m above sea level). There have 10 domestic cultivars (Gwangpyeongok, Dacheongok, Yanganok, Jangdaok, Cheongdaok, Daanok, Sinhwangok, Sinhwangok Ⅱ, Pyeonggangok, and Hwangdaok) with one imported cultivar (P1543) which tested as a control, and randomized block design with three replications. Among the 100-grains weight of the seeds, Dacheongok was the heaviest, and the germination rate for each variety was 74.6% on average, while that of Daanok and Sinhwangok were over 90%. Sinhwangok was the fastest in tasseling and silking date. The number of days required to be silking date was as slow as 85 days in Dacheongok, Cheongdaok and Pyeonggangok, and as fast as 80 days or less in Sinhwangok, Sinhwangok Ⅱ and Hwangdaok. The plant height of P1543 was the highest as 344cm, and Hwangdaok and Daanok were short. In terms of the ratio of ears, Daanok had the highest rate of 60.18%, and Jangdaok and Dacheongok had the lowest. There was no significant difference in dry matter content in stover, but P1543 was generally higher in ear and total dry matter content. The dry matter yield was highest in P1543, and the yield of TDN was significantly higher in P1543 and Yanganok. There was a significant difference in the crude protein content of ears and the dry digestibility of stems ($p<0.05$), while there was no significant difference in the content of each part or element. Combining the above results, Yanganok was the highest in terms of yield, and Dacheongok, Sinhwangok and Pyeonggangok were also recommended for domestically grown corn varieties in the mountainous regions of Gangwon-do.

(Key words: Corn, Domestic variety, Feed value, Productivity, Silage)

Ⅰ. INTRODUCTION

Corn is regarded as one of the most productive and quality crops among forage crops. It is a crop that can be cultivated regardless of latitude or elevation because of its wide range of adaptation to the environment and wide range of variability over the growing period (Kim, 1990). Recently, the cultivated area has gradually increased, but since 2018 it has been stagnant. According to the report of the Ministry of Agriculture, Food and Rural Affairs, 10,000 hectares of corn is grown among the total summer forage crops in 2020 (MAFRA, 2022).

Since corn is mechanized, it has been recognized as an easy species that can be machined from sowing to harvest. Due to the recent spread of round bale silage preparation technology, the cultivation of Sudangrass, which is easy to work with, has increased. However, with the spread of the finely cut round baler, it became possible to work with corn as well.

The biggest issue in the forage industry in Korea is market opening. When the imported forage market opens starting in 2024, it is conceivable that the ratio of domestic forage use will decrease (Jeong, 2021). Therefore, in order to protect the domestic forage market, it is necessary to expand the production and utilization of high-quality forage. As the market for imported forage is mainly hay, some research on domestic hay preparation technology is in progress. However, it is necessary to continuously produce and expand the cultivation of corn silage, which is preferred by dairy farmers.

In the corn seed market for silage, which has been dependent on imports, the price of imported seeds is rising due

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to various reasons, and this has led to a growing interest in domestic corn seeds for silage. As of 2020, 36,250 kg of imported corn seeds were introduced, and 20,634 kg of domestic seeds, accounting for 36% of the total corn seed quantity (MAFRA, 2021). Currently, Gwangpyeongok and Dacheongok are distributed through the Korea Agriculture Technology Promotion Agency, and the supply is planned to be expanded focusing on newly cultivated excellent seeds.

In the meantime, various evaluation tests have been conducted on imported silage corn (Kim et al., 2017; Kim et al., 2020). As the cultivation of domestic corn varieties has been activated, Sinkwangok (Son et al., 2014), Yanganok (Son et al., 2013a), Andaok (Son et al., 2013b), Pyeonggangok (Son et al., 2012), etc. results have been reported. However, domestic corn for silage was mainly cultivated in the plain areas, and 9 excellent varieties were evaluated in Suwon (Son et al., 2006). However, it is judged that it is necessary to evaluate the productivity in the mountainous regions of Gangwon. Therefore, this study was conducted to evaluate the growth characteristics and productivity of 10 domestic corn cultivars for silage developed by the National Institute of Crop Science, compared to the introduced cultivars.

Ⅱ. MATERIALS AND METHODS

1. Corn Varieties

This experiment was conducted with 10 domestic corn varieties (Gwangpyeongok, Dacheong, Yanganok, Jangdaok, Cheongdaok, Daanok, Sinhwangok, Sinhwangok Ⅱ, Pyeonggangok and Hwangdaok) developed at the National Institute of Crop Science, and one imported variety. A total of 11 varieties, including the cultivated P1543 variety (registered for import conformity certification in 2011, Pioneer hybrid Co., USA), were chosen and tested.

2. Germination rate measurement

For the seed characteristics of the test varieties, 100-grain weight, germination rate, and germination energy were investigated. For the measurement of 100-grain weight, 100 seeds were randomly selected for each variety and weighed in three repetitions. For the measurement of germination rate, the germination state of 100 seeds was observed for 10 days while placing filter paper on a Petri-dish and supplementing distilled water. The germination energy was calculated by adding up the germination rate from the date of the highest germination rate during the germination rate measurement period.

3. Field experiment

The field experiment for corn cultivation was conducted according to the method of Kim et al (2017). The experimental field (37°32′40″ north latitude, 128°26′33″ east longitude, 550m above sea level) was used in the Pyeongchang Campus of Seoul National University located in Pyeongchang-gun, Gangwon-do, and used as grassland before corn cultivation. As shown in Table 1, the chemical properties of the experimental field were weakly acidic, and the content of organic matter, total nitrogen and effective phosphoric acid were low.

For the purpose of supplement organic matter in the soil for corn cultivation, 10 tons/ha of organic fertilizer, mixed oil cake, was applied to the entire surface. For corn varieties, the 11 treatment were performed the randomized block design with three repetitions. For the P1543 variety directly introduced from Pioneer Hybrid Co. in the United States and 10 varieties parcel out by the National Institute of Crop Science.

Sowing of corn for silage was carried out on April 29, 2021, and the size of the plot was 15 m^2 (3m×5m). For planting density, two grains were sown at a rigid width and inter-row space of 75cm×20cm, and two seeds were planted, leaving only one superior individual in the 7th to 8th leaf stage, and the rest were removed.

The amount of fertilization was 200 kg of nitrogen, 150 kg

Table 1. Chemical properties of soil in experimental field

pH (1:5)	OM (%)	TN (%)	Av. P_2O_5 (mg/kg)	Exchangeable cation(mg/kg)				CEC (cmol/kg)
				K	Ca	Mg	Na	
6.08	3.74	0.13	84.63	221.4	130.2	108.7	30.7	15.72

* OM : Organic matter, TN : Total nitrogen, CEC : Cation exchange capacity

of phosphorus and 150 kg/ha of potassium. Phosphorus and potassium fertilizers were applied as a whole, and nitrogen fertilizer was divided by half on the day of sowing and in the 7th to 8th leaf stage. Herbicides were uniformly sprayed on the entire surface of the field on the day of sowing, and a bird net was installed to prevent damage from birds.

Harvesting for the yield of corn was carried out on September 8th. Of the corn grown in 4 rows of each variety, the middle 2 rows were harvested and the weighted. To measure the dry matter content of stovers and ears, 2 plants were selected from each treatment and dried in a air force drying oven at 65°C for 72 hours or more, then the dry matter content was calculated and converted into the yield per ha. The total digestible nutrients(TDN) yield was calculated by the method suggested by Holland et al. (1990) as TDN yield = (the yield of dry matter in stover × 0.582) + (the yield of dry matter in the ears × 0.85).

4. Feed Value Analysis

The samples for analysis of feed value were dried and then ground with a 20 mesh mill using a grinder, placed in a plastic sample container with a double stopper, and stored in a place where there was no direct sunlight.

The crude protein content was analyzed according to the AOAC (1995) method, and the NDF (neutral detergent fiber) and ADF (acid detergent fiber) contents were according to the Goering and Van Soest (1970) method, and the *in vitro* dry digestibility (IVDMD) was determined by Tilley and Terry method (1963) was modified by Moore (1970). The gastric juice used in the test was collected and used before morning feeding to Korean cattle, which had normally been fed free forage.

5. Statistical processing

For statistical processing, analysis of variance was performed using the SAS Package program (Ver. 9.0), and the least significant difference test (LSD) was used for comparison between treatment means.

Ⅲ. RESULTS AND DISCUSSION

1. Seed Characteristics

Seed characteristics for the 11 varieties used in the test are shown in Table 2. In the case of 100-grain weight, Dacheongok was the heaviest ($p<0.05$), Sinhwangok Ⅱ was the next heaviest, while Pyeonggangok and Jangdaok weighed less than 20 g. Shahzad et al. (2015) reported in a study on the evaluation of seed productivity according to corn varieties and sowing date that, the thousand grain weight of corn was significantly affected

Table 2. Seed characteristics of 11 test varieties

Varieties	100-grain weight(g)	Germination rate(%)	Germination energy(%)	Emergence rate(%)
P1543	26.53	87.3	51.3	98.7
Gwangpyeongok	28.67	70.0	42.7	99.3
Dacheongok	34.55	50.6	36.2	100
Yanganok	25.27	71.3	42.0	99.3
Jangdaok	19.20	66.7	48.7	98.0
Cheongdaok	28.87	72.7	44.7	99.3
Daanok	22.07	96.7	86.0	98.7
Sinhwangok	20.47	90.7	81.3	100
Sinhwangok II	30.20	68.7	54.7	98.7
Pyeonggangok	17.13	64.0	52.7	99.3
Hwangdaok	27.27	82.0	54.7	99.3
Mean	25.47	74.6	54.1	99.2
LSD(0.05)	1.17	17.26	13.02	NS

* LSD : Least significant difference.

by the variety and sowing date. In this experiment, there was also a significant difference in the weight of 100 grains between varieties. Bashir et al. (2000) reported that there was a correlation coefficient of 0.9171 between the 100-grain weight and dry matter yield of corn. In this test, the correlation coefficient between 100-grain weight and dry matter yield was low by -0.05534.

On the other hand, according to NIAS (2011), there was no difference at 29.70g and 29.54g among 100-grain weights of Daanok and Jangdaok, but this test showed that Daanok was heavier (22.07 vs 19.20g).

The germination rate for each variety was 74.6% on average, and Daanok and Sinhwangok showed higher than 90%, and Dacheong, Pyeonggangok, Cheongdaok and Sinhwangok Ⅱ showed a low germination rate of less than 70%. In terms of germination energy, it was high in Daanok and Sinhwangok, and it was low in Dacheongok and Gwangpyeongok. On the other hand, in terms of the emergency rate, it was judged that most of the seeds appeared with an average of 99.2%.

Nielsen (1996) found that the germination rate differs depending on the size of the seed when the conditions are not good after sowing corn. Large seeds require more moisture for germination than small seeds and small seeds have less energy stored in cold weather. It is said that the germination rate is low in cold weather or coarse soil. However, in this test, the weight of 100-grain weight (seed size) showed a correlation coefficient of -0.366 with the germination rate (Table 3), so it was judged that there was no significant relationship.

The correlations for the main seed characteristics are shown in Table 3. There was a negative correlation between 100-grain weight, germination rate and germination energy, but the correlation coefficient was not high. However, it was found that there was a high correlation between the germination rate and germination energy of 0.810361. Moshatati and Gharineh (2012) reported that 100-grain weight had no significant effect on the germination rate. However, Hunter and Kannenberg (2000) said that under ideal conditions, seed size did not affect emergence, but small size seeds decreased under stress conditions. To compensate for this, it is recommended to increase the seeding rate. In this test, Jangdaok, which had a low weight of 100-grain, had a low dry matter yield, but Pyeonggangok was high.

2. Growth characteristics

The tasseling date of the test varieties was July 20-26, and there was no significant difference between the varieties. There was no difference between the silking date, July 20-27. However, Sinhwangok showed the fastest tasseling and silking date, and

Table 3. Correlation coefficient evaluation of major seed characteristics

Item	100 grain weight	Germination rate	Germination energy
100 grain weight		-0.366	-0.51489
Germination rate			0.810361

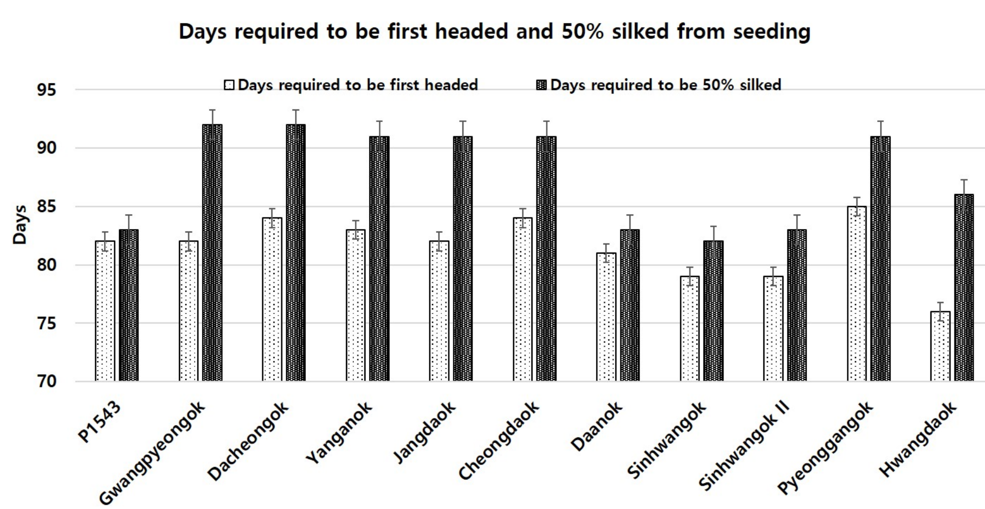

Fig. 1. Days required to be the first heading and 50% silked from seeding.

Sinhwangok Ⅱ was also faster. P1543 and Daanok were also on the fast side with July 21st, and Dacheong, Dacheongok, Cheongdaok, and Pyonggangok were slightly delayed in their tasseling and silking date. Although there was no significant difference in the cultivar and insect resistance among treatments, disease resistance was on the weak side in Daanok and Hwangdaok, and degree of stay green were good for P1543, Dacheong and Yangdaok, and it was found to be slightly inferior in Daanok, Sinhwangok Ⅱ and Hwangdaok. On the other hand, there was no significant difference among treatments, but Hwangdaok had the lowest in lodging resistance.

Fig. 1 shows the number of days required from the start of seeding to the 50% silking period. The number of days of first tasseling date was about 84 days for Dacheongok and Cheongdaok, 85 days for Pyeonggangok, and it was as early as 79 days for Sinhwangok and Sinhwangok2, 76 days for Hwangdaok. In terms of the number of days required for the 50% silking date, P1543, Daanok, Sinhwangok and Sinhwangok Ⅱ were faster than below 85 days, and Gwangpyeongok and Dacheongok took 92 days, which was the latest.

Although the test period is different, relatively comparing the tasseling date, Sinhwangok Ⅱ was the fastest and Daanok > Sinhwangok > Hwangdaok > Jangdaok > Cheongdaok > Gwangpyeongok > Dacheongok was reported in the order of the silking date (NICS, 2010: 2011; 2013), and showed a similar trend to this test. On the other hand, there was a correlation of -0.7323 between the 50% number of days required for harvesting and the ratio of ears, indicating that the shorter the time required for silking date, the higher the ratio of ears.

3. Plant characteristics

The P1543 variety had the highest in plant height of 344cm, and Cheongdaok, Yanganok, Dacheong, Gwangpyeongok, and Jangdaok were among the largest. However, Hwangdaok and Daanok showed shorter plant hyeight. As for the ear height, Yanganok was the highest at 185cm, and Dacheongok and Gwanganok were also high, and Hwangdaok, Sinhwangok Ⅱ and Pyeonggangok were low. Kim et al. (2020) reported that, in a comparative test of corn varieties for silage introduced in Pyeongchang, Gangwon, the plant and ear height of P1543 were 273 and 101 cm, respectively, showing no significant difference from other introduced varieties. Meanwhile, the average plant and ear height in this test were 315 and 138 cm, which was larger than that of general cultivation, and it was expected that the occurrence of lodging caused by the wind would be high. According to the study of Son et al. (2018), the stem height of Dacheong-ok and Gwangpyeong-ok was 267 and 280cm. In this test, there was no significant difference between the two varieties with plant heights of 331 and 330 cm(p>0.05).

On the other hand, looking at the ratio of ears, which contain most of the nutritional components of corn, Daanok

Table 4. Silking and Tasseling stage and agronomic characteristics of 11 test varieties

Varieties	Date of 50% Tasseling	Date of 50% silking	Disease resistance♪	Insect resistance♪	Lodging resistance♪	Stay green♪
P1543	21 July	21 July	3.0	2.0	1.0	6.0
Gwangpyeongok	24 July	27 July	2.7	2.0	1.0	4.7
Dacheongok	26 July	27 July	1.3	2.3	1.0	7.7
Yanganok	24 July	26 July	2.0	2.7	1.0	7.0
Jangdaok	22 July	26 July	2.7	2.3	1.0	5.7
Cheongdaok	25 July	26 July	3.0	2.3	1.0	4.7
Daanok	21 July	21 July	5.3	2.0	1.0	3.7
Sinhwangok	20 July	20 July	4.3	2.0	1.0	4.7
Sinhwangok II	20 July	21 July	4.3	2.0	1.0	3.3
Pyeonggangok	25 July	26 July	4.0	2.7	1.7	4.7
Hwangdaok	21 July	24 July	6.0	2.7	2.3	3.7
Mean	22 July	24 July	3.5	2.27	1.18	3.1
LSD(0.05)	-	-	2.81	NS	NS	1.98

* ♪ : 1(Strong, Dark green), 9(Week, light green)

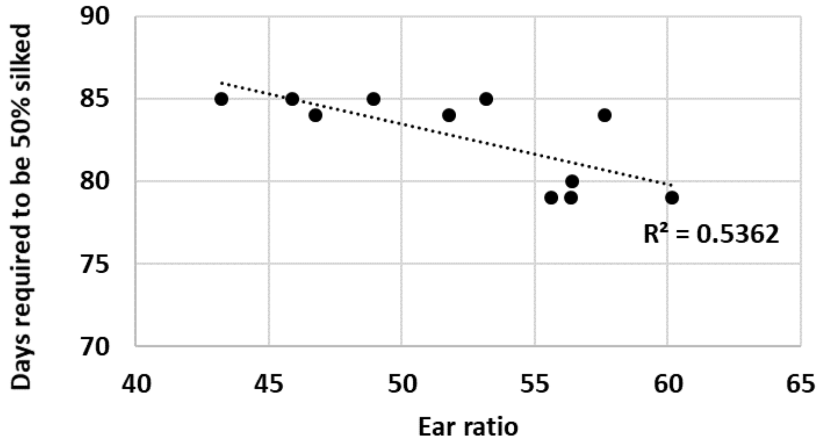

Fig. 2. Correlation of days required to be 50% silked and ear ratio.

Table 5. Plant and ear height, ear ratio and dry matter content of test varieties

Varieties	Plant height(cm)	Ear height (cm)	% of ear ratio	Dry matter(%)		
				Ear	Stover	Whole
P1543	344	136	56.39	57.09	20.30	34.13
Gwangpyeongok	330	151	53.18	53.16	18.12	29.39
Dacheongok	331	155	45.90	42.80	15.93	23.01
Yanganok	338	185	46.76	53.65	20.23	27.92
Jangdaok	330	134	43.22	42.51	24.45	28.31
Cheongdaok	340	140	51.79	53.92	16.83	28.41
Daanok	283	132	60.18	57.60	20.40	33.45
Sinhwangok	294	140	56.36	52.71	20.38	31.48
Sinhwangok Ⅱ	297	117	55.63	53.75	21.68	34.98
Pyeonggangok	309	125	48.96	49.49	18.77	28.87
Hwangdaok	265	101	57.63	58.71	18.06	30.13
Mean	315	138	52.36	52.31	19.56	30.01
LSD(0.05)	32.8	19.7	14.01	11.62	NS	6.24

was the highest at 60.18%, and Hwangdaok, Sinhwangok, P1543, and Sinhwangok Ⅱ were high, and Jangdaok and Dacheongok were low. There was a negative correlation between the ear ratio and the number of days required to be silking by 50% (Fig. 2).

At the time of harvest, there was no significant difference in the dry matter content of corn in stover, and in the case of ear, Hwangdaok, P1543 and Daanok were higher. The total dry matter content was 30.01% on average, and P1543 and Sinhwangok Ⅱ showed the highest levels, and Dacheongok had the lowest.

4. Productivity

Table 6 shows the yield each element for all 11 varieties. The average yield of fresh matter was 71,934 kg/ha and the dry matter yield was 20,757 kg/ha.

The yield of fresh matter was the highest in Dacheongok at 95,288kg/ha, and was significantly lower in Daanok and Hwangdaok at about 56 tons/ha. The dry matter yield was high at about 24 tons/ha in P1543 and Yanganok varieties, and was significantly lower in Yanganok, Sinhwangok Ⅱ and Hwangdaok. Meanwhile, the TDN yield was significantly higher in P1543 and Yanganok, and the lowest in Hwangdaok at 10,999kg/ha. On the other hand, in the evaluation of corn varieties introduced by Kim et al. (2020), the dry yield of P1543 was found to be 5,783 kg/ha. On the other hand, Son et al. (2018) found that the mean yield of Dacheongok and Gwangpyeongok grown in Suwon for three years (2014-2016) was 23.96 and 21.51 ton/ha,

Table 6. Fresh matter, dry matter and TDN yield of tested varieties

Varieties	Yield(kg/ha)						
	Fresh matter			Dry matter			TDN
	Stover	Ear	Total	Stover	Ear	Total	
P1543	52,756	24,222	76,978	10,700	13,829	24,529	17,982
Gwangpyeongok	52,444	20,311	72,755	9,493	10,800	20,294	14,705
Dacheongok	72,444	22,844	95,288	11,544	9,786	21,330	15,037
Yanganok	64,178	21,156	85,334	12,933	11,349	24,282	17,173
Jangdaok	46,400	19,700	66,100	10,937	8,679	19,616	13,742
Cheongdaok	60,311	20,044	80,355	10,086	10,821	20,907	15,068
Daanok	37,067	19,822	56,889	7,548	11,419	18,967	14,099
Sinhwangok	46,400	23,022	69,422	9,473	12,161	21,634	15,850
Sinhwangok II	38,044	19,111	57,155	8,221	10,271	18,492	13,515
Pyeonggangok	59,200	21,156	80,356	10,926	10,476	21,402	15,264
Hwangdaok	40,533	16,400	56,933	7,121	9,750	16,871	10,999
Mean	51,798	20,711	71,934	9,908	10,849	20,757	14,857
LSD(0.05)	12,405	3,902	16,943	2,919	3,452	3,685	3,480

Table 7. The content of crude protein(CP), acid detergent fiber(ADF), neutral detergent fiber(NDF) and in vitro dry matter digestibility(IVDMD) of tested varieties

Varieties	CP(%)		ADF(%)		NDF(%)		IVDMD(%)	
	Ear	Stover	Ear	Stover	Ear	Stover	Ear	Stover
P1543	7.92	9.13	6.92	31.78	30.00	62.63	88.81	58.48
Gwangpyeongok	8.58	7.74	8.23	35.05	29.61	65.91	86.96	62.12
Dacheongok	7.90	9.58	8.26	31.47	31.59	62.68	86.12	65.08
Yanganok	7.83	10.90	8.98	28.30	30.21	59.21	84.70	69.66
Jangdaok	8.51	10.23	7.06	33.23	26.06	62.23	89.30	66.95
Cheongdaok	8.11	9.25	9.47	30.06	32.58	59.06	85.67	65.36
Daanok	8.65	8.31	6.32	33.35	25.93	64.37	87.32	63.27
Sinhwangok	10.02	9.35	7.61	30.48	30.47	60.69	87.65	6328
Sinhwangok II	8.41	8.91	7.48	31.99	27.78	62.86	88.71	61.45
Pyeonggangok	7.58	8.44	8.71	30.66	28.32	61.08	85.94	67.15
Hwangdaok	8.39	7.64	7.75	32.73	31.11	64.95	88.42	64.46
Mean	8.35	9.04	7.89	31.74	29.42	62.34	87.34	64.30
LSD(0.05)	1.02	NS	NS	NS	NS	NS	NS	4.73

* NS : not significant

respectively, indicating that Dacheongok increased by about 10%, but there was no significant difference(p>0.05). But, in this test, Dacheongok was 22,330kg/ha, which was significantly higher than that of Gwangpyeongok 20,294kg/ha (p<0.05).

Hwangdaok is a variety cultivated for the purpose of grain production, and in a productivity test in Suwon, the yield of grains was reported as 7.56 tons/ha. In this test, the yield of ear was 9,750 kg/ha. The reason why the yield was high in this test was that the ear included cob(Son et al., 2019).

5. Feed Value

The feed values for all 11 varieties are shown in Table 7. Most of the feed value indicators were not significant between varieties, but there were significant differences in the crude protein content of ears and the dry matter digestibility of stover.

The crude protein content was high in the ear of Sinhwangok, and the ear of Pyeonggangok showed the lowest value at 7.58%, but there was no significant difference with the varieties other than Sinhwangok. On the other hand, there were many differences between the stovers and the ears except for the crude protein content. In particular, the ADF content of the ears was very low with an average of 7.89%. Kim et al. (2020) analyzed maize by dividing it into 5 parts, and reported that the CP content was high in the stover and grain, but the ADF and NDF contents were low in the grain. In addition, it was said that there was a difference due to the characteristics of the variety because the content was different for each part (stem, leaf, cob, bract, and grain), as there was a special difference according to the part of each cultivar.

Ⅳ. ACKNOWLEDGMENTS

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