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Research Article

Effects of Chemical Foliar Herbicide on Weed Control in Alfalfa Field

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ABSTRACT

This study aims to contribute to resolving the critical issue of weed management in newly established alfalfa fields, study has been conducted on effective herbicide use. The study evaluated the impact of various domestically available foliar herbicides on alfalfa phytotoxicity, weed control, yield, and nutritive value. The experiment was designed in a randomized complete block design with four treatments. Alfalfa 'SW 5615' seeded in the spring of 2024 on a 1 ha field (March 18), with herbicide treatments including fluazifop-P-butyl (FPB), bentazone (BEN), and a mixture of these herbicides (MIX). Herbicide efficacy, alfalfa yield, and nutritive value were assessed 30 days post-application. Results indicated that the MIX treatment achieved superior weed control comparable to hand weeding (HW), although it exhibited higher phytotoxicity, requiring extended recovery periods. While MIX led to lower overall yield, it enhanced alfalfa purity, resulting in higher crude protein (CP) content and relative feed value (RFV) compared to other treatments. The study concludes that despite the potential for increased phytotoxicity, mixed herbicide treatments could offer a strategic advantage in enhancing the quality of alfalfa feed through effective weed management, thereby improving CP and RFV, critical factors for the nutritional value of alfalfa. These findings provide valuable insights for optimizing weed management practices in alfalfa cultivation, suggesting that mixed herbicide application, although associated with increased phytotoxicity on the plants, could improve the overall feed quality by reducing weed competition.

(**Key words**: Weed control, Foliar herbicides, Alfalfa biomass, Alfalfa nutritive value)

Ⅰ. INTRODUCTION

In newly established alfalfa fields, weed management is a critical practice (Bradley et al., 2010; Dillehay et al., 2011), as weed issues often lead to the failure of alfalfa establishment in soils with otherwise suitable cultivation conditions, resulting in reduced production and quality. Spring sowing can exacerbate competition with summer annual weeds (Bradley et al., 2010), leading to increased cultivation costs and reduced crude protein content due to weed interference if sufficient plant density is not maintained. To mitigate these issues, late summer or autumn sowing is sometimes recommended; however, competition from winter annual weeds can still cause damage (Hall et al., 1995; Adjesiwor et al., 2017). Although a variety of herbicide options are available for alfalfa fields in international studies—such as carfentrazone, diuron, flumioxazin, hexazinone, imazethapyr, 2-methyl-4-chlorophenoxyacetic acid (MCPA), metribuzin, pendimethalin, paraquat, saflufenacil, and terbacil—the choices for domestic manufacturing and distribution are limited by not allowed to use unregistered crop protectors. Since alfalfa cultivation in Korea has not been studied enough, there is a lack of studies on weed control during alfalfa cultivation and new establishment. Therefore, this study aims to evaluate the effects of foliar herbicides available domestically on alfalfa phytotoxicity and weed control to reduce weed damage in alfalfa cultivation in Korea.

Ⅱ. MATERIALS AND METHODS

1. Experimental design

This experiment was conducted in 2024, and alfalfa seeded on March 18. Alfalfa 'SW 5615' was cultivated in the field Department of Animal Resources Development, National Institute of Animal Science, located in Cheonan, Chungcheongnam-do, Republic of Korea, in a 1ha alfalfa field sown at a rate of 20 kg/ha. A soil herbicide (S-metalachlor 25%) was sprayed at the sowing. After the third trifoliate, when the average length of

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legume was over 10 cm after the crown was formed, a test plot with a size of 1 m² (1 × 1 m) was randomly selected from the alfalfa field, and a test plot was formed in 6 repetitions and divided for harvest and visual inspection investigation. The experiment was designed in a randomized complete block design with four treatments. The treatment consisted of control (CON), hand weeding (HW), fluazifop-P-butyl (FPB), bentazone (BEN), and mixed with fluazifop-P-butyl and bentazone 1:1 ratio (MIX). The herbicides used were broad-leaved selective foliar herbicides (batsagran, bentazone 40%), and grass selective foliar herbicides (newonecide, fluazifop-P-butyl 17.5%), and mixed foliar herbicides (batsagran + newonecide).

2. Herbicide control

For 30 days after herbicide application, a visual inspection plot was used to investigate the damage of weakness from herbicides and the estimated recovery date and required date of the early flowering stage. To calculate weed control value, the weight of each weed was measured by hand, and alfalfa and weed were classified in a harvesting plot on the 30th day of herbicide application. Weed control value = {1-(the total DM of weed in the treatment plot/the total DM of weed in the control plot)} × 10. The efficacy of herbicides was investigated according to the standards and methods of the Rural Development Administration's pesticide effectiveness test, and the phytotoxicity evaluation was investigated according to the standards and methods of the Rural Development Administration's phytotoxicity test. Calculating the reaching date of early-flowering for each plot to estimate the effect of the weak phytotoxicity.

3. Yield and nutritive value

The harvest date was with the applied herbicide after 30 days. At the time of harvest, the height and yield were measured, and dry for dry matter analysis. All samples were dried for 72 h in a 65℃ air dryer, pulverized, and passed through a 1mm sieve mill for the nutritive value analysis. All nutritive value analyses were performed by the Association of Official Analytical Chemists (AOAC, 1990). The crude protein (CP) 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 (RFV) was calculated using the formula: relative feed value = (120 / NDF (%)) × (88.9 - 0.779 × ADF (%)) / 1.29 (Moore and Undersander, 2002).

4. 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 each herbicide treatment.

Ⅲ. RESULTS AND DISCUSSION

1. Herbicide effect

As shown in Table 1, the single selective herbicide treatment resulted in a low total weed control value (14.6 and 13.3%), while the MIX appeared a weed control value comparable to HW (98.8%) at 93.9%. The dominant weeds identified were primarily grass from the *Setaria viridis*, along with *Humulus japonicus*, *Lamium amplexicaule*, and *Abutilon theophrasti*, among the broad-leaved weeds. Due to the characteristics of the herbicide, the total weed control value was low in the FPB due to the prevalence of broad-leaved weeds (98%) and similarly low in the BEN test area where grass weeds (95%)

Table 1. Effects of chemical foliar herbicides on alfalfa weed control

	CON	HW	FPB	BEN	MIX
Weed control (%)	0	98.8	14.6	13.3	93.9
Weed ratio					
Grass (%)	22	50	2	95	26
Broad leaves (%)	78	50	98	5	74

CON, control; HW, hand weeding; FPB, fluazifop-P-butyl; BEN, bentazone; MIX, mixed with fluazifop-P-butyl and bentazone.

were dominant. As shown in Table 2 and depicted in Fig. 1 A, alfalfa in the MIX exhibited greater damage due to herbicide phytotoxicity compared to the single selective herbicide treatment (2 vs. 2 vs. 4). Over all, MIX required the longest recovery date (14 ± 4 vs. 19 ± 3 vs. 22 ± 2 day) and reaching date (44 ± 3 vs. 48 ± 4 vs. 55 ± 4 day) of the early bloom stage from herbicide phytotoxicity damage. However, all damage from herbicide phytotoxicity was recovered normally, as described in Fig. 1 B.

2. Alfalfa yield

Table 3 shows the height and yield of alfalfa under different herbicide treatments. The MIX treatment resulted in the lowest plant height ($p<0.05$), while FPB and BEN treatments produced taller plants than HW and MIX ($p<0.05$). There were no significant differences in total yields, net alfalfa yields, and weed yields among the CON, FPB, and BEN treatments ($p>0.05$). Net alfalfa yield was highest in the HW treatment ($p<0.05$), and both HW and MIX treatments had lower weed yields compared to the other herbicide treatments ($p<0.05$).

The differences in yield production are likely due to several factors influenced by the herbicides used. Generally, herbicide treatment can reduce total yield by decreasing weed biomass (Cosgrove and Barrett, 1987). Additionally, plant height may increase due to light competition from weeds (Walsh et al., 2018). However, as noted in studies where weed competition has resulted in decreased plant height (Korav et al., 2018), it is insufficient to evaluate the effects based on a single factor. Comprehensive analysis considering multiple variables is necessary to accurately assess the overall impact of herbicide treatments on alfalfa growth and yield. In this study, FPB and BEN treatments had higher weed yields than HW and MIX, likely resulting in increased plant height due to light competition. However, the low height observed in the MIX compared to HW was believed to be due to herbicide phytotoxicity rather than reduced by light competition, as the mixed herbicide treatment likely caused damage to the plants.

When weed competition is reduced, light competition

Table 2. Effects of chemical foliar herbicides on alfalfa phytotoxicity

	CON	HW	FPB	BEN	MIX
Alfalfa phytotoxicity* (index)	0	0	2	2	4
Recovery date (days)	0	0	14 ± 4	19 ± 3	22 ± 2
Required date of early flowering stage (days)	32 ± 4	38 ± 1	44 ± 3	48 ± 4	55 ± 4

CON, control; HW, hand weeding; FPB, fluazifop-P-butyl; BEN, bentazone; MIX, mixed with fluazifop-P-butyl and bentazone.
* Phytotoxicity, 0~9 (0=no damaged; 1=minor discolor; 2=quick recovery after discolor; 3=late recovery and growth; 4=reduced under 5% of yield by herbicide; 5=reduced 10% of yield by herbicide; 6=reduced 15% of yield by herbicide; 7=reduced 20% of yield by herbicide; 8=reduced 30% of yield by herbicide; 9=reduced 50% of yield by herbicide).

Fig. 1. Alfalfa phytotoxicity of 3 days after herbicide spraying (A) and weed control before harvest (B).

Table 3. Effects of chemical foliar herbicides on alfalfa height and dry matter yield

	CON	HW	FPB	BEN	MIX	SEM
Height (cm)	63.7^{ab}	60.3^{b}	66.3^{a}	64.7^{a}	48.3^{c}	3.201
Total yield (ton/ha)	7.10^{a}	5.49^{b}	6.78^{ab}	7.34^{a}	4.24^{c}	0.87
Alfalfa yield (ton/ha)	3.22^{c}	5.44^{a}	3.50^{c}	3.78^{bc}	4.05^{b}	0.36
Weed yield (ton/ha)	3.89^{a}	0.05^{b}	3.28^{a}	3.63^{a}	0.20^{b}	0.36

Con, control; HW, hand weeding; FPB, fluazifop-P-butyl; BEN, bentazone; MIX, mixed with fluazifop-P-butyl and bentazone; SEM, standard error of the mean.

Table 4. Effects of chemical foliar herbicides on alfalfa chemical composition

	CON	HW	FPB	BEN	MIX	SEM
Crude protein (%, DM)	19.5^{c}	19.1^{c}	20.7^{b}	18.7^{c}	22.7^{a}	0.492
Neutral detergent fiber (%, DM)	42.5^{b}	39.4^{b}	43.3^{b}	47.8^{a}	32.4^{c}	1.590
Acid detergent fiber (%, DM)	30.5^{a}	28.9^{a}	30.7^{a}	28.9^{a}	22.6^{b}	0.903
Relative feed value (index)	142.9^{b}	156.7^{b}	139.8^{b}	129.3^{c}	204.9^{a}	8.206

Con, control; HW, hand weeding; FPB, fluazifop-P-butyl; BEN, bentazone; MIX, mixed with fluazifop-P-butyl and bentazone; SEM, standard error of the mean.

decreases, allowing the plant to focus on canopy growth (Barnes et al., 1990). Apart from HW, the MIX treatment had a high net alfalfa yield, suggesting that removing weeds, even at the cost of some phytotoxic damage, may be beneficial for increasing alfalfa purity. Previous studies have reported a 36-39% increase in alfalfa production due to herbicide treatments (Roberts et al., 2023), and in this study, the net alfalfa yield in the MIX treatment was 26% higher than in the CON treatment (4.05 vs. 3.22 ton/ha).

3. Chemical composition

Table 4 shows the effects of herbicide treatments on the chemical composition of alfalfa. The CP content, a major indicator of alfalfa's nutritive value, was highest in the MIX treatment ($p<0.05$). MIX had the lowest NDF content, while BEN had the highest NDF content (32.4 vs. 47.8% DM, $p<0.05$). For ADF, MIX recorded the lowest values ($p<0.05$). Therefore, the relative feed value (RFV) was highest in MIX and lowest in BEN ($p<0.05$).

Depend on Montgomery et al. (2023), an increase in weed proportion typically reduces CP and RFV while increasing NDF in forage. However, they noted that ADF content does not necessarily increase under such conditions. These differences may vary depending on the specific types of weed components. Temme et al. (1979) reported that certain weeds, such as *Chenopodium album* and *Ambrosia artemisiifolia*, have crude protein content and digestibility similar to or even higher than alfalfa.

The higher CP content observed in FPB compared to HW (20.7 vs. 19.1% DM; $p<0.05$) might be attributed to the relatively high CP content found in the broadleaf weeds prevalent in the FPB treatment. In the case of MIX, the high CP content is likely due to the lower growth stage of alfalfa at the time of harvest, possibly resulting from the stress of mixed herbicide treatment, which stunted growth. This is supported by the lower NDF and ADF content in MIX compared to HW and the delayed early bloom period observed in MIX. The highest NDF content in BEN ($p<0.05$) is likely due to the dominance of dog grass, which has low CP and high NDF content.

Ⅳ. CONCLUSIONS

This study aimed to evaluate the effects of selective and mixed herbicides on alfalfa fields. The results showed that herbicide treatments were more beneficial for net alfalfa production compared to the control group. Among the treatments, mixed herbicides provided better weed control and higher net alfalfa production compared to single herbicides. While mixed herbicide treatment was less favorable for total production, it was advantageous in terms of nutritive value and net alfalfa yield. However, it also resulted in more plant damage compared to a single herbicide treatment. Therefore, considering both nutritive value and production volume, mixed herbicide treatment appears to be the most advantageous approach, but further study is necessary to mitigate the associated plant damage.

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