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Research Article

Analysis of Feed Value and Usability of Soybean Varieties as Livestock Forage

Myoung Ryoul Park[1,*], Min-Jung Seo[1], Hong-Tae Yun[1], Chang-Hwan Park[2]
[1]Dept. of Central Area Crop Science, NICS, RDA, Suwon 16429, Korea
[2]Dept. of Southern Area Crop Science, NICS, RDA, Miryang 50424, Korea

ABSTRACT

This experiment was conducted to evaluate feed value and usability of soybean varieties as livestock forage. In this study, three soybean cultivars, OT93-26, Geomjeongsaeol, and Pungwon, were harvested at R5 (beginning seed development)- and R6 (full seed)-reproductive stages for analyzing feed value of soybean. Days to R5 stage harvest of OT93-26 among the three soybean cultivars was 55 days and the shortest while Pungwon took 103 days to reach at R6 stage. The R6-harvested soybeans had higher dry matter (DM) yields and crude protein (CP) content than the R5-harvested. However, both DM and CP were the highest in the R6-harvested Geomjeongsaeol. Contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) of Pungwon harvested at R5 were the highest whereas the R6-harvested Geomjeongsaeol had the lowest. Digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) of the R6-harvested Geomjeongsaeol and Pungwon were higher than those of the R5-harvested, but in case of OT93-26, those at R6 stage were low rather than those at R5 stage. However, soybean could be used as alternative forage with high feed value for livestock. Taken together, Geomjeongsaeol could be used for developing new forage soybean varieties with high feed value, and R6 would be the optimum harvesting stage for yield and quality of forage soybean.

(**Key words** : Soybean, Forage, Feed value, Crude protein, Growth stage)

Ⅰ. Introduction

As Korean dietary life is changing, meat consumption is gradually increasing. The meat consumption has approached up to a net amount of 2.5 million tons in 2015, which was consistently increased by 0.5 million tons during 5 years from 2011 (MAFRA, 2016). The amount is likely to be continuously increased in domestic.

Livestock needs high protein forage, whereas the grass hay, timothy, Italian ryegrass, and orchardgrass, and whole crop silages, maize and rice, contain 6.6~9.0% CP as reported by various studies (Takagi et al., 2002; Islam et al., 2004; Bal, 2006; Khan et al., 2012). However, the representative forage legume, alfalfa (*Medicago sativa* L.) hay, cube, and pellet, has a high-protein content, 16.0~17.2% (Khan et al., 2012). As of 2015 in Korea, the net forage amount of 19% was imported from abroad, and the amount of alfalfa as livestock feed among the imported was 186,000 ton (MAFRA, 2016).

Soybean is an annual herbaceous leguminous plant and oil-bearing crop. Soybean seeds generally contain 35 to 38 % protein compared to approximately 20 to 30 % in other legumes (USDA, 2009). Soybean protein contains mostly easily soluble fractions up to 94 % (USDA, 2009). Before World War II, the typical legume crop, soybean, was used as high protein forage with quality similar to alfalfa (Blount et al., 2002). Soybeans as nutritious hay and silage crop are harvested in whole plants at various growth stages from flowering to early maturity (Blount et al., 2002). Days to flowering and maturity of soybean play an important role for harvesting forage, since harvesting stage significantly affects the yield and quality of forage (Acikgoz et al., 2009; Hintz et al., 1992). Various studies (Fehr et al., 1971; Darmosarkoro et al., 2001; Lee et al., 2014; Acikgoz et al., 2013) have recommended forage soybean cultivars with late maturity and harvesting stages from R5 to R7 (beginning maturity) for producing the optimum forage soybean, which generally has the best combination of low fiber, high protein content, and digestible energy.

* Corresponding author : Myoung-Ryoul Park, Dept. of Central Area Crop Science, NICS, RDA, Suwon 16429, Korea
Tel: +82-31-695-4047, Fax: +82-31-695-4029, E-mail: park5260@korea.kr.

In domestic, Kim et al. (1982) have evaluated the feed value of soybean straws of the different varieties. Usability of the soybeans as a silage, which contain CP content of 19% and are 7 t/ha in DM yield, was reported by Cho et al. (2003), and three soybean lines suited in intercropped with corn were selected by Shin (2008). Recently, Lee et al. (2014) have evaluated forage yield and quality for the soybean accessions derived from interspecific cross between wild and cultivated soybeans. Moreover, forage soybean varieties which were derived from wild soybean, Chookdu 1 and Chookdu 2, were developed (Lee, 2014). Despite the previous studies that soybean has a greater feed value as forage, commercial cultivation of soybean for livestock forage is few in domestic. In this respect, to increase cultivation and usability of forage soybean, it would be preferentially necessary to develop new soybean varieties with high feed value and forage yield, and to optimize harvesting stage which could be highly suitable for intercropping or multiple cropping systems.

For these needs, we carried out this study to investigate feed value of recent soybean cultivars, and to provide basic information for developing soybean varieties with high feed value and forage yield.

Ⅱ. Materials and methods

1. Soybean cultivation and harvesting methods

Korean soybean varieties were classified into 4 ecotype groups based on seasonal response of flowering and 3 ecotype groups based on maturity (Cho et al., 1994; Chu et al., 1996). For this study, we selected three varieties by each maturity group, a total of 9 varieties (OT89-05, OT93-26, OT93-28, Geomjeongsaeol, Heugsung Joyang 1, Mallikong, Pungwon, Jinpung). The experimental plots for this study were arranged by completely randomized designs. The soybean seeds were sown at 70×15 cm spacing to the plots in the crop experimental field in the National Institute of Crop Science (NICS), Suwon, Republic of Korea. The experimental plots were treated with a basic granular fertilizer at N-P_2O_5-K_2O=40-70-60 kg/ha before sowing and were managed by the crop standard cultural practices of NICS after sowing. Agronomic yield- and quality-related characteristics were measured according to the agricultural science technology standards for investigation of research of RDA, Republic of Korea (RDA, 2012). We harvested soybean plants at R5- and R6-reproductive stages of soybean for analyzing feed value (Fig. 1).

Fig. 1. Seed filling situations at R5 (beginning seed development) and R6 (full seed)-reproductive stages of three soybeans, OT93-26 (A and B), Geomjeongsaeol (C and D), and Pungwon (E and F).

2. Analysis of nutrient value

The harvested soybean seeds and whole plants were ground into powder under size of 1.0 mm in ultraspeed-centrifuge mill (ZM 100, Retsch, Germany), and then used for analyzing general composition contents and feed value.

General compositions, crude ash, crude fiber, crude oil, and CP, were analyzed to provide basic nutrient information of the soybeans whole plants according to the recommendation of Association of Official Analytical Chemists (AOAC, 2016). The direct ashing incineration method by heating (600oC) was used for analyzing contents of crude ash (AOAC, 2016). Crude oil was extracted by diethyl ether using Soxhlet extractor (Soxtec System HT 1043 extraction unit, Foss Tecator, Sweden), and then the extract was weighed (Kim et al., 2007). CP was analyzed according to semimicro-Kjeldhl method using Auto Sampler System (Kjeltec 2400 AUT, Foss Tecator, Sweden) (Kim et al. 2007).

3. Analysis of feed value

Contents of NDF and ADF also were measured according to the recommendation of AOAC (2016). NDF and ADF of the samples were measured by Goering and Van Soest (1970) and Van Soest and Robertson (1980) modified methods using fiber analyzer (ANKOM2000, ANKOM Technology, USA). The each ground sample of 0.5 g was used for NDF and ADF analysis. When neutral detergent solution (FND20C, ANKOM Technology, USA), sodium sulfate (Na_2SO_3), and thermally stable alpha-amylase were used for analyzing NDF, acid detergent solution (FAD20C, ANKOM Technology, USA) was added for ADF extraction. We modified the arithmetic expression of Lee et al. (2014) to calculate DDM, DMI, and RFV of the samples as following equation: DDM = 88.9 - (0.779 × ADF), DMI = 120/NDF, RFV = (DDM × DMI)/1.29.

4. Statistical Analysis

All data were subjected to analysis of variance for each character using SAS 9.2 (SAS Institute Inc., USA) software. The significance of treatment (harvesting stage), main effects (variety), and interactions (environmental conditions) were determined at the 0.05 probability levels. Multiple comparisons between samples were performed by the least significance difference (LSD) method based on three independent biological each (*n*=3) at the 0.05 probability level.

Ⅲ. Results

1. Weather conditions

The accumulated temperatures of Suwon region during whole soybean growing period in both 2015 and 2016 were not significantly different to that in the normal years (1981~2010). However, the respective amounts of precipitation during the periods in 2015 and 2016 were severely declined to 62.3% and 37.9% relative to that of the normal years although the sunshine

Table 1. Weather conditions of Suwon, Republic of Korea from May 20th to October 25th, normal years (1981~2010), 2015, and 2016, growth duration of the soybeans plants weather situation

Factor	Year	Month						Total
		May	June	July	August	September	October	
Accumulated temperature (°C)	Normal years	224.2	651.8	769.7	791.7	624.5	369.3	3431.2
	2015	238.6	691.6	789.1	812.5	662.6	411.9	3606.3
	2016	251.5	695.5	807.5	859.8	681.8	422.8	3718.9
Precipitation (mm)	Normal years	32.0	131.0	350.6	298.8	151.3	46.9	1010.6
	2015	1.1	30.2	225.8	71.0	6.9	46.0	381.0
	2016	34.1	37.4	317.7	73.0	67.8	97.8	627.8
Duration of sunshine (hours)	Normal years	88.2	188.5	136.7	166.5	181.6	162.5	924.0
	2015	140.6	245.3	165.8	205.7	241.6	183.9	1182.9
	2016	102.6	235.6	146.8	230.9	163.4	148.8	1028.1

duration were greater by 258.9 and 104.1 h, respectively (Table 1). In particular, the amounts of precipitation in June and September of both years, which are early stage of growth and maturing stage of soybean, respectively, were significantly lower than those of the normal years (Table 1).

2. Evaluation and selection of soybean for forage potential

To select appropriate soybean varieties for analyzing feed value, we investigated characteristics of growth, yield, and CP in seeds of all of the examined soybeans. Days to flowering of OT89-05 in both years were the smallest among the soybeans while that of Jinpung was over 60 days (Table 2). However, the average days to flowering of all of the soybeans in 2015 was longer than that in 2016 although the days to maturity of the soybeans were statistically similar between both years (Table 2). Based on the growth habits, the soybeans were separated into three maturity ecotype groups, early, middle, and late (Table 2). Jinpung in both years had the longest length of stem when yields of Pungwon were the highest among the soybeans (Table 2). Contents of CP in seeds of OT93-26, Geomjeongsaeol, and Pungwon in both years were the highest in each ecotype group (Table 2). Depending on these results, we selected a total of

Table 2. Characteristics of growth, yield, and crude protein (CP) of soybean ecotypes

Variety	Ecotype	Days to flowering (DAS)			Days to maturity (DAF)			Stem length at R6 stage (cm)			Matured seed yield (kg/10a)			CP in matured seeds (%)		
		2015	2016	Avg.	2015	2016	Avg.	2015	2016	Avg.	2015	2016	Avg.	2015	2016	Avg.
OT89-05	early	38	32	35	56	59	57	41.3	48.2	44.8	103	113	108	34.7	35.4	35.0
OT93-26		38	33	36	56	58	57	62.2	55.4	58.8	114	124	119	36.5	37.2	36.8
OT93-28		40	34	37	56	58	57	52.2	58	54.5	106	118	112	35.5	36.0	35.7
SubAvg.		39	33	36	56	58	57	51.9	53.9	52.7	108	118	113	35.6	36.2	35.8
Geomjeongsaeol	middle	48	43	45	57	59	58	36.8	43.9	40.4	148	161	155	40.6	41.1	40.9
Heugsung		56	50	53	57	59	58	53.8	53.2	53.5	203	216	209	36.6	37.3	37.0
Joyang 1		56	51	54	57	60	58	55.1	55	55.1	280	289	285	38.3	38.7	38.5
SubAvg.		53	48	51	57	59	58	48.6	50.7	49.7	210	222	216	38.5	39.0	38.8
Mallikong	late	62	59	60	58	59	59	58.6	56	57.3	256	269	263	38.8	38.7	38.8
Pungwon		63	58	61	57	61	59	61.1	53.9	57.5	303	311	307	39.5	39.8	39.6
Jinpung		66	60	63	59	60	60	61.8	56.7	59.3	290	303	296	37.9	38.2	38.1
SubAvg.		64	59	61	58	60	59	60.5	55.5	58.0	283	294	289	38.7	38.9	38.8
Avg.		49			58			53.5			206			37.8		
p-value		0.00^{*}			0.15^{ns}			0.01^{*}			0.01^{*}			0.01^{*}		
LSD		3.60			-			3.64			8.30			0.58		

Avg.: average (n=3), ^{ns}: non-significant ($p \geq 0.05$), LSD: least significant difference (at $^{*}p<0.05$ significant), DAS: days after sowing, DAF: days after flowering

Table 3. Yield of dry matter of three soybeans, OT93-26, Geomjeongsaeol, and Pungwon harvested at R5 (beginning seed development)- and R6 (full seed)-reproductive stages

Variety	Dry matter yield (t/ha)		R6/R5 ratio
	R5	R6	
OT93-26	7.3	9.3	1.28
Geomjeongsaeol	6.0	7.0	1.17
Pungwon	6.2	8.4	1.36
Avg.	7.3		1.27
p-value	0.01*		0.01*
LSD	1.08		0.10

Avg.: average (n=3), LSD: least significant difference (at $^{*}p<0.05$ significant) three varieties with high protein content in seeds, OT93-26, Geomjeongsaeol, and Pungwon, because protein is very important as a nutrient to evaluate livestock forage.

3. Plant harvesting time

Days to harvesting of the R5 stage-OT93-26 was the shortest, 55 days, whereas that of Pungwon harvested at R6 was 103 days (Fig. 2). The dry matter yields of OT93-26 was the highest at both R5 and R6 stages (Table 3) although the lowest ratio of DM yield was showed in the R5-harvested OT93-26 and Pungwon (Fig. 3). All of three soybeans at R6 stage had a greater DM yield than those at R5 stage (Table 3). We measured R6/R5 ratio of DM to provide the optimum harvesting stage of respective soybean. However, the R6/R5 ratio of dry matter of Pungwon was higher than that of the other soybeans and Geomjeongsaeol showed the lowest ratio (Table 3).

4. Analysis of feed value

Contents of crude ash and crude fiber in Pungwon harvested at R5 stage were the highest, but the R5-harvested OT-93-26 contained the lowest (Fig. 4). Crude oil of the R6-harvested soybeans was significantly higher than those of the R5-harvested (Fig. 4). Geomjeongsaeol at both stages contained a higher CP than the other varieties (Fig. 4). Contents of NDF and ADF of

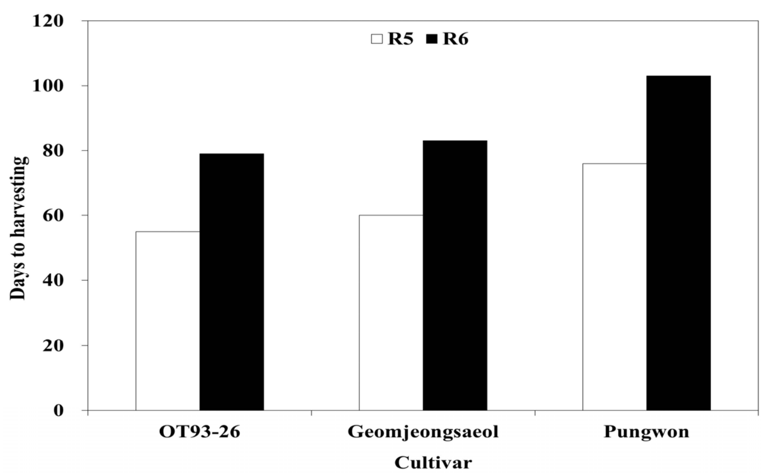

Fig. 2. Days to harvesting of three soybeans, OT93-26, Geomjeongsaeol, and Pungwon at R5 (beginning seed development)- and R6 (full seed)-reproductive stages.

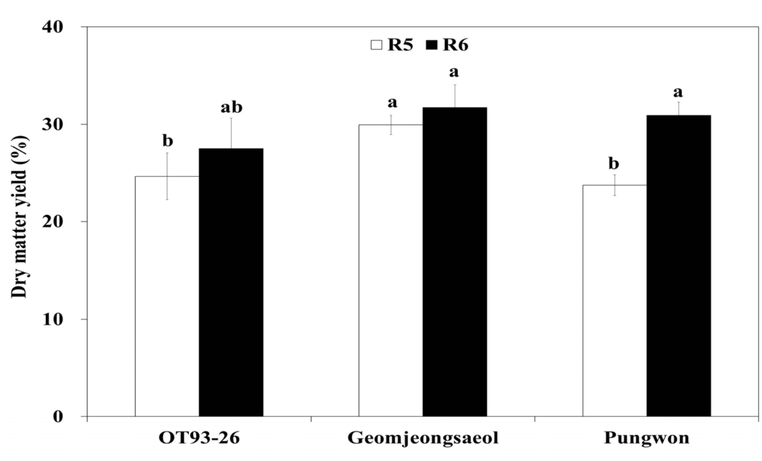

Fig. 3. Comparison of dry matter yield of three soybeans, OT93-26, Geomjeongsaeol, and Pungwon, harvested at R5 (beginning seed development)- and R6 (full seed)-reproductive stages. The treatments indicated by the different letters are significantly different at p<0.05 (n=3).

Pungwon harvested at R5 stage were the highest whereas the R6-harvested Geomjeongsaeol had the lowest contents (Table 4). On the contrary, Pungwon harvested at R5 showed the lowest DDM, DMI, and RVF while those in Geomjeongsaeol at R6 were the highest (Table 4). DDM, DMI, and RVF of Geomjeongsaeol and Pungwon harvested at R6 stage were higher than those at R5 stage, but in case of OT93-26 those at R6 stage were lower rather than those at R5 stage (Table 4).

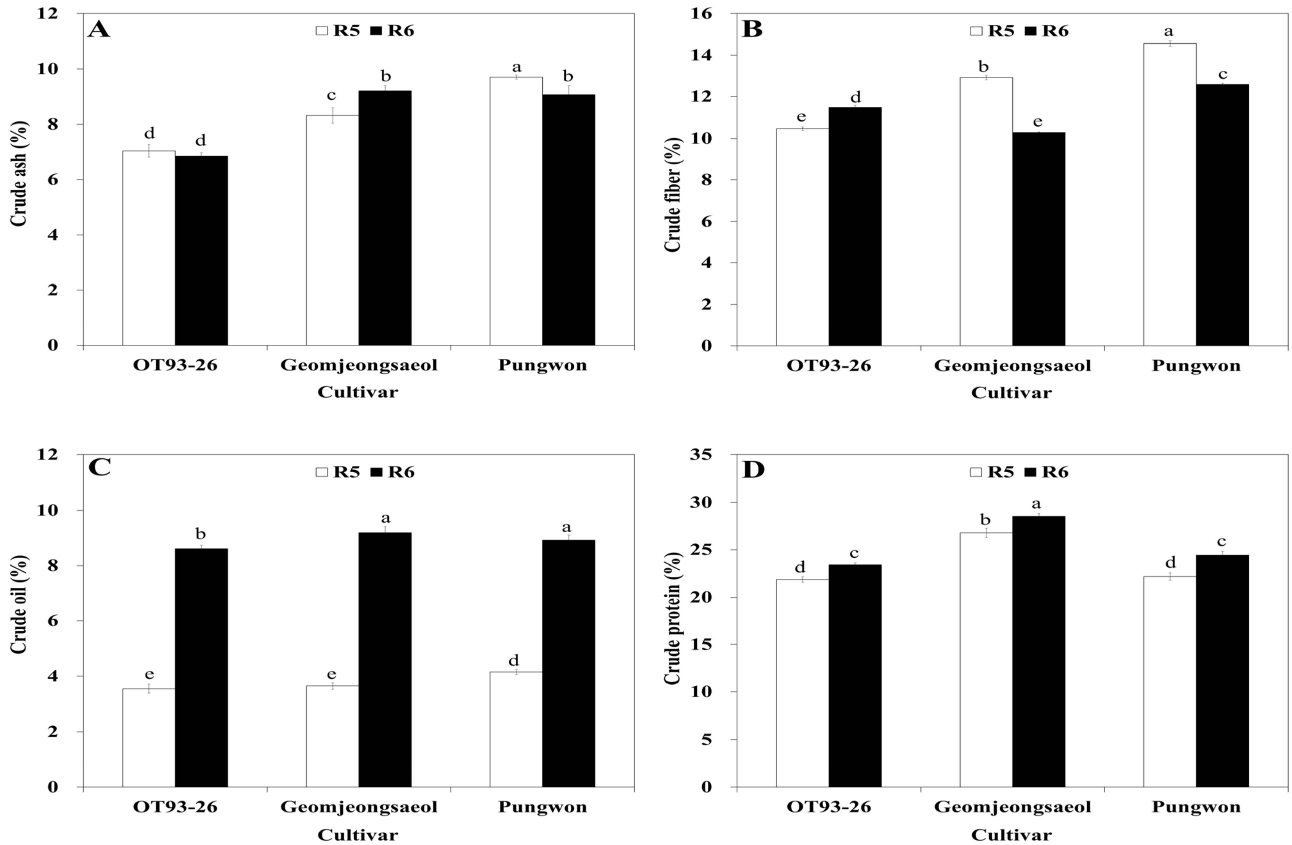

Fig. 4. Contents of crude ash (A), crude fiber (B), crude oil (C), and crude protein (D) at R5 (beginning seed development)- and R6 (full seed)-stage of three soybeans, OT93-26, Geomjeongsaeol, and Pungwon. The treatments indicated by the different letters are significantly different at $p<0.05$ ($n=3$).

Table 4. Analysis of neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) in R5 (beginning seed development) - and R6 (full seed)-stage soybeans

Variety	(stage)	NDF (%)	ADF (%)	DDM (%)	DMI (%)	RVF
OT93-26	R5	35.7	28.5	66.7	3.4	173.8
	R6	37.0	30.4	65.2	3.2	163.8
Geomjeongsaeol	R5	47.7	38.8	58.7	2.5	114.4
	R6	34.7	28.7	66.5	3.5	178.3
Pungwon	R5	48.6	41.9	56.2	2.5	107.6
	R6	39.5	29.5	65.9	3.0	155.2
Avg.		40.6	33.0	63.2	3.0	148.8
p-value		0.01*	0.01*	0.01*	0.01*	0.03*
LSD		0.40	0.40	0.28	0.06	1.98

Avg.: average ($n=3$), LSD: least significant difference (at $^{*}p<0.05$ significant)

Ⅳ. Discussion

The responses of crops by weather conditions are quite complex and difficult to describe. Previous studies had reported that weather conditions, such as accumulated temperature, precipitation, and sunshine duration, were highly related to various agricultural performances of soybean, growth and development (Purcell et al., 2014; Park et al., 2016), seed yield and yield components (Frederick et al., 2001; Kumar et al., 2008; Park et al., 2016), and oil and protein contents (Piper and Boote, 1999). Our results were similar to the previous results that drought-stress had resulted in decrease of seed yield and yield components (Frederick et al., 2001), and that an earlier flowering and maturity were caused by shorter summer day length and warmer temperatures (McWilliams et al., 2015) although there were different from the other previous report that the increased sunshine duration affects to the increase of soybean yield (Kumar et al., 2008). In addition, stem lengths of the soybean in 2015 and 2016 were not different, but Specht et al. (2001) had reported that the stem length of soybean was decreased under drought stress conditions. However, our results showed that the severely decreased precipitation of 2015 compared to that of 2016 didn't result in a significant difference of CP contents in seeds between 2015 and 2016. For these results, we assumed that weather conditions are likely to affect various agricultural performances, but could not estimate a critical major environmental factor because agricultural traits were complicatedly affected by diverse weather conditions, especially accumulated temperature, precipitation, and sunshine duration.

Willard (1925), Munoz et al. (1983), and Hintz et al. (1992) had recommended from R6 to R7 as an optimum harvesting stage for forage soybean although Lee et al. (2014) had determined that R6 stage of both lines derived from *G. soja* × *G. max* and cultivated soybean is the optimum stage for harvesting based on forage yield and quality. Depending on these recommendations, we harvested at R5 and R6 stages of the soybeans to evaluate feed value and usability of the soybean plants with or without full filled seeds, respectively, which contain high quality nutrients including protein for human being and animals.

Intercropping and multiple cropping are necessary for intensifying usability of farmland to satisfy the increasing demand for food, feed, fiber, and industrial crops. However, harvesting stages of forage crops with high yield and quality are very important to successfully realize the farming systems. All of the soybeans are shorter in days to harvesting than the forage corn and rice, which the optimum harvesting stages are 35~42 days after silking (Chung et al., 2010) and 30 days after heading (NICS, 2006), respectively. This result implied that the triple cropping system using summer forage corn (Lee, 2015) could be substitute for a cropping system using forage soybean, and soybean-used cropping models could be more various than the corn-used.

Ratio of forage DM yield makes a decision an optimum harvesting stage of each forage crop because the dry condition of forage matters highly affects to forage yield and quality, such as thermal denaturation, vitamin A and E contents, nutrient loss, fermentation, digestibility (Chung et al., 2010). In previous studies (Blount et al., 2002; Chung et al., 2010; Lee et al., 2014), the ratio of dry matter yield of soybeans from R5 to R7 were in range of 25~30%. Based on these previous results, we assumed that Geomjeongsaeol as a suitable forage soybean can be harvested at R5 and R6 stage in yield and ratio of DM although the yields at both stages are lower rather than the others, and that R6 of OT93-26 and Pungwon is the optimum stage than R5.

Livestock producers provide legume crops such as alfalfa to increase protein intake (Rotz et al., 1999; Blount et al., 2002). Soybean which is similar to feed value of alfalfa was used as a fodder to provide high-quality protein and digestible energy material for livestock (Blount et al., 2002) because proteins in soybean have high solubility and degradability by ruminant bacteria (Russell et al., 1992). Our data which showed over 21.0% CP in all of the R5- and R6-harvested soybean plants was similar to the results of Blount et al. (2002) and Lee et al. (2014) which CP of the tested forage soybeans was in a range of 16.6 to 25.8%. Therefore, our study showed that soybean could be a better substitute for the imported alfalfa in domestic, and be an alternative protein supplement when other forage crops are unavailable to provide enough protein, since it has comparatively higher CP content.

Based on legume hay grading system developed by Rohweder et al. (1987) and promoted by the America Forage and Grassland Council (AFGC), the 1st grade of legume hay has a feed value of over 19% CP, 65% DDM, 3.0% DMI and 151% RFV, and under 40% NDF and 31% ADF. However, OT93-26 harvested at R5 and R6, and Geomjeongsaeol and Pungwon harvested at R6 correspond to the 1st grade legume hay grading system.

In conclusion, soybeans can be alternative forage with high feed value with or without seed for livestock. Although early-maturing soybean, OT-89-05, was for the 1st grade legume hay, and middle and late-maturing soybeans, Geomjeongsaeol and Pungwon harvested at only R6 stage, were evaluated in the 1st grade, we could not determine whether the flowering and maturity times were linked to the forage yield and quality or not because correlation between the days and its yield or quality was not significant. Nevertheless, we assumed that quality of forage soybean was closely related to its genetic characteristic, namely variety. However, Geomjeongsaeol could be used for developing new forage soybean varieties with high feed value, and R6 stage was optimum in yield and quality to use soybean as forage.

Ⅴ. Acknowledgement

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Ⅵ. REFERENCES

Acikgoz, E., Sincik, M., Karasu, A., Tongel, O., Wietgrefe, G., Bilgili, U., Oz, M., Albayrak, S., Turan, Z.M. and Goksoy, A.T. 2009. Forage soybean production for seed in mediterranean environments. Field Crops Research. 110:213-218.

Acikgoz, E., Sincik, M., Wietgrefe, G., Surmen, M., Cecen, S., Yavuz, T., Erdurmus, C. and Goksoy, A. 2013. Dry matter accumulation and forage quality characteristics of different soybean genotypes. Turkish Journal of Agriculture and Forestry. 37:22-32.

AOAC. 2016. Official Methods of Analysis of the Association of Official Agricultural Chemists. 20th Edition. AOAC International, Rockville, MD, USA.

Bal, M.A. 2006. Effects of hybrid type, stage of maturity, and fermentation length on whole plant corn silage quality. Turkish Journal of Veterinary and Animal Sciences. 30:331-336.

Blount, A.R.S., Wright, D.L., Sprenkel, R.K., Hewitt, T.D. and Myer, R.O. 2002. Forage Soybeans for Grazing, Hay and Silage (SS-AGR-180). Retrieved from http://edis.ifas.ufl.edu.

Cho, C.H., Seung, Y.G. and Kim, S.M. 1994. Classification of Soybean Genotypes based on Seasonal Response of Flowering, and Maturity by Principal Component Analysis. Korean Journal of Breeding Science. 26:405-413.

Cho, N.K., Yun, S.T., Kang, H.S. and Cho, Y.I. 2003. Selection of forage soybean cultivars in Jeju region. Journal of the Korean Society of Grassland and Forage Science. 23:299-306.

Chu, Y.H., Oh, J.H., Chae, J.C., Seung, Y.K., Son, B.Y. and Chung, K.W. 1996. Variation of Flowering, Maturity and Morphological Characteristics in Summer Type Soybeans. Korean Journal of Breeding Science. 28:269-275.

Chung, E.S., Jo, M.H., Kim, J.K., Nam, D.W., Jin, S.J., Jang, S.Y. and Kang, H.S. 2010. Agronomic and Silage Traits of Corn over Time. Journal of the Korean Society of Grassland and Forage Science. 30:325-332.

Darmosarkoro, W., Harbur, M.M., Buxton, D.R., Moore, K.J., Devine, T.E. and Anderson, I.C. 2001. Growth development, and yield of soybean lines developed for forage. Agronomy Journal. 93:1028-1034.

Fehr, W.R., Caviness, C.E., Burmood, D.T. and Pennington, J.S. 1971. Stage of development descriptions for soybeans, Glycine max (L.) Merrill. Crop Science. 11:929-931.

Frederick, J.R., Camp, C.R. and Bauer, PJ. 2001. Drought-stress effects on branch and mainstem seed yield and yield components of determinate soybean. Crop Science. 41:759-763.

Goering, H.K. and Van Soest, P.J. 1970. Forage Fiber Analysis (apparatus, reagents, procedures and some applications). USDA Agricultural Handbook No. 379.

Hintz, R.W., Albrecht, K.A. and Oplinger, E.S. 1992. Yield and quality of soybean forage as affected by cultivar and management practices. Agronomy Journal. 84:795-798.

Islam, M.R., Ishida, M., Ando, S., Nishida, T. and Yoshida, N. 2004. Estimation of Nutritive Value of Whole Crop Rice Silage and Its Effect on Milk Production Performance by Dairy Cows. Asian Australasian Journal of Animal Sciences. 17:1383-1389.

Khan, N.A., Cone, J.W., Fievez, V. and Hendriks, W.H. 2012. Causes of variation in fatty acid content and composition in grass and maize silages. Animal Feed Science and Technology. 174:3-45.

Kim, S.L., Lee, Y.H., Chi, H.Y., Lee, S.J. and Kim, S.J. 2007. Diversity in lipid contents and fatty acid composition of soybean seeds cultivated in Korea. Korean Journal of Crop Science. 52:348-357.

Kim, Y.S., Myung, K.H. and Na, J.S. 1982. Nutritive values of soybean straws of the different varieties. Korean Journal of Animal Science. 24:422-426.

Kumar, A., Pandey, V., Shekh, A.M. and Kumar, M. 2008. Growth and yield response of soybean (Glycine max L.) in relation to temperature, photoperiod and sunshine duration at Anand, Gujarat, India. American-Eurasian Journal of Agronomy. 1:45-50.

Lee, E.J., Choi, H.J., Shin, D.H., Kwon, C.H., Shannon, J.G. and Lee, J.D. 2014. Evaluation of Forage Yield and Quality for the Accessions Derived from Inter-specific Cross between Wild and Cultivated Soybeans. Korean Journal of Breeding Science. 46:66-77.

Lee, J.D. 2014. Development of high quality forage soybean variety derived from wild soybean and establishment of soybean forage production. MAFRA. No. of publish registration: 11-1543000-000609-01.

Lee, S.H. 2015. Crops cultivation of Alternative rice by revenue model of high- production forage. Rural Development Administration (RDA). No. of project: PJ0088432013.

McWilliams, D.A., Berglund, D.R. and Endres, G.J. 2015. Soybean Growth and Management . North Dakota State University.

Ministry of Agriculture Food and Rural Affairs, Republic of Korea (MAFRA). 2016. Agriculture, Food and Rural Affairs Statistics Yearbook. Retrieved from http://lib.mafra.go.kr

Munoz, A.E., Holt, E.C. and Weaver, R.W. 1983. Yield and quality of soybean hay as influenced by stage of growth and plant density. Agronomy Journal. 75:147-148.

National Institute of Crop Science (NICS). 2006. Project report for rice research. pp. 222-224.

Park, M.R., Seo, M.J., Lee2, Y.Y. and Park, C.H. 2016. Selection of Useful Germplasm Based on the Variation Analysis of Growth and Seed Quality of Soybean Germplasms Grown at Two Different Latitudes. Plant Breeding and Biotechnology. 4:462-474.

Piper, E.L. and Boote, K.J. 1999. Temperature and cultivar effects on soybean seed oil and protein concentrations. Journal of the American Oil Chemists' Society. 76:1233-1241.

Purcell, L.C., Salmeron, M. and Ashlock, L. 2014. Arkansas Soybean Production Handbook: Soybean Growth and Development; http://www.uaex.edu/publications/pdf/mp197/ chapter2.pdf (accessed March 27, 2016).

Rohweder, D.A., Barnes, R.F. and Jorgensen, N. 1987. Proposed hay grading standards based on laboratory analyses for evaluating quality. Journal of Animal Science. 47:747-759.

Rotz, C.A., Satter, L.D., Mertens, D.R. and Muck, R.E. 1999. Feeding strategy, nitrogen cycling, and profitability of dairy farms. Journal of Dairy Science. 82:2841-2855.

Rural Development Administration (RDA). 2012. Agricultural Science Technology Standards for Investigation of Research.

Russell, B., O'Connort, J.D., Fox, D.G., Van Soest, P.J. and Sniffen, C.J. 1992. A Net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation. Journal of Animal Science. 70:3551-3561.

Shin, H.Y. 2008. Screening of soybean genetic resources for forage production. The paper for the degree of master of Gyeongsang National University.

Specht, J.E., Chase, K., Macrander, M., Graef, G.L., Chung, J., Markwell, J.P., Germann, M., Orf, J.H. and Lark, K.G. 2001. Soybean response to water: A QTL analysis of drought tolerance. Crop Science. 41:493-509.

Takagi, H., Hashimoto, Y., Yonemochi, C., Asai, Y., Yoshida, T., Ohta, Y., Ishibashi, T. and Watanabe, R. 2002. Digestibility of nutrients of roughages determined by total feces collection method in Thoroughbreds. Journal of Equine Science. 13:23-27.

USDA. 2009. Oilseeds: World Market and Trade. Table 03: Major Vegetable Oils: World Supply and Distribution at Oilseeds: World Markets and Trade Monthly Circular. FOP 1-09.

Van Soest, P.J. and Robertson, J.B. 1980. Systems of analysis for evaluating fibrous feeds. In: W.J. Pigden, C.C. Balch and M. Graham (Eds.), Standardization of Analytical Methodology in Feeds. International Research Development Center, Ottawa, Canada. pp. 49-60.

Willard, C.J. 1925. The time of harvesting soybeans for hay and seed. Agronomy Journal. 17:157-168.

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