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Research Article

Effects of Seeding Dates on Dry Matter Yield and Feed Value of Rye (*Secale cereale* L.) Cultivated in a Paddy Field of the Central Inland Region

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ABSTRACT

This study was carried out to investigate the effects of seeding dates on the growth characteristics, dry matter yield and mineral contents of rye cultivated in the paddy field. The field experiment was conceived as a randomized block design performed in triplicate with seeding dates of October 19 (T1), October (T2), November 2 (T3), November 9 (T4), and November 16 (T5). All treatments was harvested on May 22 of the following year. Plant length, stem diameter, dry matter yield, and total digestible nutrient (TDN) yield were higher in rye with early seeding dates (p<0.05), whereas TDN was higher with late seeding dates (p<0.05). There was no significant difference between crude protein and ether extract among the different seeding dates. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were higher with early seeding dates (p<0.05). K and Ca contents were significantly higher at T1 as compared to other treatments (T2, T3, T4 and T5). There was no significant difference in Mg and Na content among T1, T2, T3, T4 and T5 treatments. P content was higher in the order T1 > T2 > T3 > T4 > T5 (p<0.05). There was no significant difference in free sugar contents (glucose, fructose and sucrose) by treatments, whereas total free sugar content was the highest in T1 than in the other treatments (p<0.05). Collectively, the results obtained in this study indicate that it is favorable to seed (T1 and T2) soon after harvesting rice to increase dry matter, TDN yield and total free sugar content of rye in the midlands of Korea.

(**Key words**: Seeding date, Rye, Dry matter yield, Growth characteristics, Mineral contents)

Ⅰ. INTRODUCTION

Recently, the number of Hanwoo and beef cattle being raised in our country is approximately 3,620 thousand, showing a high increase (KREI, 2024). As a result, the supply of forage is expected to increase in the future, and any shortage will largely depend on imports from abroad. One way to solve the forage deficit is to cultivate winter crops after harvesting rice (Kim et al., 2009). Rye has high productivity per unit area, grows well even in poor soil conditions, and has strong cold resistance (Utkina and Kedrova, 2018), so it is a feed crop that is easy to cultivate in all regions of our country (Kim and Kim, 1994). In particular, rye is one of the best crops to grow as a winter forage crop after rice harvest because it is used in a variety of ways, including as a cover crop, companion crop, and green manure crop, as well as for soiling, hay, grazing, and silage (Kim et al., 2006). Recently, due to global warming, the planting and harvesting times of forage crops are changing regionally. Even in the same region, there are differences depending on geographical characteristics such as elevation, slope, and topography.

Therefore, studies on seeding times for crops are needed to cope with this situation (Jo et al., 2020). Fowler (1982) reported that the date of seeding has been shown to have a large influence on fall plant development and winter survival of rye. In addition, rye require time and favorable soil temperature and moisture for even germination followed by cool weather to promote fall tillering ensure winter survival (Szuleta et al., 2022). To increase rye production in the central inland region, we need to develop a set of best management practices for seeding dates. The objective of this study was to determine the influence of the date of seeding on growth characteristics, dry matter yield, chemical compositions and mineral contents of rye (*Secale cereale* L.) in the central inland region.

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Ⅱ. MATERIALS AND METHODS

1. Location and cultivation method

This field experiment was performed from October 18, 2020 to May 22, 2021 in paddy field in the central inland region of Gyeonbuk province (latitude 36.5592, longitude 128.1885), Korea. The field experiment employed a randomized complete block design with five different seeding dates as experimental treatments: October 19 (T1), October (T2), November 2 (T3), November 9 (T4), and November 16 (T5). All treatments was harvested on May 22 of the following year (Table 1).

The rye variety was selected as “Elbon”, an early maturing variety, considering rice cultivation. The experimental plot area was 3 m × 5 m = 15 m, in each replicate. The application rates of chemical fertilizer were as follows: total nitrogen (200 kg/ha), potassium (150 kg/ha), and phosphorus (150 kg/ha). The chemical fertilizer was applied with 40% nitrogen and potassium used as a basal fertilizer and 60% as added fertilizer, whereas total phosphorus was applied as a basal fertilizer. As a seeding method, the rye was broadcasted on the soil at a rate of 150 kg/ha. Fresh forage yield was estimated after cutting 5 m^2 in each replicate.

2. Soil and weather conditions

The paddy soil used in this experiment had a slightly acidic pH of 6.12. Compared to general upland soil (Kim et al., 2019), it exhibited slightly higher organic matter content but lower levels of P_2O_5, Ca, and K (Table 2).

Weather conditions were not very cold even in winter (December to February). Additionally, conditions were good for rye growth with moderate rainfall during the rye growing season from March to May (Table 3).

3. Analysis of chemical composition

The samples were dried for 3 days at 65℃ and used for analysis. The chemical compositions were determined using the

Table 1. Experimental design

Items	Treatments				
	T1	T2	T3	T4	T5
Seeding date	Oct. 18	Oct. 25	Nov. 1	Nov. 8	Nov. 15
Harvest date	May 22	May 22	May 22	May 22	May 22
Cultivation period	214 days	207 days	200 days	193 days	186 days

Table 2. Chemical properties of the soil before experiment

pH	OM	T-N	Av. P_2O_5	Ex. cation ($cmol^+kg^-$)			
(1:5)	(%)	(%)	(mg/kg)	K	Na	Ca	Mg
6.12	3.26	0.19	68.36	0.52	0.14	4.24	1.23

*OM : organic matter, T-N : total nitrogen.

Table 3. Monthly meteorological data during the experimental period

Month	Mean temp. (℃)	Sunshine (hr.)	Precipitation (mm)	Rainy days (day)
2020.10	13.4	207.7	1.6	4
11	8	169.3	22.1	7
12	-0.1	189.6	1.5	3
2021. 1	-1.8	182.1	165	11
2	3.2	202.2	9.7	7
3	8.9	203.0	98.4	10
4	13.6	227.3	70.5	7
5	16.7	201.0	166.5	15

method specified by the Association of Analytical Chemists (AOAC, 1995). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed using the AOAC method and the Goering and van Soest method (1970), respectively. Total digestible nutrient (TDN) was calculated using the formula (TDN% = 88.9 - (0.79 × ADF) by Holland et al. (1990). The mineral composition was analyzed from pre-treated samples using inductively coupled plasma mass spectrometry (Iris Intrepid, Thermo elemental Co., UK). Free sugar was analyzed using the method of wilson et al. (1981). Briefly, 100 mL of 80% ethanol solution was added to 5 g of sample. The sugar composition was then extracted repetitively for 2 h at 80 ℃ using the heating mantle in a reflux cooling extraction unit followed by filtering through Whatman NO. 5 filter paper. The resulting solution was then analyzed using high performance liquid chromatography (Waters 2414, Water Co., USA).

4. Statistical analysis

The results were subjected to one-way analysis of variance with seeding date as a main effect. Mean values and standard deviation of the experimental results were obtained using SAS (2012). Duncan's multiple range test was employed to identity differences among the treatments, which were considered significant when $p<0.05$.

Ⅲ. RESULTS AND DISCUSSION

1. Growth characteristics and dry matter yield

The growth characteristics according to seeding date are shown in Table 4. At the time of harvest, the maturity stages of the rye were as follows: T1 was at mid-flowering, T2 and T3 were at early flowering, and T4 and T5 were at late heading. Plant length was significantly higher in the early seeding times (T1) compared to the late seeding times (T3, T4, and T5) ($p<0.05$). The shorter plant length with delayed seeding times is consistent with the findings reported by Kim et al. (2006). However, there was no significant difference in leaf length, ear length, and leaf width. The stem diameter appeared in the order T1 > T2 > T3 > T4 = T5, which treatments with early seeding times tended to be thicker. The fresh yield in T1 was significantly higher than that in T3, T4, and T5 ($p<0.05$), which had late seeding times. In dry matter yield, there was no significant difference between T1, T2, and T3, but there was a significant difference when compared to T5 ($p<0.05$). The results of this study are in line with those reported by Suh (1981), who demonstrated that when cultivating winter crops after rice cultivation, there was a difference in yield according to the seeding date. Kim et al. (2009) reported that delaying the seeding date in autumn leads to a rapid decrease in survival rates, resulting in reduced dry matter yield. TDN yield was significantly higher ($p<0.05$) in T1 than in the other treatments, particularly T4 and T5, with

Table 4. Effects of seeding times on growth characteristics and yield

Items	Treatments				
	T1	T2	T3	T4	T5
Maturity stage	Mid flowering	Early flowering	Early flowering	Last heading	Last heading
Plant length (cm)	159.5±2.5^{a}	149.7±5.1^{ab}	140.9±2.0^{bc}	138.9±5.5^{bc}	133.4±10.2^{c}
Leaf length (cm)	24.9±1.5^{ns}	22.9±2.3	24.4±2.5	23.2±3.4	26.0±1.6
Ear length (cm)	11.1±0.4^{ns}	10.5±0.4	11.1±0.3	11.0±0.5	10.9±0.6
Leaf width (mm)	14.0±1.0^{ns}	13.9±0.9	13.4±1.7	12.4±1.2	13.1±0.6
Stem diameter (mm)	3.1±0.2^{a}	2.7±0.2^{ab}	2.4±0.4^{b}	2.3±0.2^{b}	2.3±0.1^{b}
Fresh yield (kg/ha)	52,667±707^{a}	47,235±4,362^{ab}	46,225±1,817^{b}	43,529±2,227^{b}	42,367±1,173^{b}
DMY[1)] (kg/ha)	14,152±1,291^{a}	12,571±493^{ab}	12,033±1,141^{abc}	10,084±1,120^{bc}	9,791±517^{c}
TDNY[2)] (kg/ha)	6,429±343^{a}	6114±224^{a}	6,085±53^{a}	5,232±72^{b}	5,099±119^{b}

$^{a, b, c}$ Means in a row with different superscripts are significantly different ($p<0.05$).
ns: not significant. DMY[1)]: dry matter yield. TDNY[2)]: Total digestible nutrient yield.

late seeding dates being associated with a very low yield ($p<0.05$).

Therefore, to increase the yield of rye, the conclusion is that seeding as early as possible immediately after the rice harvest is more advantageous.

2. Chemical composition

The chemical composition of rye according to seeding date is presented in Table 5. There was no significant difference in crude protein and ether extract content according to seeding date, but it tended to decrease slightly as the sowing time became earlier. Lee and Kim (2019) reported that when the harvest time is the same, delayed seeding date results in relatively slower growth (delayed maturity), which leads to an increase in crude protein content. However, Kim et al. (2006) reported that there was no difference depending on the seeding date. The contents of crude ash, NDF and ADF were significantly higher in T1 and T2 with early seeding date compared to T4 and T5 with late seeding date ($p<0.05$). These causes are presumably because as the cultivation period increases, maturity stages develop, the leaf ratio of the plant decreases, and stems harden (Kim et al., 2007). The TDN content of rye decreased significantly with an earlier seeding date, On the other hand, there was a significant increase in the treatments with late seeding date. This result is judged to be due to the softness of the stem and low NDF and ADF content because the growing days are short in the late seeding date (Lee et al., 2022).

3. Mineral contents

The mineral contents of rye according to seeding date are presented in Table 6. There was no significant difference in K content, which is the highest component among mineral contents, between T1, T2, T3, and T4. However, it was significantly lower in T5 ($p<0.05$). The Ca content appeared in the order T1 > T2 > T3 > T5 > T4, which treatments with early seeding times tending to be higher ($p<0.05$). The Ca contents in this experiment tended to be higher than those reported by Lee (2022). It was reported that mineral components vary depending on soil type, season, and stage of

Table 5. Effects of seeding times on chemical compositions (DM, %)

Items	Treatments				
	T1	T2	T3	T4	T5
Crude protein	$10.6±0.4^{ns}$	10.0±0.1	11.7±0.5	10.6±0.8	10.9±0.5
Ether extract	$1.9±0.0^{ns}$	1.9±0.3	2.0±0.1	2.0±0.1	1.9±0.1
Crude ash	$8.4±0.1^{a}$	$8.2±0.1^{a}$	$7.8±0.0^{b}$	$7.6±0.1^{bc}$	$7.3±0.2^{c}$
Crude fiber	$41.7±0.3^{ns}$	40.1±1.3	40.3±2.2	38.1±1.1	37.5±1.8
NDF[1)]	$67.4±0.7^{a}$	$66.0±1.2^{ab}$	$65.1±0.5^{b}$	$63.1±0.1^{c}$	$62.6±0.6^{c}$
ADF[2)]	$53.1±0.6^{a}$	$50.1±0.5^{b}$	$48.5±0.6^{bc}$	$46.9±0.9^{c}$	$46.6±1.6^{c}$
TDN[3)]	$46.9±0.5^{c}$	$49.3±0.9^{b}$	$50.6±0.4^{ab}$	$51.9±0.7^{a}$	$52.1±1.2^{a}$

ns: not significant. [a, b, c] Means in a row with different superscripts are significantly different ($p<0.05$).
NDF[1)]: neutral detergent fiber. ADF[2)]: acid detergent fiber. TDN[3)]: total digestible nutrients.

Table 6. Effects of seeding times on mineral contents (DM, mg/kg)

Items	Treatments				
	T1	T2	T3	T4	T5
K	$19,050±637^{a}$	$18,441±28^{a}$	$19,373±766^{a}$	$17,924±956^{a}$	$15,998±119^{b}$
Ca	$10,567±859^{a}$	$9,995±1,166^{ab}$	$8,466±216^{bc}$	$7,878±95^{c}$	$7,912±140^{c}$
Mg	$915±70^{ns}$	969±3	942±31	1,084±35	957±192
P	$579±23^{a}$	$527±16^{ab}$	$522±11^{ab}$	$464±26^{b}$	$342±65^{c}$
Na	$45±4^{ns}$	46±5	44±17	59±19	55±17

[a, b, c] Means in a row with different superscripts are significantly different ($p<0.05$).
ns: not significant.

Table 7. Effects of seeding times on free sugar contents (DM, mg/100g)

Items	Treatments				
	T1	T2	T3	T4	T5
Glucose	1,081±121[ns]	976±99	919±12	988±61	830±45
Sucrose	1,762±149[ns]	1,559±136	1,488±86	1,426±18	1,381±70
Fructose	655±9[ns]	544±13	562±64	470±82	459±18
Total	3,498±19[a]	3,079±23[b]	2,969±11[b]	2,884±124[b]	2,670±134[c]

ns: not significant.
[a, b, c] Means in a row with different superscripts are significantly different (p<0.01).

maturity even within the same variety (Metson and Saunders, 1978; Kappel et al., 1985). The P content ranged from 342 to 579 mg/kg, and T1 and T2, which had early seeding dates, were significantly higher than T5, which had a late seeding date (p<0.05). There was no significant difference in Mg and Na contents between treatments.

Consistent with the findings of Lee (2013), it was shown that the P content of Italian ryegrass decreases with an increasing delay in seeding date. According to Kappel et al. (1985), the P content of oat was reported to be a maximum of 0.83% (830 mg/kg), a minimum of 0.13% (130 mg/kg), and an average of 0.47% (470 mg/kg).

4. Free sugar contents

The free sugar contents of rye according to seeding dates are presented in Table 6. The free sugar contents of rye were high in the order sucrose > glucose > fructose. There was no significant difference in glucose, sucrose and fructose contents depending on seeding time. However, it tended to be high at early seeding times (T1).

The total free sugar content was significantly higher in T1 (3,498 mg/kg) than in the other treatments (T2, T3, T4, and T5), whereas it was the lowest in T5 (2,670 mg/kg) (p<0.05). Lee (2013) reported experiment on seeding timing for Italian ryegrass that an earlier seeding time resulted in higher free sugar content. Such results are thought to be closely related to the crop's maturity stage.

Generally, the free sugar content of forage crops is a very important ingredient because it affects silage fermentation (Lee and Kim, 2019). It has also reported that a high sugar content maintains pH at a low level, thereby promoting the rapid stabilization of silage (Davies et al., 1998).

Ⅳ. CONCLUSIONS

Rye (*Secale cereale* L.) is a forage crop well-suited to the climate and soil conditions of our country. It is particularly cold-tolerance, allowing it to be grown in any region. However, recent research on seeding times in response to climate change is very limited. Therefore, this study was conducted to investigate the optimal seeding time for increasing the yield and feed value of rye. From this experiment, we concluded that considering the growth characteristics, dry matter yield and total digestible nutrient yield, seeding dates are appropriate between October 19 (T1) and November 2nd (T3). In particular, it is judged that experiments on the optimal seeding time to respond to climate warming should be continuously conducted for each feed crop.

Ⅴ. REFERENCES

AOAC. 1995. Official Methods of analysis (16th ed.). Association of analytical chemist. Washington. DC. USA.

Davies, D.R., Merry, R.J., Williams, A.P., Bakewell, E.L., Leemans, D.K. and Tweed, J.K. 1998. Proteolysis during ensilage of forages varying in soluble sugar content. Journal of Dairy Science. 81:444-453. doi:10.3 168/jds.S0022-0302(98)75596-1

Fowler, D.B. 1982. Date of seeding, fall growth, and winter survial of winter wheat and rye. Agronomy Journal. 74:1060-1063. doi:10.2134/agronj1982.00021962007400060030x

Goring, H.K. and Van Soest, P.J. 1970. Forage fiber analysis. Agic. handbook. No.379. ARS. USDA. Washington DC.

Holland, C., Kezar, W., Kautz, W.P., Lazowski, E.J., Mahanna, W.C. and Reinhart, R. 1990. The pioneer forage manual: A nutritional guide. Pioneer Moines. IA.

Jo, H.W., Kim, S.C., Kim, M.J., Kim, J.Y. and Jo, M.H. 2020. Detecting on optimal sHi-Bred., Detecting and harvesting dates of whole crop maize via meta data. Journal of the Korean Society of Grassland and Forage Science. 40(1):66-72. doi:10.5333/KGFS.2020.40.1.66

Kappel, L.C., Morgan, E.B., Ingraham, R.H. and Babcock, D.K. 1985. Seasonal changes of mineral content of southern forages. Journal of Dairy Science. 68(7):1822-1827. doi:10.3168/jds.S0022-0302(85)81033-X

Kim, J.D. and Kim, D.A. 1994. Effect of seeding date and fall harvest method on the growth characteristics, forage yield and quality of winter rye. Journal of the Korean Grassland Science. 14(3):238-246.

Kim, M.J., Choi, G.J., Yook, W.B., Lim, Y.C., Yoon, S.H. and Kim, J.G. 2007. Effects of seeding method on the winter survival, dry matter yield and nutrient value of Italian ryegrass in paddy field. Journal of Korean Grassland Forage Science. 27:269-274.

Kim, M.J., Choi, K.J., Kim, J.G., Seo, S., Yoon, S.H., Lim, Y.C., Im, S.K., Kwon, E.G., Chang, S.S., Kim, H.C. and Kim, T.I. 2009. Effect of varieties and seeding date on over winter and dry matter yield of Italian ryegrass in paddy field. Journal of the Korean Grassland Science. 29(4):321-328.

Kim, S.G., Kim, J.D., Kwon, C.H., Ha, J.K. and Kim, D.A. 2006. Forage performance evaluation of rye cultivars with different sowing dates. Journal of the Korean Grassland Science. 26(1):31-38.

Kim, Y.H., Kong, M.S., Lee, E.J., Lee, T.G. and Jung, G.B. 2019. Status and change in chemical properties of upland soil from 2001 to 2017 in Korea. Korean Journal of Environmental Agriculture. 38(3):213-218. doi:10.5338/KJEA.2019.38.3.28

KREI. 2024. Korea rural economic institute. www.krei.re.kr.

Lee, S.H., Kim, E.J. and Lee, S.M. 2022. Effects of planting density on growth characteristics, dry matter yield and feed value of Teosinte new variety, “Geukdong 6” (*Zea mays* L. subsp. *mexicana*(Schrad.) H. H. Iltis). 2022. Journal of the Korean Society of Grassland and Forage Science. 42(3):162-168. doi:10.5333/KGFS.2020.42.3.162

Lee, S.M. 2013. Effects of seeding dates on yield and feed value of Italian ryegrass in paddy field cultivation. Journal of the Korean Society of Grassland and Forage Science. 33(3):185-192. doi:10.5333/KGFS.2013.33.3.185

Lee, S.M. 2022. Effects of mixed application of chemical fertilizer and liquid swine manure on agronomic characteristics, yield and feed value of rye (Secale cereale L.). Journal of the Korean Society of Grassland and Forage Science. 42(4):215-221. DOI/10.5333/KGFS.2022.42.4.215

Lee, S.M. and Kim, E.J. 2019. Effects of seeding dates on dry matter yield and feed values of whole crop barley cultivated in a paddy field. Journal of Animal Science Technology. 61(5):278-284. doi:10.5187/jast.2019.61.5.278

Metson, A.J. and Saunders, W.M.H. 1978. Seasonal variations in chemical composition of pasture. I. Calcium, magnesium, potassium, sodium, and phosphorus. New Zealand Journal of Agricultural Research. 21:341-353. doi:10.1080/00288233.1978.10427419

SAS. 2012. SAS user’s guide: Statistical analysis system institute. SAS Inc. Cary. NC. USA.

Suh, H.S. 1981. Comparison of several agronomic characteristics as affected by seeding dates. Korean Journal of Crop Science. 26:298-303.

Szuleta, E., Phillips, T., Knott, C.A., Lee, C.D. and Van Sanford, D.A. 2022. Influence of planting date on winter rye performance in Kentucky. Agronomy Journal. 12:2887. doi:10.3390/agronomy12112887

Utkina, E.I. and Kedrova, L.I. 2018. Winter hardiness in winter rye: Problems and solutions. The Journal of Agriculture Science. 62(1):11-18. doi:10.30766/2072-9081.2018.62.1.11-18

Wilson, A.M., Work, T.M., Bushway, A.A., Bushway, R.J. 1981. HPLC determination of fructose, glucose, and sucrose in potatoes. Journal of Food Science. 46:300-301.

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