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Research Article

Effects of Seeding Date on Dry Matter Yield and Nutritive Value of Three Italian Ryegrass Cultivars Harvested Before Heading Stage at Chuncheon, South Korea

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ABSTRACT

The objective of this study was to evaluate the dry matter yield of (DMY) of Italian ryegrass (IRG) forage crop based on two seeding date (September 25 and October 2) in 2017 and 2018, and evaluation of the potential reason of DMY reduction in IRG cultivars grown at Chuncheon, South Korea. Three cultivars of IRG including Kowinearly, Kowinmaster and Hwasan 104 were used in this experiment. The experimental field was designed as a split-split-plot arrangement. The cultivars were harvested on April 26 before the heading stage of both years. In this study, no significant effect (p>0.05) of seeding date has been found on the DMY, whereas the cultivars and year showed a significant effect on the DMY (p<0.05). Except September 25 of 2017, Hwasan 104 indicated significantly lower (p<0.05) DMY than Kowinearly and Kowinmaster in all seeding periods. Though no significant difference (p>0.05) was observed for the DMY between the two seeding dates in 2018, but the DMY was significantly lower (p<0.05) than that of 2017. Lower crude protein (CP) content of Kowinearly was observed on the seeding date of October 2 of 2017, and also in both seeding dates on 2018 (p<0.05). No significant difference (p>0.05) was observed in acid detergent fiber (ADF) between the cultivars on both seeding dates and years. Similarly, no significant difference (p>0.05) was found in neutral detergent fiber (NDF) between the cultivars in 2017. However, Kowinearly showed higher NDF content as compared to Kowinmaster and Hwasan 104 on both seeding dates and years. The seeding date has no significant difference (p>0.05). Thus, considering the extent of DMY in both years, the mean minimum temperature during winter season could be the limiting factor for the DMY of IRG cultivars. However, based on this study, the seeding dates of September 25 and October 2 have no potential effect on the DMY. Thus, on the basis of the current DMY and forge quality parameters, the cultivation Kowinmaster is recommended in Chuncheon.

(**Key words**: Cultivars, Seeding date, Dry matter yield, Italian ryegrass)

Ⅰ. INTRODUCTION

Italian ryegrass (IRG: *Lolium multiflorum* L.) is an important grass cultivated for of high-quality forage. The cultivation of IRG provides a cost-effective supply of feed during winter and spring seasons at temperate region (Choi et al., 2011). This grass known to be produced for high yield and nutritional value at early stages of growth (Valente et al., 2000).

According to Chinnusamy et al. (2007), multiple environmental stresses such as cold, heat or frost adversely affect the crop growth and development as well as yield by the inhibition of metabolic processes in plants. In winter season in South Korea, the cultivation of IRG has been conducted in the southern region of the country where the winter temperature is relatively higher than the northern and mid-northern region of the country. Considering the effect of winter season climate on forage crops, several strategies have been made for the last two decades to develop multiple abiotic stress tolerant species of IRG (Choi et al., 2011; Lee et al., 2017; Lee et al., 2018). The winter cropping of IRG being took place on drained paddy fields corresponding with rice harvesting season. However, this cropping season does not correspond in the middle and mid-northern regions of South Korea. This led to limit the production of IRG crop especially in the northern region of South Korea.

A recent study on a cold-tolerant and early-heading IRG 'Kowinearly' produced a dry matter yield (DMY) in the range of 3, 526 kg/ha to 8, 984 kg/ha from early heading to later ripening stage (Choi et al., 2006, Seo et al, 2013). Whereas mid-October seeding showed better yield than the subsequent seeding period in Gyeongbuk area (Lee, 2013). He also reported

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a decreasing trend in plant height as a result of delayed seeding.

Therefore, optimal seeding period is very important for the cultivation of forage crops. Especially the forage crops those are cultivated during the autumn period. Moreover, consideration of optimal seeding date is also vital factor so that plant can accumulate adequate nutrients for utilizing during winter season. Early or delayed seeding could have a negative consequence on the total DMY (Chemere et al., 2018).

As it is imperative to estimate the DMY of IRG through yield predictive models using climatic factors, Peng et al. (2016) and Kim et al. (2017) generated that the DMY prediction models for various locations in the South Korea. However, there was a limited information regarding the DMY characteristics of IRG in the northern region, particularly at Chuncheon. Therefore, the objective of this study was to evaluate the DMY and the nutritive value of IRG forage crop that were cultivated in two consecutive years (2017 and 2018) based on two seeding date of September 25 and October 02 at Chuncheon, South Korea.

Ⅱ. MATERIALS AND METHODS

The experiment was conducted at the experimental field of Kangwon National University farm ($37^0$56'20.46''N, $127^0$46'57.51''E) at Chuncheon, Kangwon-Do, Republic of Korea, for two growing seasons, 2006-2017 and 2017-2018, which are hereafter termed as 2017 and 2018, respectively. The soil type in the experiment field was sandy-loam (Table 1). The experiment was designed as split-split-plot arrangement with four replications of two planting dates of September 25 and October 02 (Gomez and Gomez, 1984). The seeding dates were considered as a main-plots, whereas the cultivation year as subplots. The cultivars (Early maturating; Kowinearly and Kowinmaster, and late maturing; Hwasan 104) considered to be sub-subplots. The total size of test field was 437m^2 and the sub plot had a size 2m x 4m. In experimental soil, 40 kg/ha IRG seed, and chemical fertilizer Nitrogen (140 kg/ha), Phosphorous (150 kg/ha), and Potassium (150 kg/ha) were applied. Nitrogen fertilizer was applied as a rate of 40 kg/ha of basic fertilization during the seeding and as a rate of 100 kg/ha of an additional fertilization during early spring period. Potassium fertilizer were applied as a rate of 75 kg/ha of basic fertilization at seeding and additional fertilization as a rate of 75 kg/ha. Whereas phosphorous was applied as a basic fertilization only at the seeding time. A 30 x 20 cm quadrat was put in each plot, and the standing forage crops of each cultivars were counted before and after winter to calculate their winter survival rate. In both 2017 and 2018, the cultivars were harvested on April 26th, and the DMY was determined up on drying through oven at 65 °C for 72 hrs, and grounded to pass in 0.75 mm sieve prior to analysis. Ash and crude protein (CP) were analyzed according to the method of AOAC (1990), and Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the method described by Goering and Van Soest (1970).

Data were analyzed as a split-split-plot design with repeated measures, where seeding date and year considered as random factors, and cultivars as fixed factors in analysis of variance using the PROC ANOVA procedure of SAS 9.4 (SAS Institute Inc., Cary, NC, 2018). Separation of means was done using the least significance difference (LSD) at 5%.

Ⅲ. RESULTS

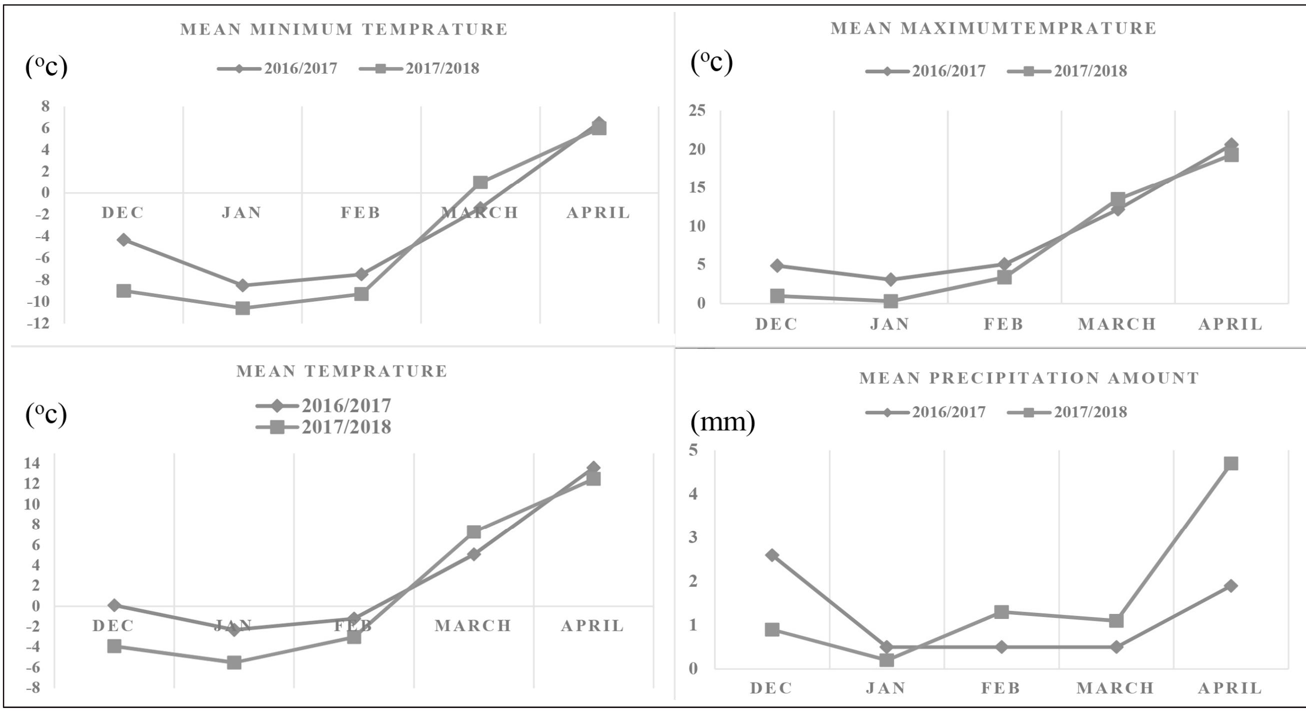
1. Climate condition during the cultivation years

The mean of maximum and minimum temperature, and precipitation of both years corresponding to the seeding and harvesting periods of IRG cultivation are presented in Fig. 1. The mean of minimum temperature in January 2017 and 2018 were -8.5 ℃ and -10.6 ℃, respectively. The mean minimum temperature in 2018 was lower than 2017. In February, the mean of minimum temperature of 2017 and 2018 were -7.5 and -9.3, respectively. The mean of minimum temperature during

Table 1. Soil chemical properties of experimental field

pH (1:5)	TN (%)	OM (g kg^{-})	Ave. P_2O_5 (mg kg^{-})	CEC (cmol+ kg^{-})	Exchangeable cation (cmol+kg^{-1})			
					Ca	K	Mg	Na
6.58	0.55	8.60	255.66	4.69	3.03	0.50	0.84	0.11

TN: total nitrogen, OM: organic matter, CEC: cation exchange capacity



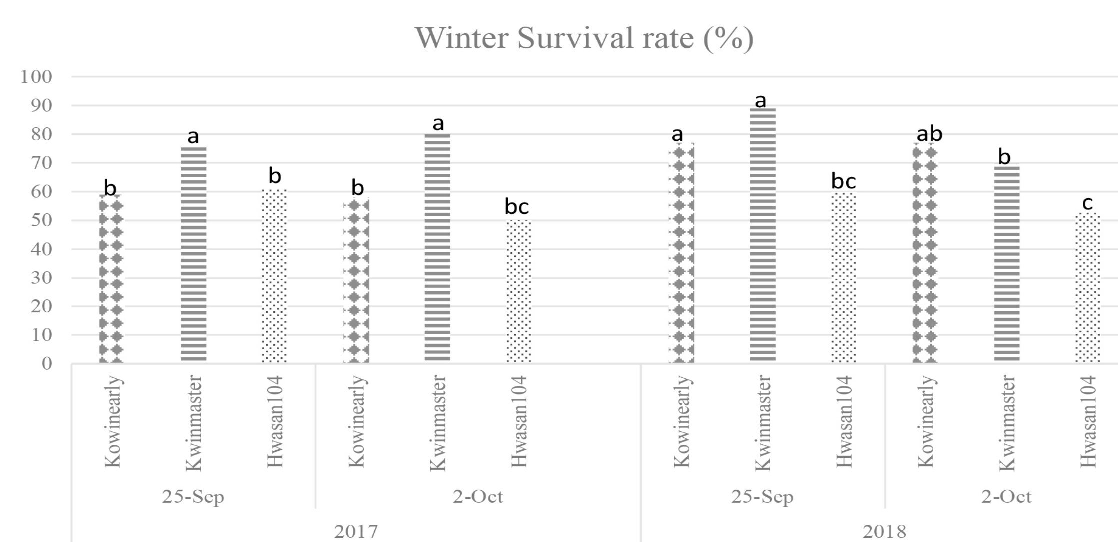
CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber

Fig. 1. Weather condition of Chuncheon, from December to April during two years corresponding to the cultivation period.

December, January and February in 2018 was lower than the 2017. Moreover, the average snowfall during winter season in 2017 and 2018 was 1.73 and 4.2 cm, respectively. This indicates that there was a tendency of lower temperature during a winter season in 2018.

2. Winter survival rate

The winter survival rate of IRG cultivars are presented in Fig. 2. The cultivars responded differently in their winter survival rate in both years. Kowinmaster had higher (p<0.05) survival rate compared to Kowinearly and Hwasan 104 in both years as



Cultivars in the same year with different letters are significantly different (p<0.05).

Fig. 2. Winter survival rate of IRG cultivars

well as in both seeding date. Despite of no significant difference (p>0.05) between Kowinearly and Hwasan 104, the later showed lower survival rate (< 65%) in both years, which has huge implication on its yield characteristics. In this study, the rate of winter survival by the IRG may not due to the involvement of weather factors, but it could be the combination of weather and genetic factors.

3. The dry matter yield and nutritive value of Italian ryegrass

The effects of seeding date, year, cultivars and their interactions on the DMY and nutritive value of IRG are presented in Table 2. The seeding dates didn't show a significant effect (p>0.05) on the DMY and nutritive value of IRG, whereas the year and cultivars showed significant differences (p<0.05) on the DMY, NDF and ash content of IRG. The CP and ADF content were not affected (p>0.05) by the year of cultivation. Meanwhile, the interaction of seeding date and year, as well as year and cultivars showed to have significant effect (p>0.05) on the DMY. The interaction of seeding date and cultivars had no significant effect (p>0.05) on the DMY.

With respect to the yield characteristics of IRG cultivars on both seeding dates and years were presented in Table 3. There were no significant differences (p>0.05) between the DMY of cultivars in both seeding date in 2017, except that Hwasan 104 that seeded on October 2 produced lower DMY than Kowinearly and Kowinmaster. During both seeding dates on 2017, Kowinmaster tended to show higher (p<0.05) DMY than Kowinearly and Hwasan 104. On 2018, there was no significant difference (p>0.05) between the two seeding dates as well as in the DMY between Kowinearly and Kowinmaster. However, significantly lower (p<0.05) DMY of Hwasan 104 was observed compared to Kowinearly and Kowinmaster. There was a difference in herbage height between the two years that the second year showed significantly lower (p<0.05) herbage height than the first year.

No difference was observed in seeding date across all cultivars (Table 4). Hwasan 104 showed the high forage quality at each seeding date (CP 19.1%, NDF 39.9%, ADF 21.3% at 25 September; CP 19.2%, NDF 37.6%, ADF 20.9% at 2 October).

Table 2. Analysis of variance of dry matter yield of Italian ryegrass

	Seeding date (SD)	Year (Y)	Cultivars (C)	Interaction			
				SD x Y	Y x C	SD x C	SD x S x C
DMY	ns	***	***	*	**	ns	ns

ns: not significant, * p<0.05, ** p<0.01, *** p<0.001, DM: Dry matter (%), DMY: Dry matter yield.

Table 3. Dry matter yield of Italian Ryegrass cultivars

Seeding date	Year	Cultivar	Herbage height (cm)	Fresh yield (kg/ha)	DM (%)	DMY (kg/ha)
September 25	2017	Kowinearly	46.8[a]	10,625[a]	17.9[a]	1,895.2[ab]
		Kowinmaster	44.8[a]	11,875[a]	19.4[a]	2,305.2[a]
		Hwasan 104	43.3[a]	11,500[a]	18.2[a]	2,246.1[a]
	2018	Kowinearly	40.5[b]	4,612.5[b]	14.3[b]	1,616.9[bc]
		Kowinmaster	38.5[b]	4,200.0[b]	14.5[b]	1,474.8[bd]
		Hwasan 104	32.2[c]	1,525.0[c]	11.8[c]	447.97[e]
October 02	2017	Kowinearly	46.8[a]	7,625.0[a]	19.1[a]	1,492.3[bc]
		Kowinmaster	41.5[a]	12,500[a]	18.5[a]	2,291.9[a]
		Hwasan 104	43.4[a]	6,750.0[b]	18.1[a]	1,229.0[cd]
	2018	Kowinearly	36.2[bc]	4,600.0[b]	15.4[b]	1,760.9[ac]
		Kowinmaster	37.6[b]	4,812.5[b]	14.7[b]	1,748.5[ac]
		Hwasan 104	28.9[c]	1,787.5[c]	11.6[c]	547.7[e]
SEM			2.0098	1667.0	0.007	238.78
P-value			0.0848	0.1722	0.1137	0.0206

DMY: dry matter yield; DM: Dry matter, Cultivars in the same column with different letters are significantly different (p < 0.05).

Table 4. Chemical composition of IRG cultivars in 2017 and 2018

Seeding date	Year	Cultivars	CP	ADF	NDF	Ash
			-----------------------------------% DM-----------------------------------			
September 25	2017	Kowinearly	19.4	22.7	41.8	11.9
		Kowinmaster	18.2	21.3	41.6	11.5
		Hwasan 104	19.7	22.1	39.9	12.5
	2018	Kowinearly	16.3	21.9	41.2	9.7
		Kowinmaster	16.2	20.5	37.9	9.7
		Hwasan 104	18.4	20.5	36..0	12.7
October 02	2017	Kowinearly	17.4	21.0	40.2	10.9
		Kowinmaster	18.7	21.2	40.7	12.1
		Hwasan 104	18.5	19.7	40..0	11.5
	2018	Kowinearly	15.4	23.7	41.9	9.3
		Kowinmaster	18.3	20.1	37.5	9.5
		Hwasan 104	19.8	22.0	37.6	13.0

Ⅳ. DISCUSSION

1. Factors involved in the dry matter yield reduction

In the current study, generally lower DMY was observed compared to results of other experiments in Korea (Choi et al., 2011; Kim et al., 2016). The temperature in both seasons relatively lower than central and southern region of South Korea where IRG was known to produce optimal DMY (Choi et al., 2018). Especially in the second season, very low mean of minimum temperature was observed throughout the winter period from December through to February (Fig. 1). As the initial cold hardening period generally occurred at temperature of approximately 0 ℃ to 7.8°C, followed by a second stage of hardening as temperatures drop below freezing (approximately -5.5 ℃ to 0 ℃), each winter presents different mechanisms of injury that complicate field condition and tolerance of climate related stresses (Thomashow, 1999).

In this study, particularly on the second year, mean of minimum temperature was close to -10.0°C that observed from December through to February. Moreover, in both years during winter period, low daily mean minimum temperature from -12.5^{o}C to -20.3^{o}C was observed continuously for over a week period. As compared to the mean of minimum temperature in Cheonan during the same period, the one recorded in Chuncheon is way lower than Cheonan. However, comparatively higher DMY was observed in Cheonan than in Chuncheon (Choi et al., 2018). In addition to lower temperature, the low precipitation amount during early spring growing season could also be one of the reason that led to the occurrence of drought, which might be responsible for lower plant height. This can be seen from the fact that the DMY of IRG is related to its shallow root (Haynes and Williams, 1993; Bolinder et al., 2002) as compared to other forage crops like rye that makes it unable to receive enough nutrients during drought season. Thus, the rapid raise in early spring temperature combined with the lower nutrition amount resulted in the drought that prompted the plant growth. Choi et al. (2011) reported an average winter survival rate of 97 % for Kowinearly from 2003 to 2006 in Suwon with plant height of 82cm. As indicated by Park et al. (1987), diploid varieties such as Kowinearly and Kwinmaster had higher cold tolerance than tetraploid varieties. That could be one of the reason that Hwasan 104 showed lower survival rate compared to the other Kowinearly and Kowinmaster. A study conducted to evaluate the winter survival rate of Hwasan 101, Kowinearly and Florida 80 from 2003 to 2006 showed lower survival rate in Yoncheon than Suwon (Choi et al., 2011). The winter minimum average air temperature recorded during the cultivation in Yoncheon was by far less than that of Suwon, which could be considered for the potential reason for low winter survival rate in Yoncheon.

A recent report by Kim et al. (2016) indicated that the DMY was influenced by the seeding date, as October 24th of

2013 seeded IRG yielded 4,998 kg/ha, whereas October 25th of 2014 and 2015 seeded IRG found to yield 8,752 kg/ha and 8,728 kg/ha of DM, respectively, with average plant height of 88cm, harvested on May 9 in Cheonan. This results indicate that the different year could bring different challenges of climatic factors.

Considering the weather condition of the northern and in mid-northern region of South Korea, it is essential to cultivate IRG earlier than the usual time of cultivation. This is due to the fact that, the winter temperature especially in Chuncheon drops earlier than the other part of the country. This inhibits the accumulation of enough nutrients that could be utilized during the period of dormancy. Hence, earlier seeding helps the plants to alter their cellular structure and accumulate protective compounds prior to winter. This is consistent to the findings of with Kim et al. (2009), who reported increased DMY and total digestible nutrient with earlier seeding dates. Furthermore, late seeding often involved in reduction of germination. For example, Hwasan 104 was not fully germinated before winter season in both years in the current experiment. This could be due to the effect of unfavorable weather which is more critical during germination and early seedling development stages than at any other stage of vegetative growth. As reported by Kim et al. (2016), harvesting Kowinearly at later stage in the middle of May increases the DMY from 23% to 39%. However, in uplands areas like Chuncheon, harvesting at later stage in May could affect the optimal seeding time of main crops such as corn.

Therefore, considering the extent of DMY on both years, the mean minimum temperature during winter season could be the limiting factor for the DMY of IRG cultivars at Chuncheon. However, based on the current study, the seeding date of September 25 and October 02 has no potential effect on the DMY. Thus, on the basis of the DMY and forge quality parameters, the cultivation Kowinmaster is recommended at Chuncheon, South Korea.

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