

Research Article

Investigation of Forage Characteristics of Three Very Early-Maturing Italian Ryegrass (*Lolium multiflorum* Lam.)

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ABSTRACT

This study was conducted to investigate the forage characteristics of very early-maturing Italian ryegrass (IRG) three cultivars within September, 2021 to July, 2022 in Cheonan, Korea. We used three different cultivars of Italian ryegrass in this study "Greenfarm" "Greenfarm2ho" and "Greenfarm3ho". The results of heading date in this study, "Greenfarm" was recorded 3 days earlier than the other two cultivars, and its lodge tolerance score was the highest among the three. However, in case of plant length, there was no significant difference in whole cultivars, in addition disease resistance, insect resistance and cold tolerance were not significantly different in three cultivars. The forage productivity of "Greenfarm2ho" was recorded the highest, especially the 1st harvesting of "Greenfarm2ho" yielded significantly the highest and superior to other varieties. As a result of feed value analysis, three cultivars were generally superior to overseas varieties and in particular, "Greenfarm2ho" was recorded to have excellent value because of the lowest NDF and ADF content. On the other hand, there was no significant difference in crude protein content among three varieties. In case of the monosaccharides content "Greenfarm3ho" had significantly higher glucose content than other two varieties, therefore the "Greenfarm" has advantage for preparing high quality of silage. In contrast, there was no significant difference among three varieties in fructose content.

(Key words: Italian ryegrass, Variety, Very early-maturing, Forage characteristics)

I. INTRODUCTION

Italian ryegrass (*Lolium multiflorum* Lam.) is an overwintering or annual herbage grass native to the Mediterranean coast. While Italian ryegrass has high yield potential, and excellent feed value and palatability for livestock, it is susceptible to drought. Since it is resistant to waterlogging, however, studies related to its cultivation in paddy fields have been actively conducted in South Korea (Lee et al., 2016; Lim et al., 2007). Studies on Italian ryegrass in South Korea have focused on its growth characteristics, productivity, and feed value (Choi et al., 2000; Choi et al., 2007) thus far, whereas studies on Italian ryegrass outside South Korea have mainly focused on the correlation between the carbohydrate content stored in Italian ryegrass stubble and its regrowth (Gonzalez et al., 1989) and the quality of Italian ryegrass silage based on its sugar content (Shao et al., 2005). While there are currently 21 Italian ryegrass cultivars in South Korea (three very early-maturing cultivars, five early-maturing cultivars, six medium-maturing cultivars, and seven late-maturing cultivars), there is a scarcity of research into

the sugar content by cultivar. The sugar content of grass is not only closely associated with its palatability, but also plays an essential role in the regrowth of grass and is also known to have an important influence on the quality of silage produced (Shao et al., 2007; Shao et al., 2005).

Consistent efforts have been made to develop new cultivars to secure the diversity of Italian ryegrass cultivars in South Korea. Very early-maturing Italian ryegrass has a short harvest time with early heading dates, thereby having the advantage of allowing an efficient crop combination with little effect on the sowing period of summer crops. Very early-maturing Italian ryegrass cultivars developed in South Korea include "Greenfarm" (applied for patenting in 2011), "Greenfarm2ho" (applied for patenting in 2012), and "Greenfarm3ho" (applied for patenting in 2015). Ji et al. (2011) reported that very early-maturing Italian ryegrass "Greenfarm" had good feed value with early heading before May, and a dry matter productivity equivalent to that of "Florida 80," an imported cultivar. Based on the study by Ji et al. (2013) conducted from 2009 to 2011, "Greenfarm2ho" had early heading before May, a dry matter productivity equivalent

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to that of "Florida 80," and outstanding feed value. The heading date of "Greenfarm3ho" was found to be two days earlier than that of "Greenfarm," and it had a dry matter productivity equivalent to that of "Greenfarm," but with much superior feed value (Ji et al., 2015). The results of previous studies suggested that the three very early-maturing Italian cultivars developed in South Korea had very early heading dates with forage value compared to that of the imported cultivar, "Florida 80." However, it is difficult to clearly determine the difference between domestic cultivars because of the cultivar comparison research was not conducted. The only study conducted on the cultivars in the same year and under the same environmental conditions was the study by Ji et al. (2015). Since Ji et al. (2015) only dealt with "Greenfarm" and "Greenfarm3ho," it is necessary to conduct research on "Greenfarm2ho."

Therefore, this study aims to investigate the growth characteristics, productivity, feed value, and sugar content of the three very early-maturing Italian ryegrass cultivars developed in South Korea (Greenfarm, Greenfarm2ho, and Greenfarm3ho).

II. MATERIALS AND METHODS

To investigate the characteristics of the three very early-maturing Italian ryegrass cultivars developed in South Korea, this study was conducted from September 2021 to July 2022 in a test field (36° 55' 54.1" N, 127° 06' 21.9" E) of the Grassland and Forages Division of the National Institute of Animal Science, located in Cheonan, Chungcheongnam-do. Three domestically cultivated cultivars of Italian ryegrass, "Greenfarm," "Greenfarm2ho," and "Greenfarm3ho," which were used.

1. Fertilizer Level and Seeding Rate

After sowing the three Italian ryegrass cultivars on September 20, 2021, the first harvest was carried out on May 3, 2022; the second harvest was carried out on June 09, 2022 to investigate the regrowth of each variety. The seeding rate of Italian ryegrass was set at 30 kg/ha, and trampling was performed immediately after sowing to evaluate the wintering ability of each variety without using different herbicides during the cultivation period. Since Italian ryegrass is known to react sensitively to nitrogen fertilizers (Redfean et al., 2002), the fertilizer level was set at N-P₂O₅-K₂O = 200-150-150 kg/ha with the aim of providing a

large amount of nitrogen. As for the fertilization method, 20% of nitrogen was applied by base-dressing, 50% at the beginning of growth in early spring, and 30% after the first harvest. 50% of phosphoric acid and potassium were applied by base-dressing and 50% at the beginning of growth in early spring.

2. Investigation of Growth Characteristics

Plant height was measured from the ground to the tip of the stem or leaf of the plant on the day of harvest and expressed in cm. The heading date was investigated by monitoring every day at 9 am, and the date on which more than 40% of the ears were formed was considered the heading date of each cultivar and marked (month and day). The growth characteristics of Italian ryegrass (cold resistance, lodging tolerance, and emergence rate) were rated from 1 to 9, with 1 indicating good or excellent plants and 9 indicating bad or poor plants.

3. Investigation of Yield

The flesh weight yield for each Italian ryegrass cultivar was used after harvesting the entire test site and then measuring the weight and converting it to the yield per 1 ha. In the process of harvesting the flesh weight yield, 300 to 400 g of samples were collected for each test site. After drying for 72 hours or more in a circulating hot air dry oven at 65 °C, the weight of the dry sample was measured, and the forage productivity parameters were calculated by using the following equation.

- Dry matter (DM, %) = [dry sample / flesh sample × 100]
- Dry matter yield (DMY, kg/ha) = [flesh weight yield × dry matter %]

4. Investigation of Feed Value and Sugar Content

The crude protein content of Italian ryegrass was analyzed using the association of official analytical chemists methods (1990) the total digestible nutrient (TDN) was calculated using the method outlined by Menke and Huss (1980), and the acid detergent fiber (ADF) content and neutral detergent fiber (NDF) content were analyzed using the method described by Goering and Van Soest (1970). Dry matter intake (DMI), digestible dry matter (DDM) and relative feed value (RFV) were calculated according to the following formula (Goering

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and Van Soest, 1970).

- TDN = 88.9 - (0.79 × ADF %)
- DDM = 88.9 - (0.779 × ADF %)
- DMI (% of Body Weight) = 120 / (NDF %)
- RFV = (DDM × DMI) / 1.29

For the sugar content of Italian ryegrass determined by high-performance liquid chromatograph (Thermo Dionex Ultimate 3000; Thermo Fisher Scientific, USA) equipped with corona discharge detector (Corona Veo RS; ESA Chelmsford, USA) and ULTRON AF-HILIC-CD 5um (4.6 × 250 mm) chromatography column.

5. Statistical analysis

The data collected were analyzed using the statistical software package SPSS 12.0 (SPSS Inc., Chicago, IL). The continuous variables were presented as the mean ± standard error, and differences were verified using Duncan's multiple range test.

III. RESULTS AND DISCUSSION

1. Meteorological Characteristics

The meteorological data during the Italian ryegrass cultivation period is show in Table 1. In this study, Italian ryegrass was sown in September, harvested primarily in May, and harvested

secondarily in June. From September to December after sowing, the temperature was similar to that of a normal year, and the wintering ability of very early-maturing Italian ryegrass cultivars was superior. The average temperature in January and February was slightly lower than that of a normal year, but considering the emergence of Italian ryegrass after that, the effect of temperature on the emergence and growth of plants seemed negligible. The average temperature from March to June was similar to that of a normal year.

As for precipitation, it was very high in September compared to that of a normal year, but the effect of precipitation in September on plant growth seemed negligible as Italian ryegrass is resistant to waterlogging. The total precipitation in October and November was similar to that of a normal year, while the total precipitation in December through February relatively low. The total precipitation from March to June was considerably different from that of a normal year. In particular, the precipitation in June, when the second harvest was carried out, was very high compared to that of a normal year.

2. Growth Characteristics

The results of the forage growth characteristics of the three very early-maturing Italian ryegrass cultivars are presented in Table 2. The heading dates of the very early-maturing Italian ryegrass cultivars, "Greenfarm," "Greenfarm2ho," and "Greenfarm3ho," were different. Among them, the heading date of "Greenfarm" was the earliest, on April 21. Compared to the results of the

Table 1. Comparative mean temperature (°C) and total precipitation (mm) over the previous decade and during the experimental in the study area in Cheon-an, South Korea

Year & Month / Parameters	Average of temperature(°C)		Total precipitation (mm)		
	Experimental period	Previous decade	Experimental period	Previous decade	
2021	Sep.	20.9	20.2	250.8	112.6
	Oct.	14	13.51	49.5	60.6
	Nov.	6.9	7	67.9	60.61
	Dec.	0.2	-0.63	5.4	29.99
2022	Jan.	-2.7	-1.97	3.3	17.46
	Feb.	-1.4	0.3	3.3	27.93
	Mar.	6.9	6.35	57.6	35.7
	Apr.	13.1	12.12	51.6	67.95
	May	17.4	17.83	9.8	64.4
	June	22.5	22.27	168	72.94

Source : Korea Meteorological Administration.

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Table 2. Growth characteristics of three very early-maturing cultivars of Italian ryegrass developed in South Korea

Cultivars / Parameters	Heading date	lodging tolerance (1-9)	Disease resistance (1-9)	Insect resistance (1-9)	Cold tolerance (1-9)	Plant height (cm)
Greenfarm	21 st April	3.67 ^a	1	1	1	96.60 ^{ns}
Greenfarm 2ho	25 th April	1.67 ^b	1	1	1	96.60
Greenfarm 3ho	24 th April	1.67 ^b	1	1	1	99.13
SEM	-	0.44	-	-	-	1.21

^{a-b} means within a row without a common superscript letter are significantly different ($p < 0.05$); ^{ns} means not significantly different; SEM: standard error of the mean.

Table 3. Forage productivity (fresh yield, dry matter, dry matter yield) of very early-maturing cultivars of Italian ryegrass developed in South Korea

Cultivars / Parameters	Fresh yield (kg/ha)			Dry matter (%)		Dry matter yield (kg/ha)		
	1 st	2 nd	Total	1 st	2 nd	1 st	2 nd	Total
Greenfarm	44,333 ^b	15,333 ^{ns}	59,667 ^{ns}	22.70 ^{ns}	29.29 ^{ns}	10,078 ^{ns}	4,262 ^{ns}	14,339 ^{ns}
Greenfarm 2ho	51,167 ^a	21,000	72,167	21.00	30.01	10,705	6,282	16,987
Greenfarm 3ho	46,167 ^{ab}	19,667	65,833	22.50	30.77	10,385	6,061	16,446
SEM	1,761	2,378	3,733	0.83	2.19	537	535	792

^{a-b} means within a row without a common superscript letter are significantly different ($p < 0.05$); ^{ns} means not significantly different; SEM: standard error of the mean.

study by Ji et al. (2011) conducted from 2009 to 2010, the heading date of "Greenfarm" was earlier by seven days. The heading dates of the cultivars in this study may have been earlier than in previous studies due to the higher average temperature with lower precipitation in April when Italian ryegrass came into ears. Lodging resistance was 3.67 for "Greenfarm," which was statistically lower than that of "Greenfarm3ho" ($p < 0.05$). All three very early-maturing Italian ryegrass cultivars exhibited excellent disease resistance, insect resistance, and cold resistance when grown in Cheonan. Although there was no significant difference in plant height among cultivars, "Greenfarm3ho" was arithmetically superior in height at 99.13 cm, with "Greenfarm" and "Greenfarm2ho" being 99.60 cm in height.

3. Forage productivity

Forage yield of the three very early-maturing Italian ryegrass cultivars are given in Table 3. The average primary flesh weight yield of the three very early-maturing Italian ryegrass cultivars was 47,222 kg/ha, and among them, that of "Greenfarm2ho" was significantly higher at 51,167 kg/ha ($p < 0.05$). The primary flesh weight yield of "Greenfarm" was 44,333 kg/ha, which was about 6,800 kg/ha less than that of "Greenfarm2ho." There

was no significant difference among varieties in terms of secondary flesh weight yield. Although there was no statistical difference in the total flesh weight yield among varieties, that of "Greenfarm2ho" was arithmetically superior. The average primary dry matter of Italian ryegrass was 22.06%, with no significant difference among varieties. The secondary dry matter was higher than the primary dry matter in general. The dry weight yield was calculated based on the flesh weight yield and dry matter. There was a slim, but not significant, difference among cultivars in terms of primary dry weight yield, which was 10,389 kg/ha on average. The dry weight yield of forage barley, a winter crop mainly used in South Korea other than Italian ryegrass, has been reported to be 5.58-6.84 tons/ha and that of rye, 7.05-10.4 tons/ha (Hwangbo and Jo, 2014). Therefore, the forage yield of the three very early-maturing Italian ryegrass cultivars used in this study seemed to be economical in terms of yield when grown in South Korea. Other than arithmetic differences, there were no significant differences in the secondary dry weight yield among the Italian ryegrass cultivars, the average of which was 5,535 kg/ha. Italian ryegrass is mainly harvested by cutting once when cultivated in South Korea. Considering that the dry matter yield was about 9.6 tons/ha during the first cutting in other countries

(Andrzejewska et al., 2018), the dry weight yield in South Korea seemed excellent. In this study, the secondary harvest was used to more clearly examine the characteristics of the very early-maturing Italian ryegrass cultivars. The productivity of Italian ryegrass was much lower at the secondary harvest compared to that in the primary harvest. As an extended harvest period may cause difficulties in establishing a crop combination with summer crops, it seems desirable to use the first harvest only in the environment of South Korea.

4. Feed Value

Feed value of the three very early-maturing Italian ryegrass cultivars are shown in Table 4. The NDF content of "Greenfarm2ho" and "Greenfarm3ho" was 51.55% and 52.94%, respectively, which was significantly superior to that of "Greenfarm" ($p < 0.05$). The ADF content of "Greenfarm2ho" was 29.28 %, which was significantly greater than that of other cultivars ($p < 0.05$). "Greenfarm2ho" has been known to have superior feed value compared to the imported variety "Florida 80," with an NDF content of 52.6% and an ADF content of 31.7% (Ji et al., 2013). The feed value of "Greenfarm2ho" in this study was slightly higher than that in the previous study. The crude protein content of the very early-maturing Italian ryegrass cultivars was 7.59% on average. While Islam et al. (2000) reported the crude protein content of Italian ryegrass to be 7.6%, that of "Greenfarm" was 7.79%, indicating its superiority in crude protein content to that of foreign varieties.

The TDN content of "Greenfarm2ho" was 65.77%, which was significantly superior to that of other very early-maturing cultivars ($p < 0.05$), while it was significantly lower in "Greenfarm" at 64.08% ($p < 0.05$). As for summer oat (*Avena Sativa L.*), which had a similar harvest period to Italian ryegrass, the TDN content

was 59.71% when sown in late February (Hwangbo and Oh, 2017). As the TDN content of Italian ryegrass used in this study was superior to that of compared to summer oat, it is considered to be economical in terms of the nutritional value of grasses. The feed value of grass is used as a very important indicator to evaluate grass as a feed resource. In this study, "Greenfarm2ho" and "Greenfarm3ho" exhibited excellent feed value, and "Greenfarm" had significantly lower feed value than other cultivars with relatively high NDF and ADF contents ($p < 0.05$). Considering the results of the feed value analysis conducted in Japan which reported the NDF content of 48.3% and the ADF content of 35.4% when Italian ryegrass was harvested at the early stage of heading (Fariani et al., 1994), the three very early-maturing Italian ryegrass cultivars developed in South Korea seemed to have superior feed value compared to foreign varieties, despite the significant differences among varieties.

5. Sugar Content

Table 5 shows the sugar content analysis results of the three very early-maturing Italian ryegrass cultivars developed in South Korea. The average glucose content recorded was 11.18 g/kg, and among the very early-maturing Italian ryegrass cultivars, the glucose content of "Greenfarm3ho" was significantly superior at 14.59 g/kg than that of "Greenfarm" and "Greenfarm2ho" ($p < 0.05$). While there was no significant difference in fructose among varieties, the fructose content of "Greenfarm3ho" was the highest at 18.13 g/kg, and that of "Greenfarm" was the lowest at 16.08 g/kg. The free sugar content in forage crops is known to have a significant effect on fermentation during silage preparation (Lee, 2012). With a high free sugar content, ammonia generation and butyric acid production are reduced, while lactic acid production is improved (Davies et al., 1998). In particular,

Table 4. Feed values (NDF, ADF, CP, TDN, DDM, DMI and RFV) of very early-maturing cultivars of Italian ryegrass developed in South Korea

Cultivars / Parameters	NDF ¹ (%)	ADF ² (%)	CP ³ (%)	TDN ⁴ (%)	DDM ⁵ (%)	DMI ⁶ (%)	RFV ⁷
Greenfarm	54.74 ^b	31.42 ^b	7.79 ^a	64.08 ^b	64.42 ^b	2.19 ^b	110 ^b
Greenfarm 2ho	51.55 ^a	29.28 ^a	7.43 ^b	65.77 ^a	66.09 ^a	2.33 ^a	119 ^a
Greenfarm 3ho	52.94 ^a	30.46 ^{ab}	7.57 ^{ab}	64.84 ^{ab}	65.17 ^{ab}	2.27 ^a	115 ^a
SEM	0.42	0.34	0.26	0.26	0.26	0.02	1.37

^{a-b} means within a row without a common superscript letter are significantly different ($p < 0.05$); ^{ns} means not significantly different; SEM: standard error of the mean; NDF¹ : neutral detergent fiber; ADF²: acid detergent fiber; CP³ : crude protein; TDN⁴ : total digestible nutrient; DDM⁵ : digestible dry matter; DMI⁶ : dry matter intake; RFV⁷: relative feed value.

Table 5. The composition of monosaccharide (glucose, fructose and galactose) of very early-maturing cultivars of Italian ryegrass developed in South Korea

Cultivars / Parameters	Glucose (g/kg)	Fructose (g/kg)	Galactose (g/kg)
Greenfarm	9.18 ^b	16.08 ^{ns}	Undetected
Greenfarm 2ho	11.66 ^b	17.93	Undetected
Greenfarm 3ho	14.56 ^a	18.13	Undetected
SEM	0.814	0.836	-

^{a-b} means within a row without a common superscript letter are significantly different ($p < 0.05$); ^{ns} means not significantly different; SEM: standard error of the mean. Undetected means less than 20ppm.

Shao et al. (2005) reported that the glucose content gradually decreased until day 0.5 after silage preparation, but completely disappeared in five days. Glucose is a monosaccharide that microorganisms can use at the initial stage of fermentation when preparing silage, and has a great influence on the quality of silage. Since the glucose content of "Greenfarm3ho" was significantly high in this study, an excellent quality of silage is expected.

IV. CONCLUSION

This study aimed to investigate the characteristics of the three very early-maturing Italian ryegrass cultivars developed in South Korea under the same spatiotemporal conditions. This study was conducted from September 2021 to July 2022 in the test field of the National Institute of Animal Science, located in Cheonan, Chungcheongnam-do, with a total of three cultivars, "Greenfarm," "Greenfarm2ho," and "Greenfarm3ho." The results of our study showed that the heading date of "Greenfarm" was more than three days earlier than that of other very early-maturing Italian ryegrass cultivars and had excellent lodging resistance. There were no clear differences in plant height, disease resistance, insect resistance, and cold resistance, among the cultivars. "Greenfarm2ho" showed relatively high forage yield compared to other cultivars. In particular, its primary flesh weight yield was superior to that of "Greenfarm" and "Greenfarm3ho." As a result of the feed value analysis, the feed value of the three very early-maturing Italian ryegrass cultivars developed in South Korea was generally superior to that of varieties in other countries. In particular, "Greenfarm2ho" demonstrated excellent food value with the lowest NDF and ADF contents, and "Greenfarm" had the highest crude protein content. As a result of the sugar

content analysis, "Greenfarm3ho" had a significantly higher glucose content than other varieties, which is expected to be advantageous in terms of the quality of silage produced.

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VI. REFERENCES

- Andrzejewska, J., Contreras-Govea, F.E., Berzagh, P. and Albrecht, K.A. 2018. Forage accumulation and nutritive value of Italian ryegrass-Kura clover mixture in central Europe. *Crop Science*. 58:443-449.
- AOAC. 1990. Official methods of analysis (15th ed.). 1995 Association of Official Analytical Chemists, Washington DC.
- Choi, G.J., Lim, Y.C., Kim, K.Y., Sung, B.R., Rim, Y.W., Kim, M.J., Lim, K.B. and Seo, S. 2006. A cold tolerant and high yield Italian ryegrass new variety, 'Kowinner'. *Journal of the Korean Society of Grassland and Forage Science*. 26:171-176.
- Choi, G.J., Rim, Y.W., Kim, K.Y., Choi, S.H., Sung, B.R., Kim, W.H., Shin, D.E. and Lim, Y.C. 2000. A cold tolerant and high yielding Italian ryegrass (*Lolium multiflorum* L.) new variety 'Hwasan 101'. *Journal of the Korean Society of Grassland and Forage Science*. 20:1-6.
- Davies, D.R., Merry, R.J., Williams, A.P., Bakewell, E.L., Leemans, D.K. and Tweed, J.K.S. 1998. Proteolysis during ensilage of forage varying in soluble sugar content. *Journal of Dairy Science*.

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81:444-453.

- Fariani, A., Warly, L., Matsui, T., Fujihara, T. and Harumoto, T. 1994. Rumen degradability of Italian ryegrass (*Lolium multiflorum*, L) harvested at three different growth stages in sheep. *AJAS*. 7(1):41-48.
- Gonzalez, B., Boucaud, J., Salette, J., Langlois, J. and Duyme, M. 1989. changes in stubble carbohydrate content during regrowth of defoliated perennial ryegrass (*Lolium perenne* L.) on two nitrogen levels. *Grass and Forage Science*. 44:411-415.
- Goring, H.K. and Van Soest, P.J. 1970. Forage fiber analysis. Agronomic Handbook No. 379. ARS. USDA, Washington DC.
- Hwangbo, S. and Jo, I.H. 2014. Effects of mixed sowing with legumes and applying cattle manure on productivity, feed values and stock carrying capacity of whole crop wheat in Gyeongbuk Regions. *Journal of the Korean Society of Grassland and Forage Science*. 34:52-59.
- Hwangbo, S. and Oh, M.G. 2017. Effects of seeding and harvest dates on the productivity, nutritive values, and livestock carrying capacity of spring-seeded oats (*Avena sativa* L.) in the Northern Gyeongbuk province. *Korean Journal of Agricultural Science*. 44(3):400-408.
- Islam, M., Abe, H., Hayashi, Y. and Terada, F. 2000. Effects of feeding Italian ryegrass with corn on rumen environment, nutrient digestibility, methane emission, and energy and nitrogen utilization at two intake levels by goats. *Small Ruminant Research*. 38(2):165-174.
- Ji, H.C., Choi, G.J., Lee, S.H., Kim, K.Y., Lee, K.W., Park, N.G. and Lee, E.S. 2013. A very early maturing Italian ryegrass (*Lolium multiflorum* L.) new variety 'Green Farm II'. *Journal of the Korean Society of Grassland and Forage Science*. 33:1-10.
- Ji, H.C., Lee, S.H., Yoon, S.H., Kim, K.Y., Choi, G.J., Park, H.S., Park, N.G., Lim, Y.C. and Lee, E.S. 2011. A very early maturing Italian ryegrass (*Lolium multiflorum* L.) new variety 'Green Farm' for double cropping system. *Journal of the Korean Society of Grassland and Forage Science*. 31:9-14.
- Ji, H.C., Whang, T.Y., Kim, K.Y., Choe, H.S., Hong, K.H., Choa, K.W., Lee, K.W. and Lee, S.H. 2015. A very early-maturing Italian Ryegrass (*Lolium multiflorum* Lam.) new variety, 'Greenfarm3ho'. *Journal of the Korean Society of Grassland and Forage Science*. 35(1):31-35.
- Lee, H.W., Lee, H.J., Kim, W.H., Yoon, B.K. and Ko, H.J. 2017. Effect of barley, Italian ryegrass and legume mixture on nitrogen fixation and transfer to grasses on spring paddy field using isotope dilution and difference method. *Journal of the Korean Society of Grassland and Forage Science*. 36(4):318-324.
- Lee, S.M. 2012. Effects of application of fermented swine manure on the amino acid and fatty acid compositions of Italian ryegrass in paddy field. *Journal of Ecology and Environmental Science*. 4:127-131.
- Lee, S.M. and Kim, E.J. 2017. Growth characteristics and nutritional composition of Italian Ryegrass (*Lolium multiflorum* Lam.) cultivars grown in a paddy field. *Journal of the Korean Society of Grassland and Forage Science*. 37(2):183-188.
- Lim, Y.C., Yoon, S.H., Kim, W.H., Kim, J.G., Choi, G.J., Kim, M.J., Jung, M.W., Seo, S. and Yook, W.B. 2007. Growth characteristics and productivity of winter crops after the continuous whole crop rice cultivation in paddy field in middle region. *Journal of the Korean Society of Grassland and Forage Science*. 27(3):183-187.
- Menke, K.H. and Huss, W. 1980. Tierernaehrung und fuettermittelkunde. UTB Ulmer. pp. 38-41.
- Redfearn, D.D., Venuto, B.C., Pitman, W.D., Alison, M.W. and Ward, J.D. 2002. Cultivar and environment effects of annual ryegrass forage yield, yield distribution and nutritive value. *Crop Science*. 42:2049-2054.
- Shao, T., Zhang, L., Shimojo, M. and Masuda, Y. 2007. Fermentation quality of Italian ryegrass (*Lolium multiflorum* Lam.) silages treated with encapsulated-glucose, sorbic acid and pre-fermented juices. *AJAS*. 20(11):1699-1704.
- Shao, T., Zhang, Z.X., Shimojo, M., Wang, T. and Masuda, Y. 2005. Comparison of fermentation characteristics of Italian ryegrass (*Lolium multiflorum* Lam.) and Guinea grass (*Panicum maximum* Jacq.) during the early stage of ensiling. *Asian-Aust. Journal of Animal Science*. 18(12):1727-1734.

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