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**Research Article**

# Effects of Fall Sowing Dates on Winter Survival and Dry Matter Yields of Alfalfa in the Central Area of South Korea

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**ABSTRACT**

This study was conducted to determine the appropriate seeding dates by verifying the difference in winter survival and productivity of alfalfa according to fall sowing dates in the central area of South Korea. The experiment was conducted for 2 years (2020 and 2021) at the field in the Department of Animal Resources Development, NIAS located in Cheonan. Sowing dates started from September 18 to November 8 with 10 days of intervals during 2020 and 2021; SO1 (September 18), SO2 (September 28), SO3 (October 8), SO4 (October 18), SO5 (October 28), and SO6 (November 8). After sowing, the winter survival rate was measured in the spring of the following year, and the dry matter yield was measured by harvesting at 10% flowering and harvesting five times a year. SO6 failed to winter survival, and SO5 also had a lower winter survival rate than SO1~4 ($p$<0.05). The average annual dry matter yield of alfalfa linearly decreased with delaying sowing dates ($p$<0.05). The feed value did not differ in the same year by delaying the sowing date in the same year. These results suggest that sowing date should be started before October 18 to increase winter survival and productivity of alfalfa in the central area of South Korea.

(**Key words**: Alfalfa, Sowing date, Winter survive)

## Ⅰ. INTRODUCTION

Alfalfa, which is widely cultivated around the world, is an essential crop in the livestock industry due to its high protein content and relatively low fiber content. In Korea, it has been considered difficult to grow due to its low soil pH and fertility. So, it has been entirely imported. Recently, the possibility of domestic cultivation has emerged, and several studies are underway (Kim et al., 2021; Lee et al., 2022a). However, studies on the cultivation system in the domestic environment is still needed. The sowing period of alfalfa varies depends on the climate and the period of the optimal temperature. Sowing dates are generally spring, late summer, or early fall. When sowing in spring, poor growth may occur due to competition with weeds. In fall sowing, the competition with weeds is reduced, but sometimes, may result in a shorter growing season for fall dormancy response. Choosing a strong fall dormancy response variety when sowing in fall is necessary for winter survival.

Root winter damage is a major cause of negative effects on winter survival, and there are various environmental conditions such as traits, soil moisture, temperature, and precipitation (Bélanger, et al., 2006; Castongua et al., 2006). Fall dormancy is an important characteristic for reducing winter damage. Metabolism, including the synthesis of compatible solutes, raffinose oligosaccharides, and amino acids, induces fall dormancy that proceeds normally (Liu et al., 2019). In addition, plant storage proteins obtained through sufficient growth promote regrowth in spring (Justes et al., 2002). Therefore, fall sowing should allow sufficient time for fall dormancy and vegetative storage proteins accumulation. In perennial crops, the fall dormancy response is essential for winter survival (Bertrand et al., 2017), but known to reduce production (Cunningham et al., 1998). Therefore, an optimal fall dormancy response for the environment is required. Unsuccessful fall dormancy causes more winter damage and negatively impacts the following spring yield. Even if winter survival is successful, the crop needs to be overcome from spring drought.

Therefore, this study was conducted to determine the alfalfa sowing dates in the central area of Korea by identifying the difference in winter survival rate and productivity.

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## Ⅱ. MATERIALS AND METHODS

### 1. Experimental design

The alfalfa (SW 5615) cultivation and harvesting experiment were conducted in the field Department of Animal Resources Development, National Institute of National Science, located in Cheonan, Chungcheongnam-do, Republic of Korea, during 2020-2021. The test area was 2 × 3 m (6 $m^2$), sowing was done on the seed drill 20 cm, and the seeding rate was 20 kg/ha. Fertilizers were converted into component amounts, respectively, and N-P-K at sowing was based on 100-300-300 kg/ha (Lee et al., 2022b). Nitrogen was added at the time of sowing, and lime and boron were applied with 300 and 20 kg/ha in the total amount. P and K were divided by harvest time. Sowing dates were SO1 (September 18), SO2 (September 28), SO3 (October 8), SO4 (October 18), SO5 (October 28), and SO6 (November 8) in each of two years. The experiments were designed in a randomized complete block design with three replications.

### 2. Analysis of yield and feed value

The winter survival was calculated by counting the number of standing alfalfa pre-winter and the number of standing alfalfa post-winter. Alfalfa was harvested at the flowering stage of 10%, and each sample was collected five harvesting times per year. After harvest, alfalfa height was measured for each replication and sampled to calculate the dry matter yield per unit area (kg/ha) based on the dry matter content. The collected samples were dried in a hot air dryer at 65°C for 72 hours, then pulverized and passed through a 1mm sieve mill for feed value analysis. All feed value analyses were performed by the Association of Official Analytical Chemists (AOAC, 1990). The crude protein content was measured using an elemental analyzer (Vario MAX cube; Elementar, Langenselbold, Germany) according to Dumas' method (AAAS, 1884). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed by Goering and Van Soest (1970) using an Ankom200 fiber analyzer (Ankom Technology, Macedon, NY, USA). The relative feed value was calculated using the formula: relative feed value = (120 / NDF (%)) × (88.9 - 0.779 × ADF (%)) / 1.29 (Mooreand and Undersander, 2002).

### 3. Statistical analysis

Statistical analysis was conducted to Tukey test ($P<0.05$) using the PROC ANOVA SAS program (v. 9.4 program, 2013) for significant differences between sowing dates, respectively. The dry matter yield of annual was tested for linear effects in sowing dates to polynomial contrast using PROC MIXED ANOVA SAS program (v. 9.4 program, 2013) after calibrating sowing dates using PROC IML

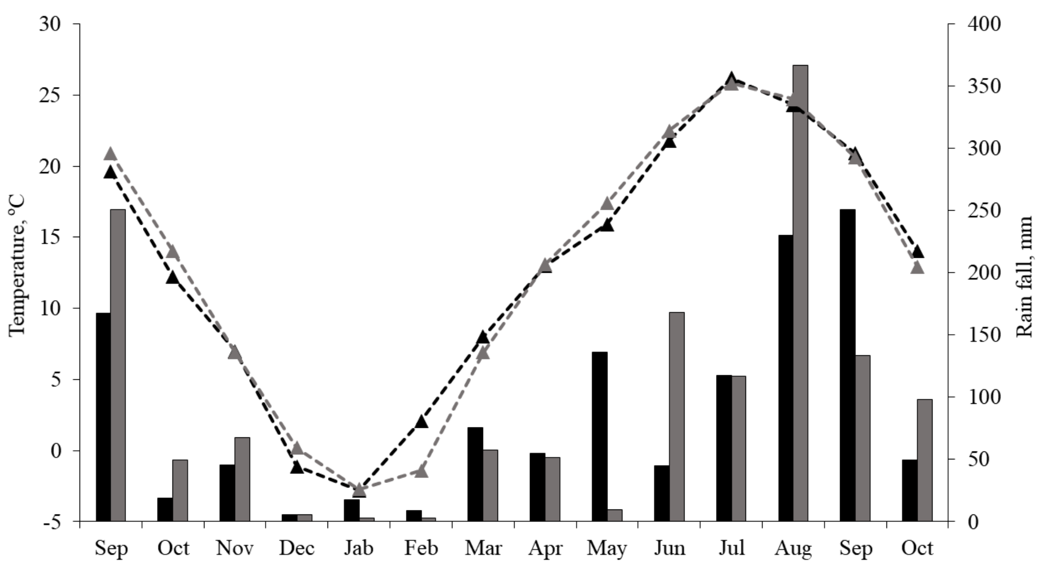


**Fig. 1. Average monthly temperature and precipitation at experimental sites for 2020 to 2022. ■, average monthly rainfall for 2020-2021; ■, average monthly rainfall for 2021-2022; ··▲··, average monthly temperature for 2020-2021; ··▲··, average monthly temperature for 2021-2022.**

## Ⅲ. RESULTS AND DISCUSSION

### 1. Average temperature and precipitation

The average monthly temperature and precipitation during the experiment period are shown in Fig. 1. The average monthly temperatures ranged from -2.8 to 26.2℃ from September 2020 to October 2021 (Y1) and from -2.7 to 25.8℃ from September 2021 to October 2022 (Y2). The average monthly temperature over the 30-years ranged from -2.4 to 25.2℃ (KMA), showing similar temperature changes during the experiment. However, compared to 0.1℃ of the average temperature over the 30-year in February, February 2021 was higher at 2.1℃, and February 2022 was lower at -1.4℃. Precipitation varied by month, but the difference was shown in May (135.9 vs. 9.8 mm) and June (44.8 vs. 168.0 mm), which are the main growth periods of alfalfa in Y1 and Y2. Total annual precipitation was higher than average over 30 years and Y2 was higher than Y1 (1415.3 vs. 1382.3 vs. 1223.1 mm).

### 2. Winter survival rate and growth characteristic

Fig 2. showed the winter survival rate according to the sowing dates during fall in Y1 and Y2. There was no difference in winter survival rate and sowing dates by year and sowing date from SO1~SO4. However, SO5 was lower than the other sowing dates, and SO6 didn't overwinter. The low winter survival of SO5 can be attributed to the difference between the stand pre and post-winter. Investigation pre-winter of SO2~4 was lower than SO5 but was higher SO2~SO4 than SO5 post-winter. Min et al (1999) reported higher densities were associated with lower winter survival in alfalfa. In this study, SO5 has a higher density than SO2~ SO4 pre-winter. SO5 and SO6 did not have enough time to activate fall dormancy and accumulate vegetative storage protein. Therefore, considering that the winter survival rate of SO5 is lower than other sowing dates, it is considered that sowing after SO5 is difficult to winter survival.

The alfalfa average growth characteristics for both years are shown in Table 1. Alfalfa total and sowing time height have no significant differences ($p$>0.05), but decreased linearly by delaying sowing dates at the 2nd and 4th harvests (L. $p$<0.05). Total annual total dry matter yield was linearly decreased with delayed sowing dates (L. $p$<0.05). Difference in precipitation between May and June in Y1 and Y2, resulted in differences in the average yield between the 2nd (4007.7 vs. 6373.3 kg/ha; $p$<0.05) and 3rd harvest (2290.0 vs. 4600.7 kg/ha; $p$<0.05). However, there was no difference between years in annual production ($p$>0.05). Yields of 10 to 20 tone DM/ha are commonly produced in Europe, China, and North America under irrigated conditions (Moot et al., 2012). In this study, the

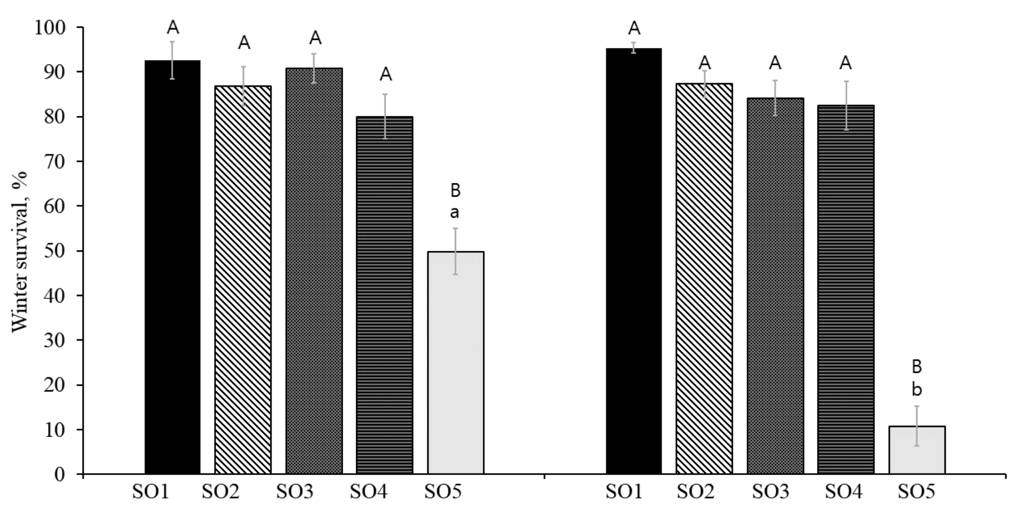


**Fig. 2. Effects of fall season sowing dates on alfalfa winter survival in 2020 and 2021. SO1, sowing date at September 18; SO2, sowing date at September 28; SO3, sowing date at October 8; SO4, sowing date at October 18; SO5, sowing date at October 28; A and B means significant difference in the same year; a and b means significant differences in the same sowing dates.**

annual average alfalfa dry matter yield was 13,884~24,404 kg/ha, which varied according to the sowing dates. Kim et al. (2021) reported that the average annual dry matter yield of alfalfa in Korea was 13,767 kg/ha. In general, yield is affected by variety, climatic environment, soil condition, etc. However, since this study was conducted in the same variety and the same place, there was no significant difference in total annual total production between years. Janssen (1929) reported that

**Table 1. Effects of fall sowing dates on average alfalfa height and dry matter yield of 2020 and 2021 in the central area of Korea**

| Treatments | SO1 | SO2 | SO3 | SO4 | SO5 | SEM | Linear |
|---|---|---|---|---|---|---|---|
| First harvest | | | | | | | |
| Height (cm) | 75.9 | 73.7 | 74.6 | 74.1 | 71.2 | 4.350 | 0.406 |
| Dry matter yield (kg/ha) | 6,417.0[a] | 5,355.0[ab] | 4,650.0[bc] | 4,023.0[bc] | 3,271.0[c] | 828.4 | <0.001 |
| Second harvest | | | | | | | |
| Height (cm) | 82.6 | 83.9 | 81.2 | 79.0 | 75.7 | 4.501 | 0.023 |
| Dry matter yield (kg/ha) | 6,689.5[a] | 5,605.0[ab] | 6,134.0[a] | 4,389.0[ab] | 3,135.5[b] | 1515 | <0.001 |
| Third harvest | | | | | | | |
| Height (cm) | 64.0 | 64.3 | 64.2 | 63.7 | 68.7 | 2.883 | 0.366 |
| Dry matter yield (kg/ha) | 3,903.5 | 3,903.0 | 3,577.0 | 2,787.0 | 3,056.5 | 1499 | 0.159 |
| Fourth harvest | | | | | | | |
| Height (cm) | 65.6 | 64.5 | 60.2 | 57.1 | 60.0 | 5.200 | 0.011 |
| Dry matter yield (kg/ha) | 2,890.0 | 3,004.0 | 2,405.0 | 1,973.5 | 1,960.5 | 858.8 | 0.015 |
| Fifth harvest | | | | | | | |
| Height (cm) | 54.3 | 52.7 | 48.2 | 48.2 | 45.6 | 5.525 | 0.084 |
| Dry matter yield (kg/ha) | 4,504.0 | 3,871.5 | 3,078.0 | 2,763.0 | 2,460.5 | 1771 | 0.032 |
| Total | | | | | | | |
| Height (cm) | 68.5 | 67.8 | 65.6 | 64.4 | 64.2 | 12.57 | 0.103 |
| Dry matter yield (kg/ha) | 24,404.0[a] | 21,738.5[ab] | 19,844.0[bc] | 15,935.5[cd] | 13,884.0[d] | 1598 | <0.001 |

SO1, sowing date at September 18; SO2, sowing date at September 28; SO3, sowing date at October 8; SO4, sowing date at October 18; SO5, sowing date at October 28; SEM, standard error of the mean; SEM, standard error of the mean; Linear, linear effects by delaying sowing dates; [a~d] means significant difference in the same row.

**Table 2. Alfalfa feed value by different sowing dates in the fall season of 2020 and 2021**

| | SO1 | SO2 | SO3 | SO4 | SO5 | SEM |
|---|---|---|---|---|---|---|
| 2020 | | | | | | |
| CP, % DM | 20.72 | 21.58 | 21.83 | 22.27 | 21.52 | 1.930 |
| NDF, % DM | 47.90 | 46.95 | 47.17 | 48.10 | 46.48 | 2.707 |
| ADF, % DM | 32.30 | 32.05 | 31.95 | 31.72 | 32.12 | 2.055 |
| RFV | 124.08 | 127.08 | 127.05 | 124.67 | 128.20 | 18.50 |
| 2021 | | | | | | |
| CP, % DM | 19.70 | 20.77 | 19.70 | 21.66 | 19.99 | 3.580 |
| NDF, % DM | 44.60 | 46.22 | 43.24 | 44.82 | 43.49 | 7.066 |
| ADF, % DM | 30.58 | 31.13 | 29.68 | 29.32 | 29.16 | 4.782 |
| RFV | 138.29 | 132.15 | 145.33 | 140.43 | 147.52 | 30.53 |
| Total | | | | | | |
| CP, % DM | 20.21 | 21.18 | 20.77 | 21.96 | 20.75 | 4.554 |
| NDF, % DM | 46.25 | 46.58 | 45.20 | 46.46 | 44.99 | 5.650 |
| ADF, % DM | 31.44 | 31.59 | 30.82 | 30.52 | 30.64 | 3.541 |
| RFV | 131.18 | 129.62 | 136.19 | 132.55 | 137.86 | 21.88 |

SO1, sowing date at September 18; SO2, sowing date at September 28; SO3, sowing date at October 8; SO4, sowing date at October 18; SO5, sowing date at October 28; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; RFV, relative feed value; SEM, standard error of the mean.

alfalfa's organic root reserves and winter injury had a negatively affected on alfalfa's stand. This study concludes that the level of winter damage by sowing dates has a negative effect on stand formation and yield.

### 3. Feed value

Table 2 showed the average feed value of alfalfa according to the sowing dates in the fall of Y1 and Y2. Nutrient content differed by sowing dates and harvesting time ($p$<0.05) but did not show a pattern. The averages of CP, NDF, ADF, and RFV for Y1 and Y2 were 20.2–22.0, 45.0–46.6, 30.5–31.6%, and 129.6–137.9 of DM, respectively. The average of feed value data were not significantly different by sowing dates ($p$>0.05) because of big variation. CP (21.6 vs. 20.4 % of DM), NDF (47.3 vs. 44.5 % of DM), and ADF (32.0 vs. 30.0 % of DM) were higher in Y1 than in Y2, while RFV was lower in Y1 than Y2 (126.2 vs. 140. 7). The CP content in this study was 19.7 ~ 22.3%, which is within the range of 17 ~ 26% (Daniel et al., 2007), which is the CP content of general Alfalfa. RFV is according to the US alfalfa hay grading standards (USDA-Hay-Markets, 2022),where Y1 alfalfa is Utility grade (<130) and Y2 alfalfa means Fair grade (130-150).

## Ⅳ. CONCLUSIONS

This study was conducted to determine the effects of the fall season sowing dates on the winter survival rate and growth characteristics of alfalfa in the central area of Korea. When sowing from September 18. to October 18., there was no significant damage to winter survival, but it decreased when sowing after October 28. Also, winter survival was not possible after November. Dry matter yield, didn’t differ in annual production from September 18. to September 28, but then decreased linearly with the later sowing and was the lowest on October 28. Therefore, for fall alfalfa sowing in the central area of Korea, sowing in mid-September is most advantageous for productivity, and winter survival is difficult after mid-October.

## Ⅴ. ACKNOWLEDGEMENTS

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