

Research Article

A Medium Maturing Variety of Italian Ryegrass (*Lolium multiflorum* Lam.), 'IR605', with High Forage Productivity in Southern Region of Korea

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ABSTRACT

This study was conducted at the National Institute of Animal Science from 2010 to 2017. As a variety that is sufficiently productive in the southern regions to replace imported varieties and sufficiently cold-resistant to be cultivated in the central-northern regions, "IR605" was developed and submitted to the Korea Seed & Variety Service in an application for protection. The novel Italian ryegrass variety "IR605" is a diploid with green leaves, a semi-erect growth habit before wintering, and an erect growth habit in the spring. "IR605" was a medium maturing variety with a heading date of around May 15th. "IR605" had a flag leaf width of 9.9 mm, flag leaf length of 26.7 cm, and plant length on the heading date of 100 cm, which was approximately 5 cm longer than "Kowinearly". The stem thickness and ear length of "IR605" are 0.08 mm thicker and 0.5 cm longer than those of "Kowinearly", respectively. The cold-resistance of "IR605" was weaker than that of "Kowinearly", but strong enough to be cultivated in Pyeongchang, Gangwon province. The dry matter yield of "IR605" (9,308 kg/hectare) was 20% higher than that of "Kowinearly", which was further pronounced in the southern region of Haenam, where there was a 52% increase ($p < 0.05$). The *in vitro* dry matter digestibility of "IR605" was 68.4% at which was slightly higher than that of "Kowinearly". The total digestible nutrients was 58.5%, which was slightly lower than "Kowinearly". Overall, the feed quality characteristics of "IR605" were similar to those of "Kowinearly".

(**Key words:** Italian ryegrass, Medium maturing, Variety, IR605)

I. Introduction

Between 2009 and 2019, cultivation of Italian ryegrass (*Lolium multiflorum* L.) increased by more than 300%, from 52,000 to 165,000 hectares, occupy 87% of the total winter forage production area (MAFRA, 2020). There is a rapid increase of cultivation due to the high palatability high feed value, and tolerance to excess humidity, which is an advantage in paddy fields. Also, to those advantages, as demonstrated in the cold-tolerant domestic variety "Kowinearly", the seed self-sufficiency of IRG seed production dramatically increased from 5.7% in 2009 to 31% in 2019 (NIAS, 2019a). Furthermore, the cold-resistant variety facilitated IRG harvest in the central-northern regions, where IRG harvest had not previously been feasible.

However, the seed production of domestically developed IRG is not enough to meet the market demand in southern regions of South Korea.

To date, there are a total of 15 IRG varieties that have been

developed in South Korea: three extremely early maturing varieties, including "Green Farm" (Ji et al., 2011), "Green Farm II" (Ji et al., 2013), and "Green Farm III" (Ji et al., 2015); five early maturing varieties, including "Kogreen" (Choi et al., 2006a), "Kospeed" (Choi et al., 2007), "Kowinearly" (Choi et al., 2011), "Green Call" (Ji et al., 2018), and "Green Call II" (Ji et al., 2019); one medium maturing variety, "Kowinmaster" (Choi et al., 2008); and five late maturing varieties, including "Hwasan 101" (Choi et al., 2000), "Hwasan 102" (Choi et al., 2001a), "Hwasan 103" (Choi et al., 2001b), "Hwasan 104" (Choi et al., 2005), and "Kowinner" (Choi et al., 2006b). Amongst these varieties, "Kowinmaster", "Hwasan 101", and "Hwasan 104" are highly productive in the southern regions. However, as farmers are not aware of the exact characteristics of each variety, they generally select early maturing varieties, which is restricting the growth of the seed self-sufficiency ratio.

In the central and northern regions, cold-resistant IRG varieties, such as "Kowinearly", are cultivated instead of imported varieties. Cold-resistance is also necessary even in the southern regions

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of S. Korea to realize the advantage of longer growing season in the corresponding areas, however, effort for developing medium/late maturing IRG varieties and efficient seed supplies are required to compete with imported varieties. Therefore, a breeding program was carried out to develop a new domestic variety targeting high forage production and cold tolerance for cultivation in central South Korea.

1. Cross Combination Composition

After considering the heading date, growth and development characteristics, and productivity of nutrient lines raised between 2010 and 2011, cross combinations between five lines were tested. The lineage name of "IR605" was "ARX 2", and its cross combinations were the lines such as 12EtYG2N18, 12EtYG2N18, 12EtYG2N27, ARIKG07, and ARIXRO18.

2. Combined Line Production

Polycross-combined nutrient lines formed a combined field according to the 2012 polycross triangular placement method. Furthermore, rye was cultivated in the periphery to exclude foreign pollen from the production of the "ARX 2" seeds.

3. Production Level and Regional Adaptability Evaluation

Forage production of the new variety was conducted in 2014 at the Cheonan experimental field. From 2015 to 2017, the regional adaptability evaluation was conducted over three years as part of the Rural Development Administration's novel variety development research in three regions, including Cheonan, Pyeongchang, and Haenam, for which the selected control variety was the domestic "Kowinearly". The sowing periods differed according to the region as follows: late September for Cheonan, mid to late September for Pyeongchang, and early October for Haenam. The seeding rate was 30 kg/hectare using 20 cm drill seeding. The amount of fertilizer applied was 200, 150, and 150 kg/hectare of N, P₂O₅, and K₂O, respectively. The nitrogen fertilizer was split-applied as 20% in the basal fertilizer, 50% in early spring during the commencement of growth and development, and 30% after the primary harvest. In addition, phosphoric acid and potassium were split-applied as 50% in early spring during the commencement of growth and development. The experimental plot was arranged in a randomized block design, and each measurement was carried out in triplicate.

Concerning the characteristics of growth and development, cold-tolerance, plant length, heading date, lodging, blight, and leafiness were assessed. Visual characteristics of the variety were investigated in Cheonan, and cold-tolerance was investigated in three regions via a regional adaptability evaluation in early spring after winter. For cold-tolerance evaluation, live plants were visually estimated according to a scale of 1 to 9 (1 = strong, 9 = weak). The quantity investigation was carried out in the same regions used for the regional adaptability evaluation. This was completed on the heading date by harvesting the whole 6 m² experimental field, and only the grain obtained from one harvest was utilized. For the fresh mass yield, the weight harvested from the 6 m³ experimental field was converted to a standard of 1 hectare. From each experimental group, less than <500 g of forage sample was dried at 65 °C in a forced air drying oven for more than 72 hours. Statistical analyses were conducted using proc GLM or Mixed of SAS statistical software program (SAS, 2004), and Duncan's multiple range test was used for variety comparisons.

4. Feed Value Analysis

The general treatment components were analyzed using the AOAC method (1990), an internationally recognized analysis method. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed using the methods of Goering and Van Soest (1970). The *in vitro* dry matter digestibility (IVDMD) was analyzed using the method of Tilley and Terry (1963), as revised by Moore (1970).

II. Results and Discussion

1. Variety Characteristics

The characteristics of the novel IRG variety "IR605" are shown in Table 1. "IR605" is diploid and has a semi-erect growth habit before wintering and an erect growth habit in the spring, similar to "Kowinearly". "IR605" has a flag leaf width and length of 9.9 mm and 26.7 cm respectively, which is 0.1 mm wider and 0.4 cm longer than that of "Kowinearly". The plant length of "IR605" on the heading date is 100 cm, which is approximately 5 cm longer than that of "Kowinearly". The stem thickness of "IR605" is 0.08 mm thicker than that of "Kowinearly". "IR605" has a leaf color that is similar to the green of "Kowinearly".

Table 1. Agronomic characteristics of Italian ryegrass varieties

Characteristics	IR605	Kowinearly
Ploidy	Diploid	Diploid
Growth habit in autumn	Semi-erect	Semi-erect
Growth habit in spring	Erect	Erect
Leaf color	Green	Green
Flag leaf width (mm)	9.9	9.8
Flag leaf length (cm)	26.7	26.3
Leafiness (1-9)*	2.2	3.1
Plant length (cm)	100	95
Stem thickness (mm)	2.65	2.57
Length of longest stem (cm)	85.1	82.9
Spikelets per ear	20.6	19.4
Length of ear	24.0	23.5
Lodging resistance (1-9)*	1.0	1.5
Regrowth (1-9)*	3.4	2.7
Heading date	May 15	May 5

*(1-9): 1 = Good (strong), 9 = Bad (weak).

Furthermore, the heading date of "IR605" was May 15th, which was 10 days later than that of "Kowinearly", a medium maturing variety.

Most Italian ryegrass in South Korea is cultivated in rice paddies. According to Hwang et al. (2019), considering that the quality of rice plants depends upon the temperature during the ripening stage, the ideal rice transplantation time is early to late June in the southern regions and mid to late May in the central regions. Therefore, to ensure that the rice transplantation times correspond, medium to late maturing varieties of Italian ryegrass should be cultivated in the southern regions, while early maturing varieties should be cultivated in the central regions.

2. Cold-Resistance

The average lowest temperatures and precipitation in January, which exert the most influence over cold-resistance during IRG cultivation, are shown in Table 2. In Pyeongchang, Gangwon

province, the average lowest temperatures in January ranged between -11.2 and -12.1 °C, while the precipitation ranged between 2.6 and 22.3 mm. In January 2016, the precipitation in Haenam and Cheonan was 8.8 and 8.0 mm, respectively, highlighting the deficiency in Pyeongchang (precipitation of 2.6 mm). In Pyeongchang, the cold-resistance of "IR605" was scored at 1.8, which was lower than that of "Kowinearly" at 1.0. However, amongst the domestically developed varieties, "Kowinearly" had the strongest cold-resistance. Therefore, a score of 1.8 can be considered strong. According to Ji et al. (2018), after cultivation for three years (2015 to 2017) in Yeoncheon, Gyeonggi Province, "Green Call" and "Florida 80" scored 1.4 and 7.3 for cold-resistance, respectively. Therefore, it can be seen that domestic varieties have a drastically higher cold-resistance compared to imported varieties. Furthermore, from a comparative examination of domestic and foreign IRG varieties, domestic varieties were overall reported to have stronger cold-resistance (Kim et al., 2015).

3. Forage productivity

The dry matter yield of each IRG variety is shown in Table 4. Amongst the average dry matter yields of the three regions, "IR605" at 9,308 kg/hectare was 20% greater than that of "Kowinearly" at 7,734 kg/hectare. In particular, in the southern region of Haenam there was a 52% increase in the dry matter yield of "IR605" compared to "Kowinearly" ($p < 0.05$). According to a report regarding IRG seed dissemination in 2019, "Florida 80" accounted for approximately 60% of domestically-distributed imported varieties (NIAS, 2019b). Furthermore, these imported varieties are mostly cultivated in the southern regions, where low cold-resistance is not a significant disadvantage. As a medium maturing IRG, "IR605" has a significantly higher yield ability in the southern regions compared to "Kowinearly". Therefore, it is necessary to reinforce "IR605" production and expand the seed supply. If "IR605" is cultivated in large quantities in the southern regions, the coarse fodder productivity will dramatically

Table 2. Minimum average air temperature and precipitation in January from 2015 to 2017 in trial regions of Korea

Trial region	Min. average air temp. (°C)				Precipitation (mm)			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Pyeongchang	-11.2	-12.1	-11.8	-11.7	21.4	2.6	22.3	15.4
Cheonan	-5.5	-7.0	-7.6	-6.7	12.7	8.0	13.9	11.5
Haenam	-1.8	-3.6	-3.6	-3.0	31.3	56.3	8.8	32.1

Table 3. Cold tolerance scores of Italian ryegrass varieties cultivated in the three trial regions from 2015 to 2017

Trial region	Year	Cold tolerance (1-9)*	
		IR605	Kowinearly
Pyeongchang	2015	2.3	1.0
	2016	2.0	1.0
	2017	1.0	1.0
	Mean	1.8	1.0
Cheonan	2015	1.0	1.0
	2016	2.0	1.0
	2017	2.0	1.0
	Mean	1.7	1.0
Haenam	2015	1.0	1.0
	2016	1.0	1.0
	2017	1.0	1.0
	Mean	1.0	1.0
Mean		1.5	1.0

* (1-9): 1 = Good (strong), 9 = Bad (weak).

increase and seed self-sufficiency rates will increase to over 50%.

In Pyeongchang, Gangwon province, and Cheonan, Chungnam Province, the dry matter yield of "IR605" was slightly higher than that of "Kowinearly", but this was not a statistically significant difference. Currently, in the central-northern regions, cultivation is predominantly the strongly cold-resistant early maturing variety "Kowinearly". Early maturing varieties are selected and cultivated to match rice transplantation times. However, it is likely that in fields where rice is not sown, "IR605"

could also be sufficiently cultivated in the central-northern

regions as it is highly cold-resistant. Cultivating medium maturing varieties increases the growth duration, prompting productivity to increase accordingly. In addition, Kim et al. (2015 and 2016) reported that the medium maturing IRG variety "Kowinmaster" has a higher dry matter yield compared to that of the early maturing variety "Kowinearly".

4. Feed Value

The feed value of the novel Italian ryegrass variety "IR605" is shown in Table 5. The IVDMD was 68.4%, which is slightly higher than that of "Kowinearly". The total digestible nutrients (TDN) was 58.5%, which is slightly lower than that of "Kowinearly". The ADF and NDF were 38.5% and 59.0%, respectively, which are slightly higher than those of "Kowinearly". Overall, the feed value of "IR605" appeared to be similar to those of "Kowinearly".

III. ACKNOWLEDGEMENTS

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IV. REFERENCES

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Table 4. Dry matter yield of Italian ryegrass varieties cultivated in trial regions from 2015 to 2017

Trial region	Dry matter yield (kg/ha)							
	IR605				Kowinearly			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Pyeongchang	4,203	8,990	5,500	6,231	5,815	7,168	4,891	5,958
Cheonan	11,917	9,555	7,062	9,511	12,993	9,027	5,737	9,252
Haenam	14,046	16,736	5,763	12,182 ^a	10,678	8,174	5,121	7,991 ^b
Mean	10,055	11,760	6,108	9,308 ^a	9,829	8,123	5,250	7,734 ^b

^{a,b} Means in the same row with different letters are significantly different ($p < 0.05$).

Table 5. Crude protein (CP), *in vitro* dry matter digestibility (IVDMD), acid detergent fiber (ADF), neutral detergent fiber (NDF), and total digestible nutrients (TDN) of Italian ryegrass varieties cultivated in Cheonan from 2015 to 2017

Variety	CP (%)	IVDMD (%)	ADF (%)	NDF (%)	TDN (%)
Kowinearly	8.8	67.2	36.9	57.3	59.7
IR605	8.4	68.4	38.5	59.0	58.5

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