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EFFECTS OF SUPPRESSION APPLICATIONS ON SUMMER ASPHODEL (*Asphodelus aestivus* Brot.) DENSITY, BOTANICAL COMPOSITION, FORAGE YIELD AND QUALITY OF AEGEAN RANGELANDS

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ABSTRACT

Summer asphodel (*Asphodelus aestivus* Brot.) has an underground storage organ that enables the plant to survive extreme conditions and contains alkaloids that are toxic to the livestock in rangelands. For this reason, the experiment was carried out in the rangeland of Aydin province (Turkey) in order to determine the most effective methods of weed management where there is an increase in the summer asphodel (*Asphodelus aestivus* Brot.) population. In the study, the effects of 8 different control methods (control, mowing, fertilization, paraquat, glyphosate, 2,4-D, 2,4-D + Picloram, grubbing) on yield, quality and botanical composition were investigated. Result of the findings in this study shows that the grasses increased more in vegetation. The highest values of hay yield were observed in paraquat and fertilization applications. High values of crude protein yield were found in fertilization and grubbing applications. The lowest population of summer asphodel (*Asphodelus aestivus* Brot.) was obtained grubbing and paraquat applications. Together with these results, grubbing, fertilization, paraquat and glyphosate applications come to the fore. However, due to the high workforce, it is significant to choose an application considering the size of the rangeland and the population of the indicator weed species.

Keywords: *Asphodelus aestivus*, forage quality, herbicide, range improvement, weed control

INTRODUCTION

In addition to many ecosystem services, natural rangelands provide forage for livestock and wildlife (Barnes et al., 1995; USDA, 2018). However, mismanagement mainly overgrazing is the main problem of the rangelands in Turkey. It was claimed that because of mismanagement practices, the rangelands of Turkey have lost approximately 90% of their original vegetation (Genckan et al., 1990; Cetiner et al., 2012; Turan et al., 2015; Gokkus, 2020; Koc et al., 2021). As a result of these conditions, an increase in invasive weed populations has been observed in rangelands. Impacts of this increase to the livestock industry not included in the estimate are the negative effects of invasive plants on yield and quality of forage, livestock poisoning, interference with grazing, supplemental costs associated with managing and producing livestock, and land values. Also, invasive weeds can decrease wildlife and plant biodiversity (Mack et al., 2000; DiTomaso et al., 2010).

The genus *Asphodelus* is native to temperate Europe, the Mediterranean, Africa, the Middle East, and the Indian Subcontinent, and now naturalized in other places (New Zealand, Australia, Mexico, southwestern United States, etc.). It reaches its maximum diversity in the Mediterranean rangelands (Malmir et al., 2018). The family consists of three subfamilies: *Asphodeloideae* Burnett (including 13 genera), *Hemerocallidoideae* Lindley (including 19 genera) and *Xanthorrhoeoideae* M.W. Chase (with only one genus) (Malmir et al., 2018). As with other geophytes, *Asphodelus aestivus* Brot. is a dominant species in some degraded Mediterranean ecosystems. These regions are sometimes referred to as "asphodel deserts" (Sawidis et al., 2005).

A severe neurological syndrome accompanied by intense neuronal pigmentation in sheep in Turkey was observed after the ingestion of summer asphodel (Calis et al., 2006). The high silicon (Si) content of mature leaves contributes to its unpalatability, whereas the tubers are protected from herbivores through the accumulation of defense substances, such as alkaloids that are harmful to sheep and goats (Rhizopoulou et al., 1997).

Currently, mechanical, cultural and chemical methods are used in weed management. These methods include such as grubbing, mowing and herbicides (DiTomaso et al., 2010). Fertilization can increase the density of grasses and other families in the rangeland areas and restrict some species such as *Asphodelus aestivus* from dominating (Aydin and Uzun, 2000; Masters and Sheley, 2001; Yavuz et al., 2008). Grubbing is a mechanical treatment, but the high cost of this treatment limits its use to control rangeland weeds. Mowing is often used to control annuals but can occasionally reduce seed production and provide suppression of biennials and perennials (Rinella et al., 2001; DiTomaso et al., 2010). On rangelands, herbicides are the most frequently used tool for the control of invasive and dominant species. The most used herbicides on rangelands are 2,4-D (auxin-like growth regulator that selectively controls broadleaf species), glyphosate (a non-selective foliar-applied systemic herbicide), paraquat (photosystem 1 energized cell membrane disrupter contact herbicide) (Gokkus and Koc, 1996; Masters and Sheley, 2001; DiTomaso et al., 2010).

The density of asphodel is gradually increasing in the rangeland areas where it is mismanaged for a long time in the region. Different control methods have been tried in order to suppress this species from being more dominant than other species in the rangeland. Due to the lack of research on summer asphodel control in the region, the study was designed and performed for 3 years.

MATERIALS AND METHODS

The experiment was carried out in Cakmar rangelands (37° 45' N, 27° 45' E) in Kocarli district of Aydin, which has an altitude of 60 m with Mediterranean climate, for a period of 3 years between 2016-2018. When the climate data of the experimental area were viewed, fluctuations were observed between years according to the average of the three years, while the average temperature was similar. Decreases in rangeland production were observed due to lower amounts and irregular distribution patterns of precipitation. The most obvious difference was recorded rainfall in January (2017) compared to the long-term average (Figure 1.).

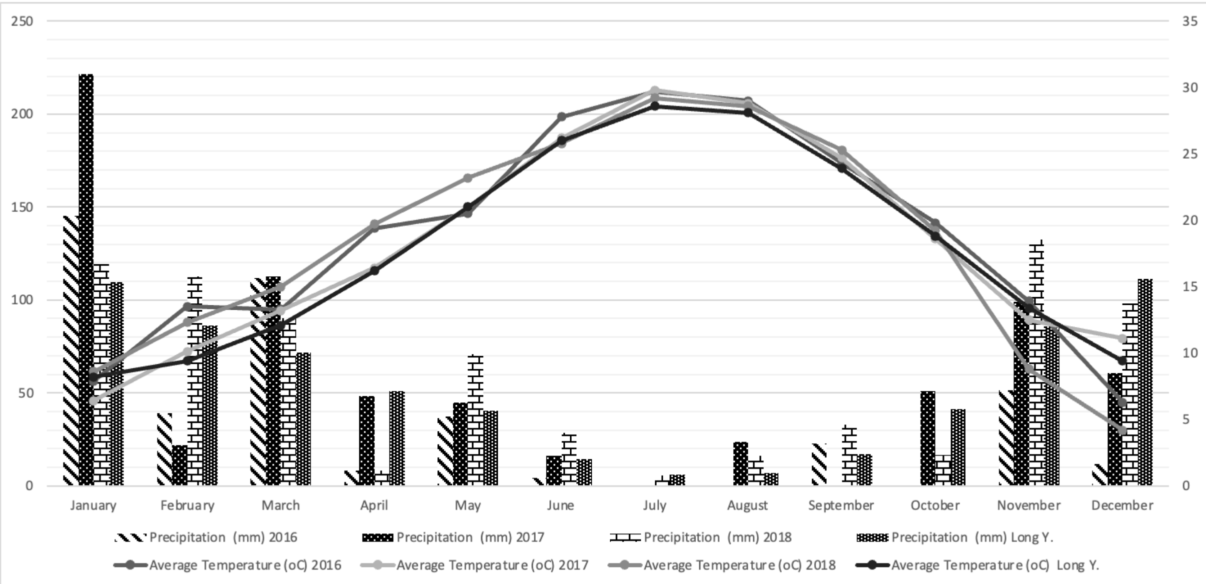

Figure 1. The average monthly meteorological datas for the years of 2016-18 and long years of Aydin province (Turkish State Meteorological Service, 2019).

The soil samples of the experimental area taken from 0-30 cm depth were analyzed at the laboratories of the Department of Soil Science and Plant Nutrition at the Faculty of Agriculture, Aydin Adnan Menderes University. According to the results, it was observed that the experimental area soils have sandy loam texture, a slightly alkaline with pH of 7.54 and rich in soil organic matter with 3.26%. According to other macro and micro-element analyzes, it was determined that except for Na (30 ppm) and Mg (80 ppm), the other nutrient elements were sufficient or high.

The experiment was established in the randomized complete block design. Each plot was designed in size of 4 x5 m. In the experiment, control, mowing, fertilization, paraquat (N, N′-dimethyl-4,4′-bipyridinium dichloride), glyphosate (N-(phosphonomethyl)glycine), 2,4-D (2,4-Dichlorophenoxyacetic acid), 2,4-D + Picloram and grubbing were performed. The mowing process was carried out at the time when the budding or beginning of the flowering in which the stage of summer asphodels has the lowest energy in storage organs (Altin, 1992). Fertilizer application consisted of 50 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} N. Herbicides are applied directly to summer asphodels in the 1^{st} and 2^{nd} year in 3-5 leaves growing stage (Darrell, 2005). The grubbing was practiced to remove all of summer asphodel (*Asphodelus aestivus* Brot.) tubers in the parcel. Asphodel density was determined by counting plants in 2 quadrats (0.50 x 0.50 m) in each parcel. In the experiment, harvesting operations were carried out in each of the parcels during the beginning of the flowering period of common grasses, leaving 5 cm stubble in 4 (0.50 x 0.50 m) quadrats. Samples taken from each plot were separated considering functional plant groups. In the laboratory, the samples were dried in the oven (Mikrotest, MST) for 48 hours at 70 °C and weighted to determine botanical composition (Cook and Stubbendieck, 1986). The samples, whose dry weight was measured, were then ground in the grinding mill and prepared for chemical analysis. Neutral Detergent Fiber (NDF), and Acid Detergent Fiber (ADF) were measured using ANKOM (ANKOM^{200}, Ankom Technology, Fairport, NY) for fiber analysis (Van Soest et al., 1991). Nitrogen determination was made by using Kjeldahl method and the nitrogen content was multiplied with 6.25 coefficient to calculate the crude protein ratio (AOAC, 1990). Following the measurements, crude protein yield (kg ha^{-1}) was calculated by proportioning with hay yield. Relative feed value (RFV) was calculated using the formulas (Horrocks and Vallentine, 1999).

An arc-sine transformation was applied to botanical composition and summer asphodel values. ANOVA was performed for all data considering repeated measurement and means were compared using Duncan multiple range tests using SAS statistical software (SAS Institute, 1998).

RESULTS AND DISCUSSION

Management practices cause significantly changes in the botanical composition of natural rangelands. In the study, we observed the effects of different applications on legumes, grasses, and other families percentages (Table 1.). The data showed that all applications (years and treatments) and their interaction effects also significantly affect functional plant group percentage. While grasses percentage was about 17% in first two years it increased significantly in 3rd year. Whereas legume percentage decreased significantly in the second year and increased again in the third year. The other families percentage was 65.25% and it increased significantly in the second year and then decreased sharply.

Table 1. Percentage of botanical composition by weight of families in different suppression methods (%)

	Grass (%)	Legume (%)	Other Families (%)
Year			
2016	17.18 b	17.54 a	65.27 b
2017	17.52 b	2.85 c	79.61 a
2018	50.71 a	16.32 b	32.96 c
Applications			
Control	6.13 f	22.34 a	71.51 b
Mowing	40.94 a	3.78 e	55.27 d
Fertilization	24.90 d	17.92 b	57.16 d
Paraquat	26.29 d	10.41 c	63.29 c
Glyphosate	19.77 e	5.20 de	75.01 a
2,4-D	42.04 a	6.40 d	51.55 e
2,4-D+Picloram	31.06 c	17.92 c	57.70 d
Grubbing	36.64 b	20.60 a	42.74 f
Mean	28.47	12.23	59.28
Year	**	**	**
Applications	**	**	**
Y*A	**	**	**
	*: P≤0,05 **: P≤0,01 ns: non-significant		

All treatments caused significantly increases in grasses percentage compared to control, however, 2,4-D and moving caused the highest increases. The increase in grasses, which has increased since the beginning of the experiment, was evident especially in the 3rd year. However, fertilization and 2,4 D + Picloram applications caused higher increases in grasses percentage. (Figure 2.). Except for grubbing, all treatments caused significantly decreases in legume percentage, but the decreases were more pronounced in moving, glyphosate and 2,4-D treatments (Table 1.). In terms of legumes, the rate changed greater in the first year in the areas where the application took place, but a decrease was observed in all applications in the second year. By the 3rd year of the experiment, the increase in legumes seen in 2,4 D + Picloram applications was more than in other applications (Figure 3.).

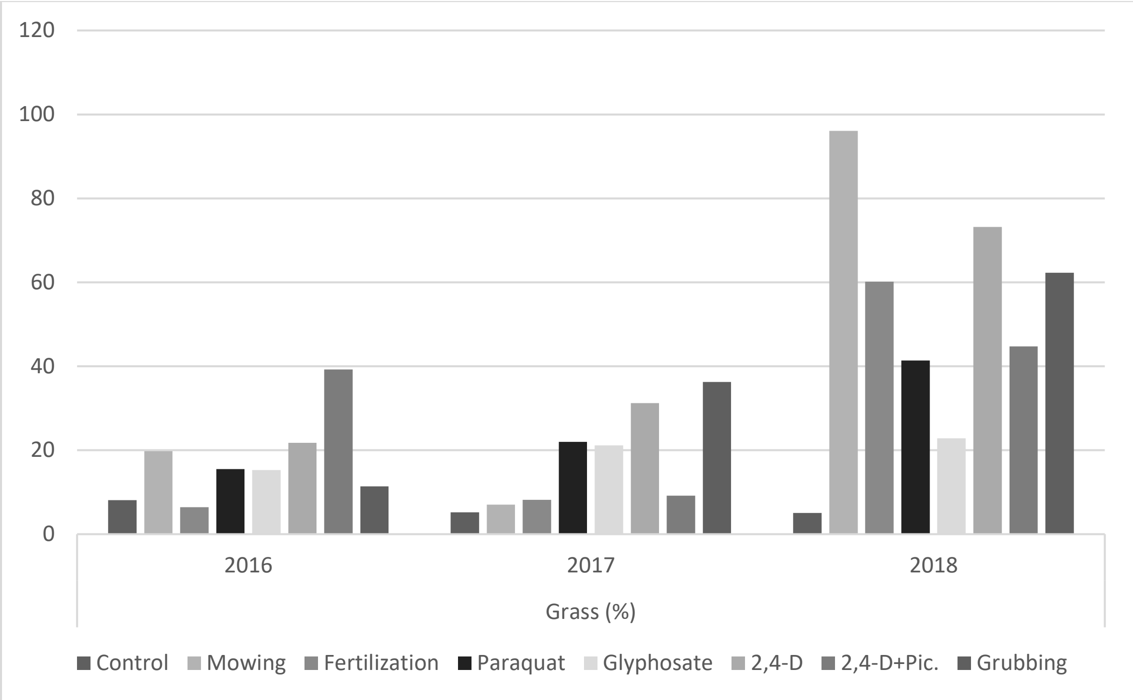

Figure 2. Change in grass ratio depending on years and practices

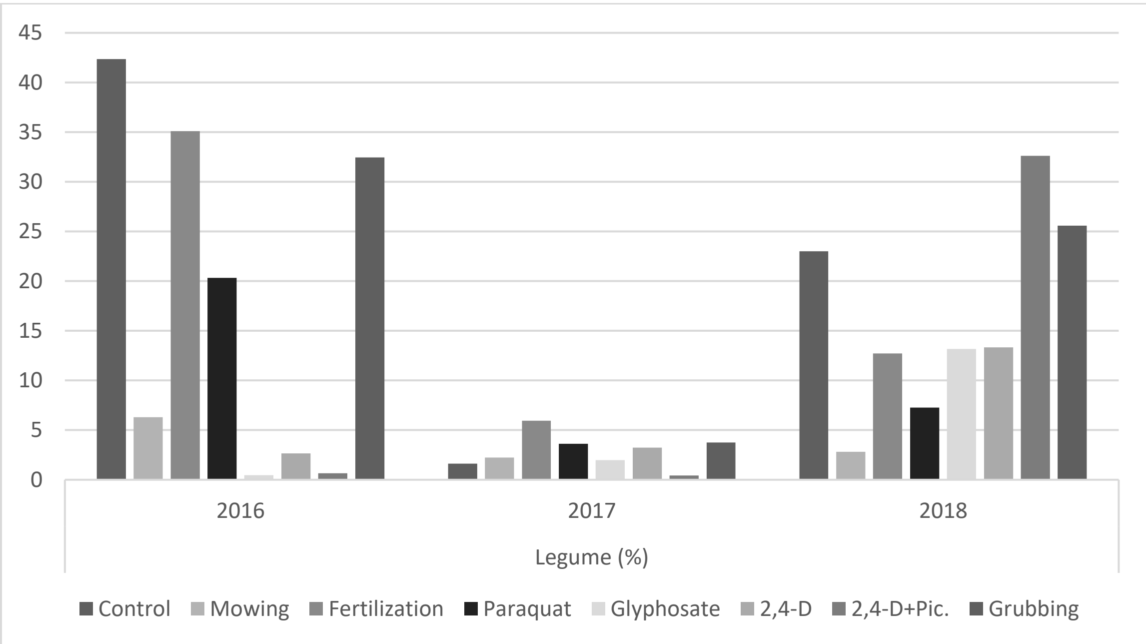

Figure 3. Change in legume ratio depending on years and practices

Except for glyphosate treatment, the other families percentage decreased significantly depending on treatments compared to control. However, the highest decreases were observed in grubbing treatment (Table 1.). In terms of other families, while the 2nd year values increased in general, a decrease was observed in most of the applications in the 3rd year. Among them, the fertilization application effect was clear in the 3rd year (Figure 4.).

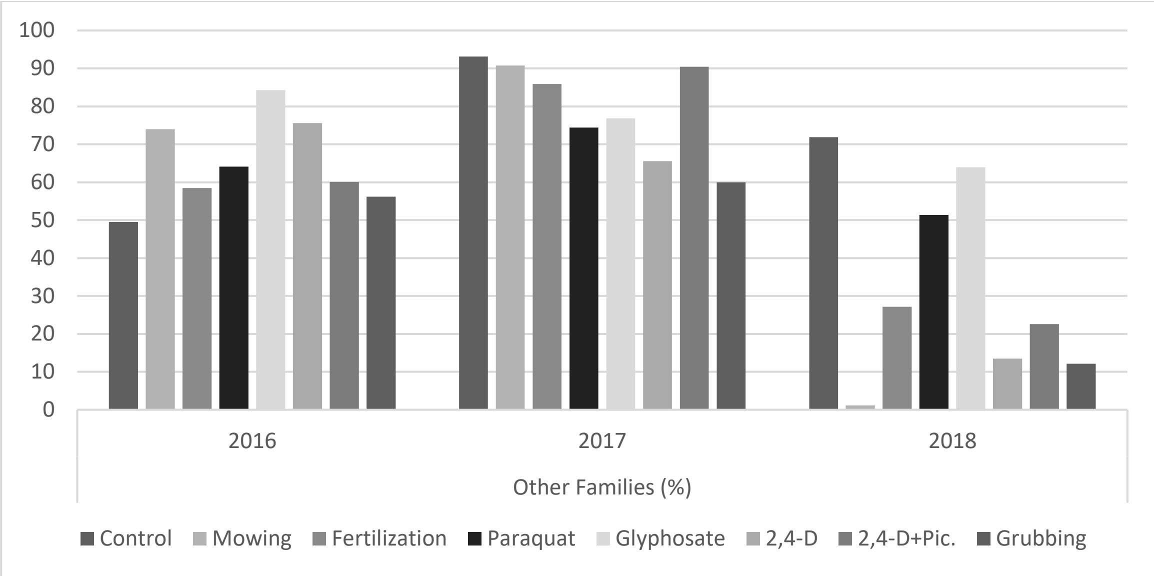

Figure 4. Change in other families ratio depending on years and practices

The summer asphodel population decreased in the 2nd and 3rd years of the experiment in all suppression methods except control. While it was determined that the highest decrease in the summer asphodel density was in the 2nd year of paraquat application, the least change was seen in the fertilization applications. Paraquat and glyphosate applications have been the most effective methods for reducing summer asphodel (Figure 5.).

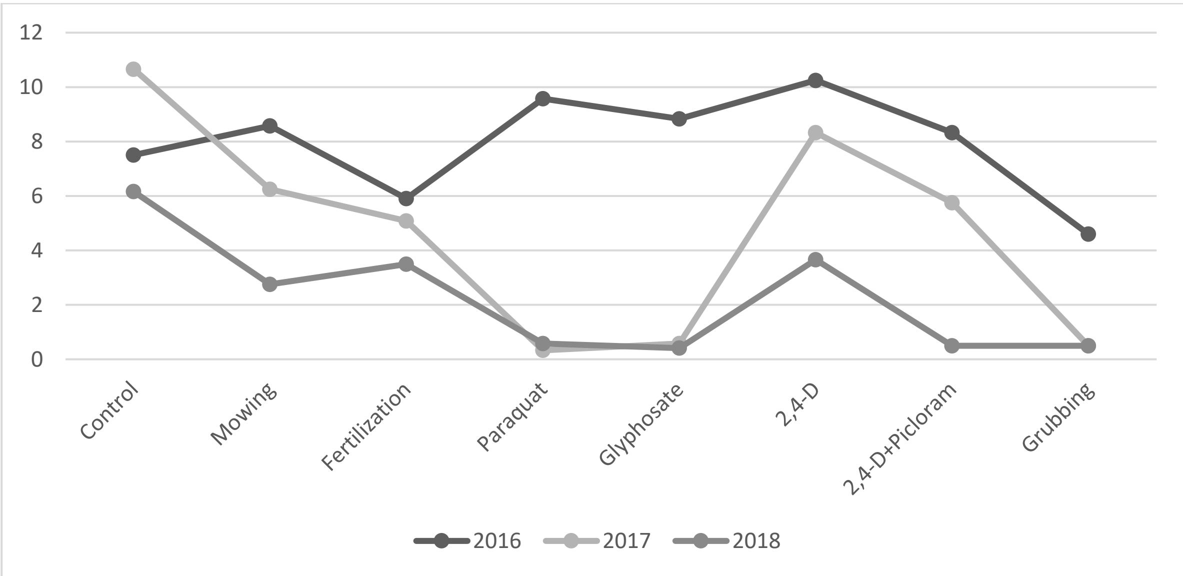

Figure 5. Changes in *Asphodelus aestivus* Brot. population density depending on years and applications

In all applications, decreases in hay yield were observed as of the 2nd year. However, paraquat has been the application in which the yield increased rapidly after the 2nd year (Figure 6). While yield decreases were observed in other applications, the change in botanical composition caused the yield to be affected. The highest hay yield was determined in paraquat application with 4443.3 kg ha^{-1}. While other applications did not reach this efficiency, the lowest efficiency was seen in the glyphosate application (Table 2.). It is seen that this systemic herbicide with low yields depending on the years in glyphosate application, causes a decrease in yield due to a decrease in the population. The crude protein ratio has increased over the years due to the decrease in yield and the increase of legume species in the botanical composition.

Table 2. Hay yield (kg ha^{-1}), Crude Protein Ratio (%) and Crude Protein Yield (kg ha^{-1}) averages of different suppression methods

	Hay yield (kg ha^{-1})	CPR (%)	CPY (kg ha^{-1})
Year			
2016	4798.3 a	15.98 ab	808.5 a
2017	2709.6 b	14.59 b	388.6 b
2018	2484.6 b	16.70 a	327.8 b
Applications			
Control	3403.3 bc	17.78 a	592.2 ab
Mowing	2881.1 cd	14.93 bc	428.4 bc
Fertilization	3590.0 b	17.60 a	637.7 a
Paraquat	4443.3 a	17.12 ab	561.8 ab
Glyphosate	2411.1 d	12.24 d	332.9 c
2,4-D	3734.4 b	13.88 cd	518.2 ac
2,4-D+Picloram	2687.8 d	13.70 cd	366.4 c
Grubbing	3495.6 b	18.82 a	628.7 a
Mean	3330.8	15.76	508.3
Year	**	*	**
Applications	**	**	**
Y*A	**	**	**
	*: P≤0,05 **: P≤0,01 ns: non-significant		

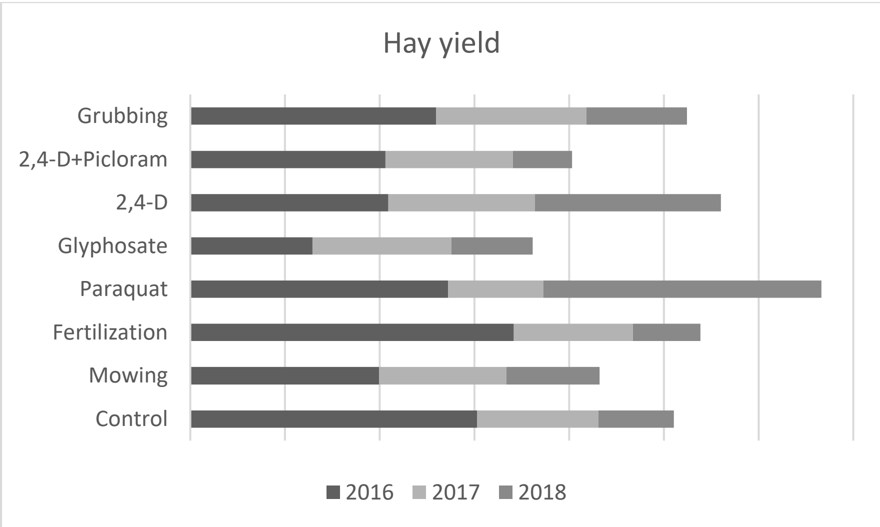

Figure 6. Change in hay yield (kg ha^{-1}) depending on years and practices

Grubbing, control, fertilization and paraquat applications are the applications with the highest crude protein ratios, 18.82, 17.78, 17.60 and 17.12%, respectively. Especially in the 3rd year of the experiment, the increase in the rate of legumes caused this situation. (Table 2.) While the sudden decrease in grubber application was remarkable, there was a continuous increase in mowing application (Figure 7.). Crude protein yield is also among those that show a decrease similar to hay yield. Crude protein yield is also among those that show a decrease similar to hay yield. Crude protein yield, which had an average of 808.5 kg ha^{-1} in the first year of the experiment, decreased to 327.8 kg ha^{-1}in the 3rd year of the experiment. Among the applications, the most decreases depending on the years are in fertilization and control applications (Figure 8.). Despite the increase in crude protein ratio, the decrease in the ratio of other families, which have an important role in yield, was also effective in crude protein yield. 2,4-D + Picloram, glyphosate and applications other than mowing had high values, while the highest values were obtained from fertilization. While the increase in crude protein ratio caused a decrease in fiber properties such as NDF and ADF, the difference between applications was not significant in terms of NDF (Table 3). Only a downward trend was observed over the years. The increase in yield and the decrease in crude protein ratio in Paraquat application caused an increase in ADF ratio. After all these, an increase is observed over the years according to the relative feed value obtained. While the value of 99.98 was obtained in the first year of the experiment, it increased to 112.78 in the third year. While there was a general increase among the applications, the highest increase was detected in the glyphosate application (Figure 9.).

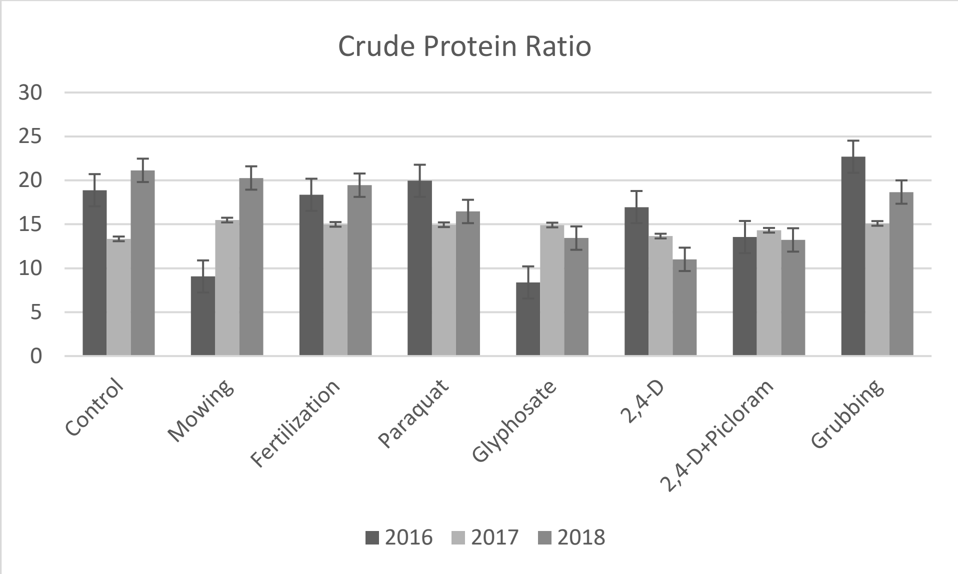

Figure 7. Change in crude protein ratio (%) depending on years and practices

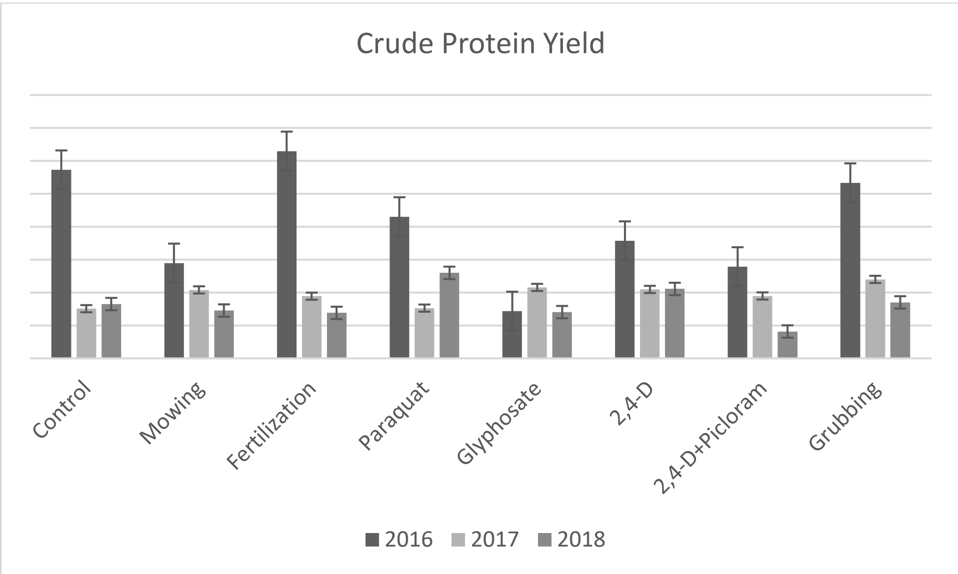

Figure 8. Change in crude protein yield (kg ha^{-1}) depending on years and practices

Table 3. NDF(%), ADF(%) and relative field value averages of different suppression methods

	NDF(%)	ADF(%)	RFV(%)
Year			
2016	52.72 a	41.78 a	99.98 b
2017	51.54 a	41.22 a	102.67 b
2018	50.03 b	36.29 c	112.78 a
Applications			
Control	49.27	38.88 c	110.70 a
Mowing	51.91	41.17 ab	102.36 cd
Fertilization	52.49	38.71 c	104.77 bd
Paraquat	51.82	42.04 a	100.85 d
Glyphosate	51.79	39.80 bc	104.61 bd
2,4-D	51.55	40.96 ab	103.41 bd
2,4-D+Picloram	51.59	38.34 c	106.50 ac
Grubbing	51.03	38.22 c	107.96 ab
Mean	51.43	39.77	105.14
Year	**	**	**
Applications	ns	**	**
Y*A	**	**	**

*: P≤0,05 **: P≤0,01 ns: non-significant

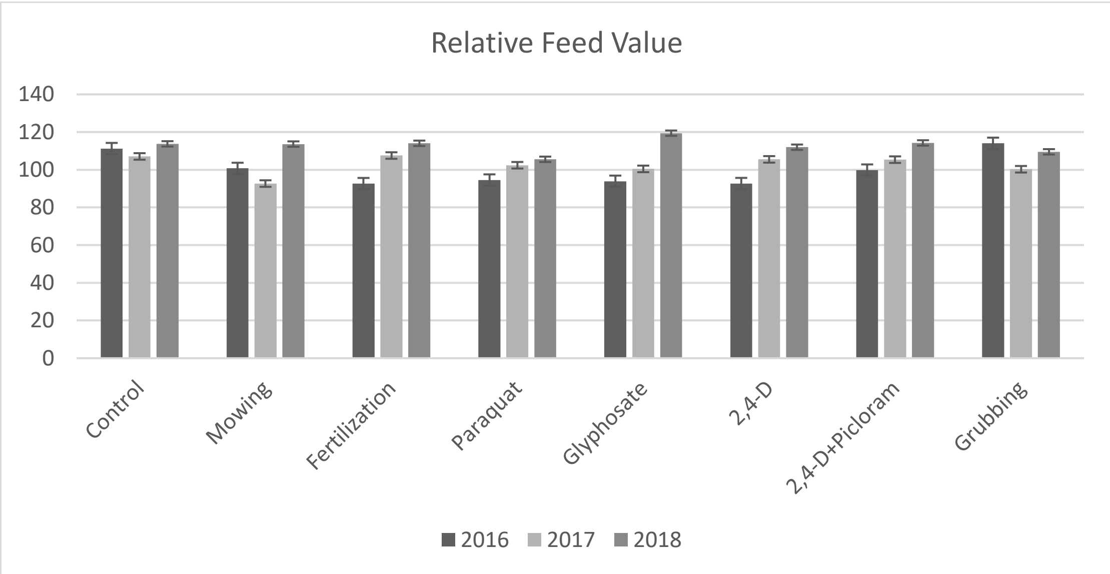

Figure 9. Change in relative feed value depending on years and practices

According to the effects of the applications, some researchers mentioned that fertilization has led to an increase in grass density and decreased legume density in the botanical composition (Kir, 1997; Tranel, 2000; Turk et al., 2005; Mut et al., 2010). whereas, some researchers claim that herbicide application reduces the weed population and encourages the grass population (Vallentine, 1989; Sheley et al., 2001).

Alaturk et al. (2018) reported that herbicide use could decrease the summer asphodel population. In addition to herbicide application to remove unwanted plants, fertilization can be done to increase plant growth and desired development can be achieved (Altin and Tuna, 1991).

Fertilization and the herbicide to be applied have the effect of increasing the rangeland yield. However, the cost calculation should be done while performing the applications (Tranel, 2000; Balabanli et al, 2010; Kowaljow et al., 2010; Mut et al., 2010; Sahinoglu and Uzun, 2016).

Suppression applications, which were carried out in the rangeland areas, have led to changes in yield, quality and botanical composition. Considering the characteristics that determine yield and quality, such as crude protein yield and relative feed value, it has been observed that glyphosate and paraquat applications have positive effects. In addition to these, it is clear that these herbicide applications are the most effective ways to remove the target species from the environment. Considering the positive contributions of other applications, these applications can be preferred to control this species (summer asphodel), which has a widespread problem in the Mediterranean rangeland. However, due to the large size of rangeland areas, it will be evaluated from an economic point of view and the most reasonable application will be preferred, which will facilitate the control of this species.

In the experiment, it was found that there were significant changes in crude protein content with applications. Changes in botanical composition due to applications and the disappearance of grazing pressure caused a decrease in crude protein content after the first year, while an increase in many applications in the following year. This is an expected situation when examined considering the botanical composition (Dovel, 1996; Severoglu and Gullap, 2020). Depending on the applications, the decrease and increase of the legume ratio in botanical composition brought about changes in the crude protein ratio.

ADF and NDF contents are indicators of the digestibility of forage crops (Ball et al., 2001; Rayburn, 2004) and it depends on the plant species (Ball et al., 2001). Changes in botanical composition resulted in significant decreases in ADF and NDF (Severoglu and Gullap, 2020). Forage quality declines with the advancing maturity because of the proportion of leaves in forage. As the CP concentration increases the ADF and NDF contents decrease together with the change of botanical composition (Erkovan et al., 2009).

Relative feed value is an important quality characteristic for determining the quality of forage crops. It is closely related to the fiber content, especially depending on the maturity (Jerenyama and Garcia, 2004). Depending on the decrease in ADF and NDF content, an increase in the RFV rate was observed in the trial. This negative relationship caused significantly changes in the years of the experiment (Table 3).

CONCLUSION

According to the results obtained from the experiment, environmental factors such as climate and management practices have significant effects on botanical composition change. However, there have been obvious decreases in weeds in applications without control plots and these have been replaced by desired species. Among the results obtained, depending on the years of change and not under the pressure of grazing in the rangeland, the grass population increased. When the crude protein yield, relative feed value and weed density are examined, the best application is grubbing. However, fact that grubbing requires intensive human power, thus, this application is not economical for broad-scale applications. Glyphosate and paraquat herbicide applications, which will be applied locally as an alternative to this application, have been determined as applications to increase the yield and quality of rangeland. The proper management after the applications are made will make these areas sustainable and will enable them to be used for many years.

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