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Growth characteristics and productivity of new Italian ryegrass (*Lolium multiflorum* Lam.) variation, IR 604

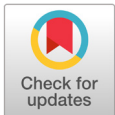
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Abstract

This experiment was carried out to breed a medium maturing variety of Italian ryegrass (*Lolium multiflorum* Lam.) in Grassland and Forage Crops Division, National Institute of Animal Science, Rural Development Administration (RDA), Cheonan from 2019 to 2020. An Italian ryegrass variety, IR 604 is a tetraploid variety with green in leaf color and has half-erect growth habit in late autumn and erect growth habit in early spring, IR 604 was on May 17 in heading date as a medium maturing variety. Also, IR 604 was longer by 11 cm in flag leaf length and longer by 1.3 cm in plant height than those of the control variety, Kowinner, respectively. IR 604 was also thicker by 1.0 mm in stem thickness and strong in winter hardness. Dry matter (DM) yield (11,036 kg/ha) of IR 604 was 16.6% higher than that of Kowinner. Total digestible nutrient (TDN), crude protein (CP) and relative feed value (RFV) of IR 604 were 60.4, 13.8% and 100.6 which are 1.4, 3.3%, 7.7 higher than those of Kowinner, respectively. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) of IR 604 were 35.5 and 56.7% which are 1.3 and 3.6% lower than those of Kowinner, respectively.



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Key words: IR 604, Italian ryegrass, medium maturing, variety

Introduction

The forage industry in South Korea utilizes high-quality forage crops, such as Italian ryegrass, forage corn, and forage oats, rather than rice straw. Forage is essential for livestock; however, few farmers are unaware of the importance of forage quality. Because rice straw lacked sufficient nutrients, farmers used to compensate by consuming more rice straw or using compound feed. However, they sought high-quality rice options such as Italian ryegrass (IRG), silage corn, and whole-crop rice. IRG has been an important winter forage crop since 2007. IRG is suitable for cultivation in paddy fields with higher soil moisture, higher quality, and higher productivity and is a favorable forage crop for livestock. However, most imported IRG varieties were weak in winter and could only be cultivated below Daejeon. Recently, 21 new varieties of IRG have been developed at the National Institute of Animal Science (NIAS) located in Cheonan, which endures cold weather in South Korea. The seed

supply of domestically developed IRG varieties is increasing annually. The Korean variety of IRG has higher cold tolerance and adaptability than any other country-developed variety and has expanded to cultivation areas from the southern location to the middle-northern location.

The development of a new IRG variety began with cold tolerance in 1995, and 21 developed varieties are available, including high-quality and medium-maturing varieties, which include IR 601, IR 602, IR 603, IR 604, and IR 605; early maturing varieties include Green farm (Ji et al., 2011), Green Farm 2 (Ji et al., 2013), and Green Farm 3 (Ji et al., 2015); early maturing varieties include Green call 2 (Ji et al., 2019), Green call (Ji et al., 2018), Kogreen (Choi et al., 2006a), and Kowinearly (Choi et al., 2011), and Kospeed (Choi et al., 2007); medium maturing varieties include Kowinmaster (Choi et al., 2008); late maturing varieties include IR901, 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). Recently, farmers with a double cropping system have been observed to prefer medium-maturing varieties to early-maturing varieties due to forage yield.

The cultivation area of IRG was expanded by approximately 165,000 ha in South Korea in 2019 (MAFRA, 2020), and the cultivation area of IRG has been increasing until the northern region of South Korea.

However, recently developed domestic varieties of the medium-maturing variety have enough harvesting time despite delayed heading dates in the southern area; however, the medium-maturing variety of Italian ryegrass in the NIAS has only one variety, Kowinmaster. We must supply numerous medium-maturing varieties for the farmers who choose a suitable variety depending on the local area.

This study evaluated the growth characteristics and productivity of IR 604, an Italian ryegrass variety, for developing medium-maturing varieties with high yielding and relative feed value (RFV) in South Korea.

Materials and Methods

Plant material

The Italian ryegrass varieties used in the experiment were IR 604 and Kowinner. IR 604 is a medium-maturing variety developed by the NIAS at the Rural Development Administration in 2019. Kowinner is a medium-to-late-maturing variety. IR 604 is a thick-stem variety with high lodging tolerance and yield developed by the NIAS breeding program in 2019 and comprises five lines (15CR18, 15CR12, 15CR13, 15CR24, and 15CR21).

Field test

The experiments were conducted from 2019 to 2020 in Yeoncheon, Cheonan, Yesan, Iksan, and Jeju. The experimental plots were laid out according to three replicates of a randomized block design. Six experimental plots were 6 m² (2 m × 3 m). Each year from 2019 to 2020, drill seeding was performed between September 20 and 26 in Yeoncheon, September 25 and 30 in Cheonan, September 28 and October 10 in Yesan, October 15 and October 24 in Iksan, and October 22 and October 26 in Jeju.

The seeding rate was 30 kg/ha, and the seeding method was 20 cm drill seeding. The fertilizers applied were N, P₂O₅, and K₂O at the rates of 140, 120, and 120 kg/ha, respectively. Regarding the fertilization schedule, 40 kg/ha of nitrogen was applied as the basal fertilizer, and 100 kg/ha of nitrogen was applied at the start of the growth period in early spring. Half

of the phosphoric acid and potassium were applied as basal dressings, and the remaining half was applied at the start of the growth period in early spring. The winter survival degree evaluation of Italian ryegrass varieties was visually examined and graded from 1 to 9 (9 = strong, 1 = weak). The heading date was determined as the day when 40% of the plants in an experimental plot had headed. Once 80 % of the heading was finished, the entire experimental plot was harvested, and the weight of the green forage was measured. A green forage sample (500 g) was dried at 60°C for 48 h to calculate the dry matter rate, and the weight of green forage was converted into dry matter yield using the dry matter rate. Regarding feed value analysis, crude protein (CP) was analyzed using the AOAC method (1990). Total digestible nutrients (TDN) were calculated using the Menke and Huss method (1980), and *in vitro* dry matter digestibility (IVDMD) was examined using the method proposed by Tilley and Terry (1963). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed using the method described by Goering and Van Soest (1970). Analysis of the variance of the dry matter yield was carried out using the SAS (SAS/STAT 9.1, SAS Institute Inc., USA) package program. The significance of the differences ($p < 0.05$) was verified using Duncan's multiple range test.

Results and Discussion

Climate conditions

The surviving IRG plants in the winter field were affected by the cold temperature and amount of precipitation during the coldest month of January. Table 1 lists the average temperature and precipitation in the two areas during the winter months of the experiment. The average low temperature in January in Yeoncheon from 2019 to 2020 was between -5.1 and -3.3°C. However, temperatures in Cheonan, Yesan, Iksan, and Jeju did not affect the survival of IRG during the winter (Kim et al., 2020).

Table 1. Minimum average air temperature and amount of precipitation in January from 2019 to 2020.

Trial region	Min. average air temp. (°C)			Amount of precipitation (mm)		
	2019	2020	Mean	2019	2020	Mean
Cheonan	-2.6	-3.4	-3.0	87.0	59.7	73.4
Yeoncheon	-5.1	-3.3	-4.2	0	64.1	32.1
Yesan	-1.3	-2.5	-1.9	0.5	73.0	36.8
Iksan	-0.4	-0.5	-0.5	3.0	70.6	36.8
Jeju	5.5	7.0	6.3	18.5	116.7	67.6
Mean	-0.8	-0.5	-0.7	21.8	76.8	49.3

Agricultural characteristics and comparison of the cold tolerance of the new variety

As shown in Table 2, IR 604 is a tetraploid variety that uses a tetraploid, half-erect leaf type in autumn and an erect leaf type in spring. IR 604 had green leaves, and its flag leaves were longer than the Kowinner ones. Additionally, IR 604 was the same by 0.7 cm in width of the flag leaf, longer by 10 cm in length, and longer by 3 cm in plant height than those of the control variety Kowinner. Similar to Kowinner, the spikelets of IR 604 were 5 cm longer than those of Kowinner. The stem thickness of IR 604 was 1.0 mm thicker than that of the control variety, Kowinner, and a medium-maturing variety; its heading date is May 17, 3 d later than Kowinner.

Table 2. Agronomic characteristics and ear characters of Italian ryegrass 'IR 604' varieties.

Characteristic	Kowinner	IR 604
Ploidy	Tetraploid	Tetraploid
Growth habit in autumn	Semi-erect	Half-erect
Growth habit in spring	Medium	Erect
Leaf color	Green	Green
Flag leaf width (cm)	0.8 ± 0.17	0.7 ± 0.14
Flag leaf length (cm)	21.2 ± 3.64	22.5 ± 4.69
Leafiness (1 - 9) ^z	1.2 ± 0.21	1.6 ± 0.71
Plant height (cm)	90 ± 3.89	101 ± 5.35
Stem thickness (mm)	2.6 ± 0.50	3.6 ± 0.28
Length of longest stem (cm)	63.4 ± 5.20	60.8 ± 4.80
Spikelets per ear	22.7 ± 2.52	21.9 ± 2.22
Length of ear	26.4 ± 3.51	24.6 ± 4.67
Lodging resistance (1 - 9) ^z	1.81	1.5
Regrowth (1 - 9) ^z	1.0	1.1
Heading date	May 14	May 17

Mean ± standard deviation.

^z 1 = good (strong), 9 = bad (weak).

The climate of the cultivation region affected the cold tolerance of Italian ryegrass IR 604 (e.g., Yeoncheon). As shown in Table 3, the difference in cold tolerance between IR 604 and Kowinner in the Yeoncheon region was significant. IR 604 from Yeoncheon showed stronger cold tolerance, similar to that of Kowinner. As Pfahler et al. (1984) reported, diploid-tetraploid differences in rye were influenced by genetic background. In contrast, Lacadena and Villena (1967) reported that the differences between numerous diploid populations and their tetraploid counterparts in terms of cold resistance were influenced by genetic background. Based on these results, it can be inferred that IR 604, which is similar to Kowinner, is a cold-tolerant variety that displays a consistent winter survival rate.

Table 3. Winter survival degree of Italian ryegrass varieties cultivated in Cheonan, Yeoncheon, Yesan, Iksan and Jeju from 2019 to 2020.

Region	Years	Winter survival degree (1 - 9) ^z	
		Kowinner	IR 604
Cheonan	2019	1.0	1.1
	2020	1.0	1.0
	Mean	1.0	1.1
Yeoncheon	2019	1.0	1.3
	2020	1.0	1.0
	Mean	1.0	1.2
Yesan	2019	1.0	1.0
	2020	1.0	1.0
	Mean	1.0	1.0
Iksan	2019	1.0	1.0
	2020	1.0	1.0
	Mean	1.0	1.0
Jeju	2019	1.0	1.0
	2020	1.0	1.0
	Mean	1.0	1.0
Mean		1.0	1.1

^z 1 = strong, 9 = weak.

Dry matter yield

Table 4 lists the dry matter yields of the two Italian ryegrass varieties. The dry matter yields was more than 1,572 kg/ha than that of Kowinner. The dry matter yield of IR 604 in 2019 and 2020 were 12,000 and 10,070 kg/ha, respectively, 23.7 and 9.1% greater than Kowinner's yields of 9,698 and 9,230 kg/ha. As reported by Redfearn et al. (2005), given the large annual fluctuations in yields, there are unpredictable environmental factors, including climate and disease. The dry matter yield of IR 604 was similar to that of Kowinner in Yeoncheon in 2019, when the climate was warm in the winter. The differences in dry matter yield between the two varieties regarding plant height and stem thickness directly affected the dry matter yields, similar to the Jeju cultivation region.

Table 4. Dry matter yield of Italian ryegrass varieties cultivated in Cheonan, Yeoncheon, Yesan, Iksan and Jeju from 2019 to 2020.

Region	Dry matter yield (kg/ha)					
	Kowinner			IR 604		
	2019	2020	Mean	2019	2020	Mean
Cheonan	7,544	13,049	10,297	8,164	13,747	10,956
Yeoncheon	5,082	7,371	6,227	5,282	7,986	6,634
Jeju	18,653	16,520	17,587	20,317	18,457	19,387
Average	10,426	12,313	11,370ab	11,254	13,397	12,326a
Yesan	10,564	6,342	8,453	14,446	6,559	10,503
Iksan	7,374	5,952	6,663	11,046	6,925	8,986
Average	8,969	6,147	7,558b	12,746	6,742	9,745a
Mean	9,698	9,230	9,464b	12,000	10,070	11,036a

a, b: Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

Feed value

Table 5 shows the crude protein (CP), *in vitro* dry matter digestibility (IVDMD), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), and relative feed value (RFV) of IRG varieties cultivated in Cheonan between 2019 and 2020. IR 604's CP was 13.8%, which was higher than that of Kowinner. IR 604's IVDMD was 75.7, 3.7% higher than Kowinner. IR 604's RFV was 100.6, 7.7% higher than Kowinner. IR 604's TDN was 60.4%, 0.6% higher than Kowinner.

Table 5. Crude protein (CP), *in vitro* dry matter digestibility (IVDMD), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN) and relative feed value (RFV) of Italian ryegrass varieties cultivated in Cheonan from 2019 to 2020.

Varieties	CP (%)	IVDMD (%)	ADF (%)	NDF (%)	TDN (%)	RFV
Kowinner	10.5	72.0	36.8	60.3	59.8	92.9
IR 604	13.8	75.7	35.5	56.7	60.4	100.6

Conclusion

A variety of Italian ryegrass, IR 604, is a tetraploid variety with a green leaf color and has a half-erect growth habit in late autumn and an erect growth habit in early spring. IR 604 was on May 17 in heading date as a medium-maturing variety. In addition, IR 604 plants were 11 cm longer in flag leaf length and longer by 1.3 cm in height than Kowinner plants. IR 604

was thicker, with a 1.0 mm stem thickness and strong winter hardiness. Dry matter (DM) yield (11,036 kg/ha) of IR 604 was 16% higher than that of Kowinner. TDN, CP, and RFV of IR 604 were 60.4, 13.8, and 100.6%, which are 1.4, 3.3, and 7.7% higher than those of Kowinner, respectively. ADF and NDF of IR 604 were 35.5 and 56.7%, 1.3 and 3.6% lower than those of Kowinner, respectively.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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