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**Research Article**

# Growth Characteristics and Productivity of Korean Winter Forage Crops in Uzbekistan

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## ABSTRACT

We examined the adaptability of Korean winter forage crops such as Italian ryegrass, barley, oat, and triticale in Uzbekistan. The overall growth before wintering was slightly different between Uzbekistani and Korean varieties, but there was no significant difference among winter forage crops. The heading date of the Korean triticale 'Shinyoung' was the earliest, (April 4), and the heading date of the Uzbekistani triticale 'Frack cerebristy' was quite late, (April 25). The heading date of the Korean Italian ryegrass 'Kowinearly' was four days earlier than that of 'Kowinmaster,' on April 13, and that of the Korean barley 'Youngyang' and 'Yuyeon' were five days earlier than that of the Uzbekistani barley 'Bolgaly'. The maximum dry matter yield of winter forage crop was from Uzbekistan triticale, 'Frack cerebristy', which was 13,536 kg/ha. The dry matter yield of Uzbekistan barley was 8,222 kg/ha. Compared with Uzbekistan barley, 'Bolgaly', yields of Korean barley 'Youngyang' and 'Yuyeon', Korean oat 'Samhan', and Korean Italian ryegrass 'Kowinearly' and 'Kowinmaster' were 59～64%, 125%, and 113～133%, respectively.

(**Key words**: Winter forage crop, Growth characteristics, Productivity, Uzbekistan)

## Ⅰ. INTRODUCTION

In Korea, Italian ryegrass (*Lolium multiflorum*; IRG), Triticale (*X Triticosecale*), Barley (*Hordeum vulgare*), and Oat (*Avena sativa*) are grown as winter forage crops. Among them, Italian ryegrass accounts for 97% of the total cultivated area of winter forage crops (Kim, 2019). Italian ryegrass has been introduced in Korea since 1955 from the United States, and of late, the cultivated area has been increasing every year. Italian ryegrass is known as an annual or bi-annual crop with high productivity, good feed value, and high palatability to livestock (Chae et al., 1996; Choi et al., 2011). The Italian ryegrass 'Kowinearly' and 'Kowinmaster' varieties developed by the Rural Development Administration (RDA) to grow in Korea's cold winter, were characterized with strong cold tolerance and high productivity (Choi et al., 2011).

Barley has a high competitive advantage because it has excellent feed quality and is more affordable, when compared to imported forages. In addition, it performs the function of both forage and concentrated feed because it contains seeds, leaves and stems, (Kim et al., 2007; Seo et al., 2010). Since 2000, studies have been actively carried out to utilize barley as a forage, and the name of the barley for feed has been changed to "Chungbori". New varieties of barley for forage have been developed, such as 'Youngyang,' which is higher in forage productivity when compared with the general grain barley, 'Wooho' and 'Yuyeon', which are more preferred by livestock, and 'Yuho,' which improves the shattering habit (Choi et al., 2007; Kim et al. 2007; Park et al., 2008).

Triticale is a hybrid of wheat (*Triticum*) and rye (*Secale*), first bred in laboratories of Scotland and Germany during the late 19th century (Stace, 1987; Hills et al., 2007; Mergoum et al., 2009). Only recently has it been developed into a commercially viable crop. Depending on the cultivar, triticale can more or less resemble either of its parents. It is grown mostly for forage or fodder, although some triticale-based foods can be purchased at health food stores and found in some breakfast cereals. In Korea, triticale is cultivated for the production of forage and can be cultivated anywhere in the country because of its high adaptability to adverse environmental conditions

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(Mergoum et al., 2009). In Korea, a new variety of triticale, 'Shinyoung' (Heo et al., 2002), has been developed and cultivated in some farms.

In Korea, oats were cultivated on a small scale in mountainous areas such as Gangwon-do before the 1970s. In the mid-1980s, oats were cultivated in livestock farms as a forage crop. The Oat cultivar ‘Samhan’ (Heo et al., 2003), which was raised by the Rural Development Administration in 2001, is cold-resistant and can be sown in autumn and harvested in spring.

In this study, we investigated the growth characteristics and yields of Korean varieties grown in Uzbekistan, and Korean varieties of winter forage crops grown in Uzbekistan as a part of the Rural Development Administration's overseas agricultural technology development project. The minimum temperature during winter is -10 ℃, and the average winter temperature is 2.8 ℃. The summer precipitation of this country is less than 10 mm and its climate is classified as continental, with high temperature and dry desert like conditions. The scale of livestock industry in Uzbekistan is so small that more than 90% of livestock rearing is carried out as a source of side income by farmers , and most of the feed supply comes from wild grass and agricultural by-products (KRC, 2009). In Uzbekistan, the production of high-quality roughage is absolutely necessary and has been a matter of growing interest.

## Ⅱ. MATERIALS AND METHODS

### 1. Test site and cultivation environment

This study was conducted to evaluate the adaptability, agronomic characteristics, and productivity of Korean winter forage crop cultivars which were cultivated in the USRSC (Uzbek Scientific Research Station of Corn) belonging to the SPCA (Scientific Production Center of Agriculture) near Uzbekistan's capital Tashkent for two years (from 2010 to 2011). Uzbekistan has a hot and dry continental desert climate with a summer maximum temperature of 42°C and an average temperature of around 26.8~28.6°C. The winter minimum temperature is -10°C and the average temperature is around 2.8°C. Precipitation is 22~

**Table 1. Mean, minimum (Min.), and maximum (Max.) air temperature and precipitation amount of two years (October 2010 -December 2011) at Tashkent in Uzbekistan (GisMetro) and Cheonan (NWS) in Korea**

| Year | Month | Air Temperature (℃) | | | | | | Precipitation (mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Tashkent | | | Cheonan | | | | |
| | | Mean | Max. | Min. | Mean | Max. | Min. | Tashkent | Cheonan |
| 2010 | Oct. | 16.5 | 33 | 4 | 13.2 | 24.8 | -4.3 | 15.0 | 19.4 |
| | Nov. | 9.7 | 27 | 6 | 6.1 | 18.7 | -5.2 | 26.0 | 13.5 |
| | Dec. | 3.8 | 22 | -5 | -0.3 | 16.5 | -15.9 | 13.0 | 24.5 |
| 2011 | Jan. | 1.3 | 16 | -3 | -6.9 | 3.5 | -18.3 | 26.0 | 7.9 |
| | Feb. | 2.4 | 15 | -8 | 0.9 | 13.9 | -11.6 | 98.0 | 31.0 |
| | Mar. | 9.7 | 30 | -1 | 3.6 | 19.0 | -6.7 | 58.0 | 26.5 |
| | Apr. | 17.7 | 33 | 4 | 10.6 | 25.0 | -1.3 | 22.0 | 133.2 |
| | May | 22.8 | 37 | 17 | 18.1 | 29.9 | 6.4 | 30.0 | 103.3 |
| | Jun. | 26.8 | 39 | 22 | 22.4 | 32.5 | 13.1 | 25.0 | 374.6 |
| | Jul. | 28.6 | 40 | 27 | 25.6 | 33.7 | 18.1 | - | 645.1 |
| | Aug. | 27.7 | 42 | 20 | 25.5 | 34.3 | 16.7 | - | 268.2 |
| | Sep. | 21.6 | 36 | 15 | 20.6 | 32.5 | 8.8 | - | 153.2 |
| | Oct. | 15.3 | 34 | 2 | 12.7 | 24.9 | -0.9 | 30.0 | 26.5 |
| | Nov. | 5.4 | 18 | -4 | 10.7 | 25.3 | -4.1 | 170.0 | 65.8 |
| | Dec. | -0.5 | 11 | -10 | -0.4 | 10.1 | -13.4 | 38.0 | 10.5 |
| | Sum | | | | | | | 497 | 1,845.8 |

**Table 2. Chemical characteristics of experimental fields at Tashkent in Uzbekistan (2010)**

| pH | TN[1] (%) | OM[2] (g/kg) | CEC[3] (cmol/kg) | Exchangeable cation($cmol^+/kg$) | | | |
|---|---|---|---|---|---|---|---|
| | | | | K | Na | Ca | Mg |
| 8.12 | 0.09 | 5.45 | 9.50 | 0.51 | 0.22 | 22.63 | 2.45 |

TN[1], Total nitrogen; OM[2], Organic matter; CEC[3]: Cation exchange capacity

**Table 3. Chemical characteristics of experimental fields in Cheonan region (Kim et al., 2016)**

| Year | pH (1:5) | TN[1] (%) | OM[2] (g/kg) | $P_2O_5$ (mg/kg) | Exchangeable cation ($cmol^+/kg$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | K | Ca | Mg |
| 2011 | 6.24 | 0.22 | 23.5 | 240 | 0.83 | 5.37 | 1.49 |
| 2012 | 6.35 | 0.24 | 25.1 | 245 | 0.81 | 5.43 | 1.46 |

TN[1], Total nitrogen; OM[2], Organic matter

**Table 4. Winter crops and cultivars used in the present study**

| Crop | Breeding country | Cultivar |
|---|---|---|
| Italian ryegrass | Korea | Kowinearly, Kowinmaster |
| Barley | Korea | Youngyang, Yuyeon |
| | Uzbekistan | Bolgaly |
| Oat | Korea | Samhan |
| | Uzbekistan | Uz Shirokoristy |
| Triticale | Korea | Shinyoung |
| | Uzbekistan | Frack cerebristy |

58 mm in spring, 0~25 mm in summer, 0~170 mm in autumn, and 13~98 mm in winter. There is little rain in summer. Table 1 summarizes the weather data of Uzbekistan (GisMeteo, http://www.gismeteo.ru) and Korea's Cheonan region (KMA website, http://www.kma.go.kr.) during the test period.

Table 2 shows the results of analysis of soil samples collected before the sowing of winter forage crops. The pH was 8.12 higher than that of Korea, and the organic matter content was 5.45 g/kg, which was less than the average of Korean soil. Potassium content was 0.51 $cmol^+/kg$, which was also less than that of Korean soil (Table 3).

## 2. Crops and varieties

In this study about the winter forage crops, Italian ryegrass (‘Kowinearly’ and ‘Kowinmaster’), barley (‘Youngyang’ and ‘Yuyeon’), oat (‘Samhan’), and triticale (‘Shinyoung’) were used, and for the Uzbekistan winter crops, barley (‘Bolgaly’), oat (‘Uz Shirokoristy’), and triticale (‘Frack cerebristy’) were used (Table 4).

## 3. Plot design and cultivation conditions

In the test area, nine varieties were placed in the treatment, and plots were designed with three replications using a completely randomized block design. The size of one plot was 6 $m^2$(1.5 × 4 m),two ridges (width 75 cm) were made in the plot and sowed by a broadcasting method. The seeding rate per ha was 40 kg for Italian ryegrass, and 150 kg each for barley, oat, and triticale. Sowing was carried out on October 19, 2010.

The application rate of Italian ryegrass was N-$P_2O_5$-$K_2O$ = 140-120-120 kg per ha, and the application rate of barley, oats, and triticale was N-$P_2O_5$-$K_2O$ = 120-100-100 kg per ha. Fifty percent of the nitrogen fertilizer was applied at the time of sowing, and the remaining 50% was used in early spring, while the whole amount of phosphate and potassium fertilizers were utilized at the time of sowing. During the cultivation period, irrigation was carried out over the entire period except for winter.

### 4. Growth characteristics and productivity

On December 21, 2010, we carried out pre-wintering growth survey of winter forage crops for factors such as establishment ratio, plant length, plant height, number of tillers, and growth condition. The establishment ratio of each plot was visually examined and expressed as a percentage, and the length of the plant was measured from the ground surface to the tip of the plant. The number of tillers was recorded by counting the number of tillers per plant, and the heading date was recorded as the number of days when the heading was over 50%. The growth status was visually examined and graded from 1 to 9 (1 = good, 9 = poor).

In the spring of the following year, the growth characteristics such as heading date, plant length, lodging resistance, disease resistance, and cold tolerance were investigated. The lodging resistance, disease resistance, and cold tolerance were graded from 1 to 9 (1 = strong, 9 = weak).

Fresh yield of each plot was calculated by harvesting whole 6 $m^2$ at three replications of treatments. To calculate DM (Dry matter) content, the samples collected at each harvest were dried at 65℃ for 72 h or more, in a hot air circulation dryer. DM yield was calculated by multiplying the ratio of DM with fresh yield, and the value was converted as DM per hectare. Mean values and standard deviations of the experimental results were obtained using SAS (Statistics Analytical System, SAS Institute Inc., Cary, NC, USA, 2010). Duncan's multiple comparison test was used to identify differences among the treatments, which were considered significant at $p < 0.05$.

### 5. Nutritive value analysis

The winter forage crop samples examined for DM content were used for chemical composition analysis after crushing and filtering through a 20-mesh sieve. The crude protein (CP) was analyzed according to AOAC (1990) using a Kjeltec 2400 Auto Sampler System (FOSS, Hillerod, Denmark). Neutral detergent fibers (NDF) and acid detergent fibers (ADF) were analyzed according to the method described by Goering and Van Soest (1970) in an Ankom Fiber Analyzer (ANKOM Technology, 2005a & 2005b, Macedon, NY, USA).

## Ⅲ. RESULTS AND DISCUSSION

The soil in Uzbekistan has a high overall pH, and high calcium, bicarbonate, and carbonate content. When sulfate or urea fertilizers are used, sediments such as calcium phosphate or magnesium phosphate are generated. Therefore, these should be carefully examined and applied, depending on the crop to be cultivated.

Table 5 and table 6 show the growth characteristics of winter feed crops cultivated at the USRSC (Uzbek Scientific Research Station of Corn). In all test plots, germination occurred after 9 days of sowing, and seedlings were observed around October 28. As a result of examining the growth in the seedling stage, the establishment ratio was the highest at 92% for Italian ryegrass 'Kowinmaster' and the lowest at 75% for Uzbek Barley 'Bolgaly'. At this time, the plant length of all forage crops was

**Table 5. Growth characteristics of winter forage crops before winter (December 21, 2010) at Tashkent in Uzbekistan**

| Crop | Cultivar | SS[1] (%) | PL[2] (cm) | NT[3] (ea) | Gr[4] (1~9)* |
|---|---|---|---|---|---|
| Italian ryegrass | Kowinearly | 87 | 23 | 4 | 2 |
| | Kowinmaster | 92 | 22 | 4 | 1 |
| Barley | Youngyang | 85 | 24 | 4 | 1 |
| | Yuyeon | 79 | 24 | 4 | 2 |
| | Bolgaly | 75 | 25 | 5 | 3 |
| Oat | Samhan | 86 | 23 | 4 | 3 |
| | Uz Shirokoristy | 81 | 23 | 4 | 2 |
| Triticale | Shinyoung | 85 | 25 | 5 | 2 |
| | Frack cerebristy | 83 | 25 | 5 | 1 |

(1~9)*: 1 = Excellent (or strong), 9 = Worst (or week)
SS[1], Seedling stand; PL[2], Plant length; NT[3], No. of tillers; Gr[4], Growth

**Table 6. Growth characteristics of winter forage crops at Tashkent in Uzbekistan**

| Crop | Cultivar | HD[1)] (mm.dd) | PL[2)] (cm) | LR[3)] (1~9)* | DR[4)] (1~9)* | CT[5)] (1~9)* |
|---|---|---|---|---|---|---|
| Italian ryegrass | Kowinearly | 04.13 | 143 | 4 | 3 | 1 |
| | Kowinmaster | 04.17 | 135 | 4 | 3 | 1 |
| Barley | Youngyang | 04.05 | 81 | 3 | 2 | 1 |
| | Yuyeon | 04.05 | 83 | 3 | 2 | 1 |
| | Bolgaly | 04.10 | 127 | 4 | 3 | 1 |
| Oat | Samhan | 04.25 | 118 | 4 | 4 | 1 |
| | Uz Shirokoristy | 04.30 | 139 | 4 | 4 | 1 |
| Triticale | Shinyoung | 04.04 | 116 | 5 | 4 | 1 |
| | Frack cerebristy | 04.25 | 148 | 5 | 4 | 1 |

(1~9)*: 1 = Excellent (or strong), 9 = Worst (or week)
HD[1)], Heading date; PL[2)], Plant length; LR[3)], Lodging resistance; DR[4)], Disease resistance; CT[5)], Cold tolerance

almost the same (22~25cm), and the number of tillers was similar (4~5). The overall growth status before wintering was slightly different between Uzbekistani and Korean varieties, but there was no significant difference among forage crops (Table 5).

Over winter, the survival ratios of winter forage crops were generally high, as shown in Table 6. The reason is that the temperature on the coldest day in Uzbekistan is -8°C, which is much higher than the temperature of Cheonan in Korea. The heading date and growth stages were about one month earlier than those of crops grown in central Korea. This is because the winter temperatures in Uzbekistan are warm enough to be similar to those of Jeju in Korea (Park et al., 2008, Choi et al., 2008). The heading date of the Korean triticale 'Shinyoung' was the earliest, on April 4, while that of the Uzbekistani triticale 'Frack cerebristy' was April 25, three weeks later than that of 'Shinyoung'. The heading date of the Italian ryegrass 'Kowinearly' was four days earlier than that of 'Kowinmaster', on April 13, and that of the Korean barley ('Youngyang' and 'Yuyeon') was five days earlier than that of the Uzbekistani barley 'Bolgaly'. The heading date of the Korean oat 'Samhan' was five days earlier than that of the Uzbekistani oat 'Uz Shirokoristy'. Among the growth characteristics related to the yield, plant length height was examined at the harvest time of each crop, because of differences in their growth stages. Uzbekistani varieties were longer by 20–30 cm than all crops except Italian ryegrass. In Korea, the common harvest stages for Italian ryegrass, oats, barley, and triticale, are, dough stage, heading stage, milk stage, and yellow ripe stage, respectively (Kim, 2019).

The productivity of 'Frack cerebristy' was the highest among cultivated winter forage crops, with 46,199 kg/ha of fresh yield and 13,536 kg/ha of dry matter yield. Both dry matter and TDN yield of Korean Italian ryegrass ('Kowinearly' and 'Kowinmaster') were higher than those of the Uzbekistani barley, 'Bolgaly'. The dry matter yield of Korean barley 'Youngyang' and 'Yuyeon' were lower, and that of the Korean oat 'Samhan' was higher than that of the Uzbekistani barley 'Bolgaly'. Compared with Uzbekistan barley, 'Bolgaly', yields of Korean barley 'Youngyang' and 'Yuyeon', Korean oat 'Samhan', and Korean Italian ryegrass 'Kowinearly' and 'Kowinmaster' were 59~64%, 125%, and 113~133%, respectively. The Uzbekistani triticale 'Frack cerebristy' was 65% higher in DM yield and 48% higher in TDN yield than was the Uzbekistani barley 'Bolgaly', while the DM and TDN yields of the Korean triticale 'Shinyoung' were 31% and 28% higher than those of the Uzbekistani barley 'Bolgaly', respectively (Table 7).

In winter forage crops, the TDN yield increased in Italian ryegrass (5~24%), triticale (28~48%), and Korean oat 'Samhan' (15%) but decreased in Korean barley (28~36%) relative to the Uzbekistan barley 'Bolgaly'. Though DM yield and TDN value were higher in triticale ('Frack cerebristy'), harvest date for triticale was 30th May. Thus, it was too late to be used as a crop in the Uzbekistani cropping system, relative to Italian ryegrass (May 10th). As a result, Italian ryegrass would be considered as the best winter crop in Uzbekistan.

**Table 7. Fresh weight, dry matter, and total digestible nutrient (TDN) yield of winter forage crops at Tashkent in Uzbekistan**

| Crop | Cultivar | Yield (kg/ha) | | | | |
|---|---|---|---|---|---|---|
| | | Fresh weight | Dry matter | Index (%) | TDN | Index (%) |
| Italian ryegrass | Kowinearly | 36,743[d] | 9,259[e] | 113 | 5,202[e] | 105 |
| | Kowinmaster | 44,798[b] | 10,976[b] | 133 | 6,121[c] | 124 |
| Barley | Youngyang | 28,389[g] | 5,252[h] | 64 | 3,542[g] | 72 |
| | Yuyeon | 25,243[h] | 4,872[i] | 59 | 3,172[h] | 64 |
| | Bolgaly | 38,785[c] | 8,222[g] | 100 | 4,953[f] | 100 |
| Oat | Samhan | 36,304[e] | 10,238[d] | 125 | 5,677[d] | 115 |
| | Uz Shirokoristy | 38,865[c] | 8,706[f] | 106 | 4,891[f] | 99 |
| Triticale | Shinyoung | 35,033[f] | 10,755[e] | 131 | 6,330[b] | 128 |
| | Frack cerebristy | 46,199[a] | 13,536[a] | 165 | 7,313[a] | 148 |

[a-i]Means in the same row with different letters are significantly different ($p < 0.05$).

Because of Uzbekistan's agricultural policy, the harvest must be completed no later than mid-May for cotton cultivation. Among the possible species at this time are Italian ryegrass, which is superior in productivity and quantity. In general, early or medium-maturing varieties known in Korea were found to have grown faster in Uzbekistan. This is presumably because of the warmer climate compared to the winter in Korea. The heading stage was 7 days less than southern region of Korea, and 3 weeks faster than central region of Korea. However, the productivity per unit area tended to decrease more than when grown in Korea. The reason for this is thought to be cultivation in 75 cm intervals furrows for irrigation. As the soil analysis revealed, the soil of Uzbekistan had a high pH and low organic and potassium contents. These soils are disadvantageous for the sufficient maturation of the grain. Uzbekistan barley 'Bolgaly' showed better overall growth and higher yields than Korean barley varieties. This variety can be used as a good breeding material for breeding of barley or development of intergenetic hybrids in the Poaceae family.

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