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Management of Johnsongrass (*Sorghum halepense* (L.) Pers.) in Alfalfa Cultivation Areas of Iğdır Province

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Abstract

One of the most important weed species that reduces productivity and quality in alfalfa (*Medicago sativa* L.) crops is *Sorghum halepense* (L.) Pers. (Johnsongrass). Therefore, it is of great importance to control this weed in alfalfa cultivation areas. In this context, this study was carried out in 2022-2023 to determine the frequency and density of *S. halepense*, which is a problem in alfalfa cultivation areas in Iğdır province, and the effects of some herbicides with different active substances on *S. halepense* and alfalfa yield. Within the scope of the study, surveys were carried out in 50 alfalfa cultivation areas in Iğdır province and its districts. In addition, herbicides with the active substances Quizalofop-p-ethy (Q), Haloxyfop (R) methyl ester (H) and Propaquizafop (P) and the mowing process with the Q+H mixture were compared with each other in order to determine their effects on *S. halepense* and alfalfa yield. As a result of the study, at the end of both years, theoccurrence frequency of *S. halepense* in alfalfa cultivation areas in Iğdır province was determined as 92.25% and its density was 48.15 plants/m^2. In the study, the effectiveness rates of herbicides on *S. halepense* varied between 95% and 100% in the last assessment. The effect of the herbicides used in the study on *S. halepense* dry weight varied between 78.90% and 91.56%. As a result of the study, herbicides with different active ingredients and their mixtures resulted in a statistical difference of 1% ($p<0.00$) on the, plant height, fresh weight and dry weight of *S. halepense* in alfalfa. At the end of the two year period, the highest plant height (80.98 cm), fresh weight (3483.41 kg/da) and dry weight (896.49 kg/da) were obtained in Q+H treatment. However, this herbicide mixture was in the same statistical group with the other herbicides used in terms of alfalfa yield and yield components. As a result, the herbicides used were effective on *S. halepense* and caused an increase in alfalfa yield.

Keywords: Alfalfa, *Sorghum halepense*, Herbicide, Weed, Iğdır, Survey

INTRODUCTION

Alfalfa (*Medicago sativa* L.), known as the queen of forage plants (Uslu and Balcı, 2020), is a perennial herbaceous plant with a deep and strong root system in the Fabaceae family (Davis, 1988). It is stated that its homeland is Asia, Iran, Turkmenistan and the surrounding areas (Bolton, 1962; McWilliam, 1968). Some of the features that make alfalfa superior to other plants are its high adaptability, longevity, high yield and nutritional values, and the ability to mow more than once during the vegetation period (; Karadaş and Aksoy, 2019). Alfalfa has become the most cultivated forage crop worldwide because it grows easily in both tropical and temperate climate zones (Berg et al., 2007; Zhang et al., 2008; Karadaş and Aksoy, 2019). Alfalfa has a higher feed value than forage crops and its protein yield per unit area is also higher. The dry and fresh weight of alfalfa is delicious and nutritious for all kinds of animals (Çaçan and Arslan, 2021). Alfalfa boasts protein, vitamins, minerals, and fiber (Richter et al., 2003), making the crop highly nutritious feed (Salzano et al., 2021). The herb, which is very rich in vitamins, also contains many substances that increase milk, meat and fertility (Collier et al., 1982). Alfalfa is also a legume forage plant and has an important place in maintaining and protecting the fertility of soils thanks to its deep roots (Çaçan et al., 2015). Alfalfa is of the most importance in the world and in Türkiye (Şakiroğlu et al., 2015; Keskin et al., 2020a; Eren and Keskin, 2021), since alfalfa, which is

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such an important food source for animals, has wide adaptability, It is the most grown forage plant in Türkiye. The country that produces the most alfalfa in the world is the USA (FAO, 2023). In 2022, the alfalfa area in Türkiye was 643,592.7 ha, producing 19,064,213 tonnes of alfalfa. In Iğdır province, the alfalfa area was 18,641 ha, with a production of 1,003,231 tonnes (TÜİK, 2023).

Alfalfa is also used in pellet feed and artificial pasture mixtures, as well as in the supply of hay, silage production (Karakurt and Fırıncıoğlu, 2002). As the availability of resources for crop production space and management continues to decrease, maximizing the yield and nutritional value of alfalfa is critical to meeting the agricultural needs of growers, farmers, ranchers, livestock producers and industry professionals (Beck et al., 20120. Although alfalfa is such an important forage crop in the world and in Turkiye, there are factors that affect alfalfa yield. Weeds are the most important of these factors. Weeds are a major problem in alfalfa production. They reduce forage quality and yield by competing with alfalfa for nutrients, space, sunlight and water (Konstantinovic and Meseldzija, 2005; Noroozi et al.,2022; Yang et al., 2022).

In their study, Tan and Serin (1998) found that when alfalfa was planted with a shelter crop, 581.5 - 629.1 kg/da of grass was taken in the first year and only 11.6 - 15.4% of this was weeds. Many weed species are problems in alfalfa cultivation areas (Özmen, 2019). Identifying the weeds seen in these areas and examining the changes of these weeds depending on the age of the alfalfa helps in weed control (Bükün, 2012). The overall value of alfalfa hay is enhanced by its primary role as forage and feed in livestock production, including dairy, meat, and fiber. Early-seeded weeds compete primarily for light, water, space, and nutrients, while late-season weeds in established alfalfa fields persistently compete for resources, affecting yields in subsequent growing seasons (Ashigh et al., 2010). Additionally, the presence of annual and perennial weeds at any time can reduce the nutritional value of the forage, reduce the lifespan of alfalfa caused by premature plant loss or decline, host diseases and insects, and create harmful harvest problems (Green et al., 2003). Controlling perennial weed populations in perennial crops such as alfalfa is particularly challenging because management practices must address seed production and vegetative reproductive structures that enable the plant to survive from season to season (Beck et al., 2020). Moreover, weeds mainly have low nutritional value, unpleasant odor and taste, and also contribute to the deterioration of alfalfa seed quality (Konstantinovic and Meseldzija, 2005). The mainly economically important perennial weed species that cause problems in alfalfa are: *Cirsium arvense, Sorghum halepense*, *Convolvulus arvensis* and species from the Cuscuta genus (Konstantinovic and Meseldzija, 2005).

Sorghum halepense L. (Pers.) (Johnsongrass) is a C4 perennial plant species from the Poaceae family and is among the world's most persistent weeds (Holm et al., 1997). Johnsongrass is a weed that can form a dense habitus, grow up to 50-200 cm tall and form many stems. Its reproductive ability is enormous, as it can produce up to 70 m of rhizome per plant in one growing season and can produce 28,000 seeds per plant (Monaghan, 1980) or more (up to 80,000 seeds per plant (Anderson, 1996). Along with the dense seed-forming potential of Johnsongrass, It also has an extremely strong vegetative reproduction system. As a matter of fact, a Johnsongrass plant can form a 200-300 m long rhizome in four weeks. Under suitable conditions, it can produce 1.8 tons of rhizome and 50 kg of seeds per decare in 16 weeks (McWhorter, 1981).

Therefore, it is very difficult to remove the Johnsongrass, which has all these features together, from where it entered. It can easily adapt to different ecological conditions (Davis, 1988). It is distributed over more than one-third of the total global area, causing significant losses in agriculture and natural biodiversity in Asia, Africa, America and Europe (Chirita et al., 2007; Peerzada, et al., 2017). *S. halepense* is ranked as the world's sixth worst weed, infesting 30 different crops in 53 countries, and is widely naturalized on millions of hectares worldwide (Peerzada, et al., 2017). *S. halepense* is well known for its detrimental effects on the growth and development of neighboring plants, owing to its strong competitive abilities and allelopathic potential (Huang et al., 2018 ; Peerzada et al., 2017). *S. halepense* is a serious perennial weed species worldwide, especially in humid warm-temperate and subtropical regions (McWhorter, 1989). It can cause significant yield losses in many products (Follak and Essl, 2013). Plants emerging from rhizomes are more competitive than seedlings due to their faster growth rate, even under stress conditions (Acciaresi and Guiamet, 2010). It is increasingly common in many European countries and harmful worldwide (Travlos et al., 2019), and is widely found in agricultural areas (Follak and Essl, 2013). *S. halepense* is considered a serious weed in the world causing significant yield losses as well as increases in production costs in a wide range of field crops such as corn, sorghum, soybeans, sunflowers, sugar cane, cotton, pastures and alfalfa (Travlos et al. al., 2018). *S. halepense* is one of the most important weed species with a wide range of climate adaptations with favorable growing conditions in managed and unmanaged areas in the world (Barney and DiTommaso, 2011; Peerzada, et al., 2017; Yazlık and Üremiş, 2022). *S. halepense* has a wide colonization in Turkiye (Uludağ et al., 1999; Arıkan et al., 2015). Considering this situation, *S. halepense* can be called a widespread species in Turkiye (Yazlık, 2014), due to the wide ecological tolerance of *S. halepense* and its strong competitive ability as an expanding species, necessary measures should be taken to control its distribution in every region. and even if it is in natural distribution, risk analysis should be done (Yazlık and Üremiş, 2022). Good soil preparation, timely and high quality planting, and all cultural practices that ensure higher crop establishment are the basic measures to protect lucerne and alfalfa from perennial weed species. In order to control these, treatment can be done in the one to three leaf phase of the alfalfa (Konstantinovic and Meseldzija, 2005). Adopting modified crop management practices, refining tillage strategies, and employing multiple chemical-based techniques stand out as optimal choices for effective control of johnsongrass (Travlos et al., 2019). Currently, within agricultural domains, the preference for chemical control methods to manage weeds is on the rise. This trend is driven by escalating costs and labour requirements, with chemical approaches favoured for their rapid efficacy, ease of use and economic nature. (Kitiş ve Gürbüz, 2021). Due to its rapid vegetative growth and increased herbicide tolerance, the scope of conventional management approaches is limited in the management of this weed (Peerzada, et al., 2017). The integration of chemical methods with cultural or mechanical approaches is important to limit future spread to uninfested areas (Peerzada, et al., 2017). Some of these effective techniques can be used in combination with herbicides (Travlos et al., 2019).

Since Iğdır province is hot and the ground water level is high, *S. halepense* is found not only in alfalfa cultivation areas but also in corn (Açıkgöz et al., 2023) and tomato (Akelma et al., 2022; Tülek et al., 2022; Usanmaz Bozhüyük et al., 2022) and in orchards (Parin and Gürbüz, 2022). It is abundant and causes significant yield and quality losses. That's why the local people call *S. halepense* "kankurutan". Metaphorically, a "blood dryer" symbolises something harmful that drains vitality, similar to the depletion of blood in veins, and represents situations or actions that drain energy, strength and resources, leading to significant challenges. This weed species poses a big problem in Iğdır province and it is extremely important to combat it. Due to all these features listed above, canker is a problem in almost all regions of our country, as well as throughout the world. *S. halepense* also poses a major problem in alfalfa production areas and causes a negative impact on alfalfa quality and yield. Therefore, it is necessary to combat Johnsongrass, which has a negative effect on alfalfa yield and quality. The aim of the study is to determine the occurrence of frequency and density of *S. halepense*, which poses a problem in the alfalfa cultivation areas of Iğdır province. It was also carried out to determine the effects of herbicides with different active ingredients on *S. halepense* and alfalfa yield.

MATERIALS and METHODS

The research was carried out in a 2-year-old alfalfa cultivation area in Mürşitali village of Karakoyunlu district of Iğdır province (40°01'14"N 44°08'01"E) during the growing season of 2022 and 2023. Surface irrigation was used during the growing season of alfalfa. In the first year, the drum was mowed with a mower a total of 4 times. In addition, surveys were carried out in the alfalfa planting areas in Iğdır province and its affiliated districts to determine the frequency and density of *S. halepense* in the alfalfa planting areas. In the first year, the alfalfa field was mowed four times with a mowing machine. In addition, extensive surveys were carried out within the alfalfa production areas of Iğdır province and its districts. The aim of these surveys was to determine the frequency and density of *S. halepense* in alfalfa fields. The climate data for the months in which the study was conducted and the long-term average (1941–2022) are given in Table 1, and the soil properties of the trial field are given in Table 2.

Table 1. *The weather conditions of the region*

Months	Temperature (°C)			Precipitation (mm)			Humidity (%)		
	2022	**2023**	**LTP (1941-2022)**	**2022**	**2023**	**LTP (1941-2022)**	**2022**	**2023**	**LTP (1941-2022)**
March	5.1	11,7	6,2	17,7	27,2	22,1	54,8	55,40	52,2
April	15.7	13,7	13	24,7	51,2	33,8	44,1	60,10	49,9
May	17.1	18,1	17,7	50,5	43,2	46,5	53,8	53,80	51,5
June	24.5	23	22,1	22,3	48,3	32	47,5	52,60	47,3
July	27.7	26,5	25,9	1,4	10,5	13,7	37,5	42,20	45,3
August	27.9	28,3	25,3	2,3	0,8	9,7	42,3	39,80	47,1
September	23.1	22	20,4	5,1	7,6	11,5	41.9	50,10	46,2
October	15.4	15,1	13,1	12	29,5	26,3	49.6	64,70	48,53

LTP= Long-term period, Meteorological Service (MS, 2023).

Table 2. *Soil characteristics of the trial field*

Soil characteristics	Units	Trial area
Profile Depth	cm	0-30
Constitution Class	-	Clay-Loam
Phosphorus (P_2O_5)	kg da^{-1}	0,82
Lime ($CACO_3$)	%	11,01
Potassium (K_2O)	kg da^{-1}	9,05
pH	-	7,7
Total Salt	mmhos/cm	1,8
Organic Matter	%	1,82

Quizalofop-p-ethy, Haloxyfop (R) methyl ester and Propaquizafop herbicides and mixtures of Quizalofop-p-ethy + Haloxyfop (R) methyl ester herbicides were used in the research. General properties of the herbicides used in the experiment are given in Table 3.

Table 3. *Herbicides used in the study and their general properties*

Kod	Active ingredients	Formulation	Mode of Action	Dose	Application time
Q	Quizalofop-p-ethyl	EC	A1	75 ml/da 100 ml/da	Post Emergence
H	Haloxyfop (R) methyl ester	EC	A1	45-60 ml/da	Post Emergence
P	Propaquizafop	EC	A	50-100 ml/da	Post Emergence

In the study, a total of 100 alfalfa fields in 50 different alfalfa fields were surveyed in both years to determine the frequency and density of *S. halepense* in alfalfa production areas in Iğdır province and its districts.

Experiment setup and herbicide application

In the Mürşitali village of Karakoyunlu district of Iğdır province, where the research was conducted, there is 2-year-old alfalfa ready planted and the alfalfa is irrigated with surface irrigation. The drum mower was used for mowing a total of 4 times in the first year. The experiment was carried out in a randomized block design with 6 characters (Quizalofop-p-ethy, Haloxyfop (R) methyl ester, Propaquizafop, Quizalofop-p-ethy + Haloxyfop (R) methyl ester herbicide mixtures, mowing and weedy check) with 4 replications, totaling 24 samples. Parcelization was done after alfalfa emergence before herbicide application. The plots will be 20 m^2 (5×4 m) wide, with 1 m strips left between the plots and 1.5 m strips between the blocks. For parcelization, slats were fixed to the ground and rope was used in strips. The trial area was 710.5 m^2 in total. The herbicides with 3 different active substances and the mixture of herbicides with 2 active substances used in the research were set up with different mowing times and weedy control plots. For herbicide applications, herbicide was applied when the alfalfa height reached 10 cm. In the study, the herbicide application was carried out on 22 March 2020, two days after the parcelling process, when the Johnsongrass was approximately 25 - 40 cm in height. Herbicides in the trial; It was applied with a 25 liter tank capacity, gasoline engine, back sprayer with fan beam heads. Afterwards, when the alfalfa reached the full bloom period, the mowing was done. For the mowing control process, mowing was done when the alfalfa reached the 10% flowering period. Control plots were mowed when the alfalfa reached the full bloom period and were evaluated until the second mowing was performed. The experiment was conducted for 2 mowing periods.

Determination of the effects of herbicides

In the study, in order to determine the effect of the applications on *S. halepense*, the weeds in the plots were counted before harvest, a 1 m^2 frame was used, and the *S. halepenses* in the frame were counted by randomly throwing them into each plot (TAGEM, 2020). *S. halepense* counts in herbicide, mowing and control plots were evaluated 4 times throughout the application (Table 4). In addition, some symptoms of phytotoxicity on alfalfa of the herbicides used in the study (number of plants in a certain period, length, weight, diameter, etc. of plants or plant parts) were evaluated (TAGEM, 2020).

In the evaluations made in the study, the percentage effect rates of herbicides on *S. halepense* were determined according to the following formula (Abbott, 1925).

$$\text{Herbicide effect (\%)} = \frac{(\text{Number of Weeds in Control } - \text{Number of Weeds in Treatments}) \times 100}{\text{Number of Weeds in Control}}$$

Table 4. *Assessments and time in study*

Assessments	Assessment time
1. Assessment	10 days after application
2. Assessment	30 days after application
3. Assessment	50 days after application
4. Assessment	Just before harvest

Effect of herbicides on *Sorghum halepense* dry weight

Following the conclusive assessment in the study, *S. halepense* specimens identified within each plot were meticulously trimmed at ground level using scissors. Subsequently, these specimens were gathered, segregated, and carefully deposited into distinct paper bags for further analysis. The samples were then taken to the Herbology Laboratory of the Faculty of Agriculture at Iğdır University. The weeds were then individually placed in paper bags and placed in an oven at 70°C for 24 hours to facilitate desiccation. Following this process, each dried sample was carefully weighed to determine its individual dry weight. The resulting numerical data were carefully noted and recorded for analysis.

Alfalfa yield and yield components

Following the assessment of plant height, the alfalfa within each plot underwent uniform mowing using a sickle, leaving a 0.5-meter space from the plot's inception and excluding one row from each edge to mitigate edge effects. The freshly harvested alfalfa from each plot was then quantified by weight to determine the fresh yield per decare in kilograms. To determine the dry matter content of the alfalfa, samples were taken from a 1 square metre area of freshly harvested alfalfa in each plot. These samples were dried in ovens set at a constant temperature of 70°C until a constant weight was reached. The study aimed to analyse the effect of the herbicides used on various parameters, including alfalfa plant height (measured in centimetres), alfalfa fresh weight (measured in kilograms per decare) and alfalfa dry weight (measured in kilograms per decare).

Surveys

In both years of the study, surveys were carried out in the alfalfa production areas of Iğdır province and its districts to determine the frequency and density of *S. halepense*, which is a problem in alfalfa production areas. According to TÜİK, the surveys carried out by districts were determined based on the alfalfa production areas in Iğdır province. The alfalfa area and the number of surveys in Iğdır province and districts are shown in Table 5.

Table 5. *Alfalfa planting areas and survey numbers in Iğdır province and districts*

	Year 2022		Year 2023	
Districts	**Cultivation area (da)**	**Number of surveys**	**Cultivation area (da)**	**Number of surveys**
Centre	72.000	13	65.000	17
Aralık	160.000	26	67.000	18
Karakoyunlu	45.120	9	45.410	12
Tuzluca	8.300	2	9.000	3
Total	277.431	50	186.410	50

Prior to the surveys, specific alfalfa fields were identified. Surveyors then traversed these areas in linear paths, stopping intermittently at random points approximately every 10 kilometres to access the nearest field (Uygur, 1985). Using the methodology outlined by Sırma et al. (2001), frames were strategically positioned according to field dimensions, as shown in Table 6. This methodology facilitated the survey of a total of 50 alfalfa fields for each year.

Table 6. *Number of frames taken in surveys according to field size*

Field size (da)	Frames (number)
0-5	4
5-10	6
10-20	8
20-50	12
50	16

A 1 m² frame was used for the counts, starting from 5-10 m inside, away from the edge effect, to represent the field, and the *S. halepense* that entered the frame were counted randomly. Occurrence Frequency (R.S) was calculated according to (Odum, 1983; Uygur, 1985). Frequency of Occurrence; It is the value that shows the percentage of a weed species encountered within the surveyed regions. The calculation of these values was made with the formula below.

$$R.S.(\%) = 100X\frac{N}{M}$$

R.S: Occurrence Frequency (%)

N = Number of fields where a species is found

M = Total number of fields surveyed

In determining *S. halepense* densities, an evaluation was made based on the arithmetic mean. Weed density (plant/m^2) was calculated by dividing the total number of plants per m^2 in the surveys by the number of surveys (Odum, 1971).

$$\text{Density (number/m}^2\text{)} = \frac{\text{B}}{\text{M}}$$

B; Total sample count

M; Total number of frames that were thrown

Statistical analysis

As a result of four different counts, *S. halepense* densities per square meter, dry weights and alfalfa yield and yield components were evaluated. Relevant data were subjected to one-way analysis of variance. Means were compared using Duncan's multiple comparison test ($p < 0.05$) (SPSS 20). Additionally, a series of statistical analyzes were conducted to correlate the findings of the study. After the transformation/normalisation of the data, we carried out a series of analyses: Correlation analysis using JASP, Heat map clustering using SRplot, Principal component analysis (PCA) using PAST software, Network graph analysis using PAST software.

RESULTS and DISCUSSION

Frequencies and densities of *Sorghum halepense* in alfalfa cultivation areas

The frequency and density of encountering *S. halepense* throughout Iğdır province varied according to districts, and the highest frequency and density were determined in the central district (Table 6). In both study years, the peak *S. halepense* frequencies (first year = 100% and second year = 96%) and density (first year = 56 numbers/m^2 and second year 50 numbers/m^2) were determined in the central district. In the study, Iğdır province-wide, the frequency of *S.halepense* was determined as 94% in the first year and 90.5% in the second year, and its density was determined as 49.75 numbers/m^2 in the first year and 46.5 numbers/m^2 in the second year.

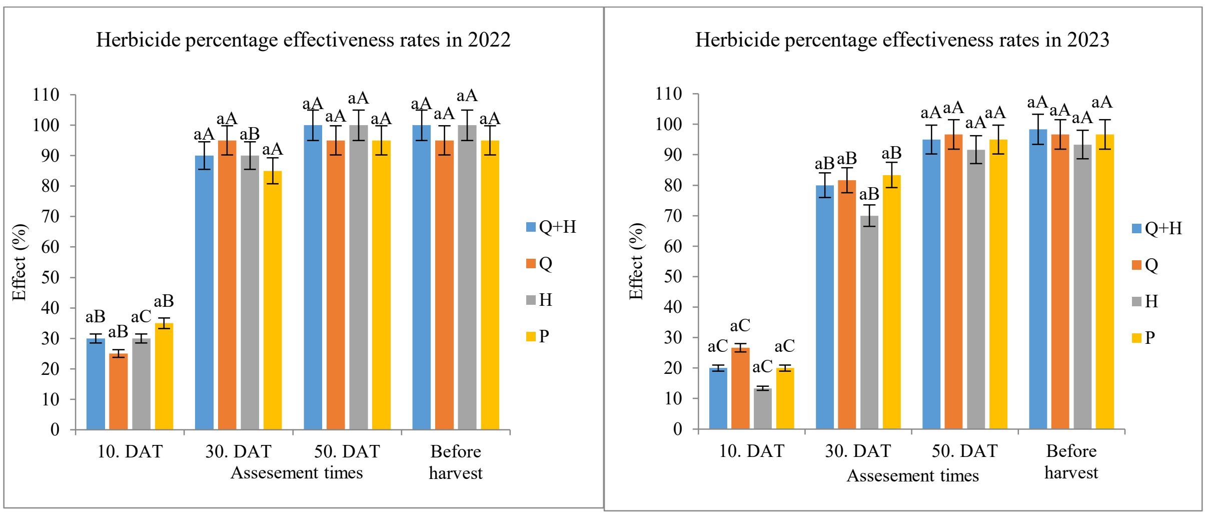
Table 6. *Frequencies and densities of S. halepense in alfalfa cultivation areas in Iğdır province and its districts*

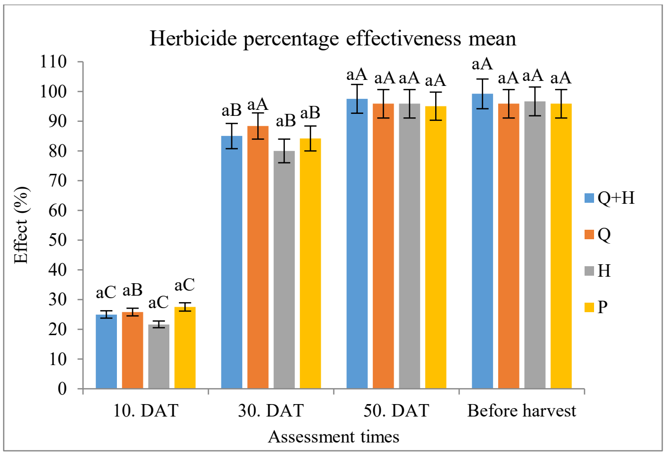
District	**2022**		**2023**		**Mean**	
	Frequency (%)	Density	Frequency	Density	Frequency	Density
Centre	100	56	96	50	98	53
Aralık	86	48	88	42	87	45
Karakoyunlu	94	50	90	48	92	49
Tuzluca	96	45	88	46	92	45,5
Mean	94	49,75	90,5	46,5	92,25	48,15

The average frequency of both years on a provincial basis was determined as 92.25% and the density was 48.15 numbers/m^2 (Table 6). Özmen (2019), determined the frequency of *S. halepense* in alfalfa cultivation areas as 9.75. According to Konstantinović et al. (2004), *S. halepense* was one of the most important weed species affecting alfalfa yield. Karkanis et al. (2022) found that *S. halepense* was abundant in the trial area. The frequency of of weeds may vary from region to region (Güncan, 2019). One of the most important reasons for the high frequency of *S. halepense* in Iğdır province is due to the high air temperature and ground water level. In Iğdır province, the frequency of S. *halepense* has been determined not only in alfalfa but also in corn, 94% (Açıkgöz et al., 2023) and tomato (82% in the first year, 86% in the second year) (Akelma et al., 2022). Kostov and Pacanoski (2006) determined the density of *S. halepense* in the trial area as 132.8 numbers/m^2. Özmen (2019) determined the density of *S. halepense* in alfalfa cultivation areas as 0.11 numbers/m^2. Karkanis et al. (2022) found that *S. halepense* was abundant in the trial area. According to Konstantinović et al. (2004), *S. halepense* is one of the most common weed species found in alfalfa cultivation areas and it affects the yield of alfalfa. In Iğdır province, *S. halepense* density is 24.24 numbers/m^2 in corn (Açıkgöz et al., 2023), 24.24 numbers/m^2 in tomato (first year: 24.24 numbers/m^2 and 19.2% numbers/m^2 in the second year (Akelma et al., 2022) and 19.2% numbers/m^2 in the second year (Akelma et al., 2022) and other products. For tomatoes, they determined it to be 10.5 numbers/m^2 in the first year and 12.25 numbers/m^2 in the second year (Tülek et al., 2022).

Effect of herbicides on weeds

The effects of the herbicides used in the study on *S. halepense* were similar in both years. In all four evaluations, no statistical difference was observed in the effects of the herbicides on *S. halepense* (Figure 1).





Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop (R) methyl ester, DAT: Day after treatment

Figure 1. *Percentage effects of herbicides on S. halepense according to evaluation times*

The effects of herbicides on S. halepsense were low in the first evaluation, but high effect rates were determined in the second evaluation. over 95% at the end of both years. *S. halepense* effect rates were determined (Figure 1). Kostov and Pacanoski (2006) found that the effects of the herbicides used in the study on *S. halepense* ranged between 93.4% and 97.7%. Çağlar et al. (2023), the effects of herbicides on *S. halepense* on the 7th day were 30.00% to 62.5%, on the 21st day; It was determined that it yielded between 83.75% and 80.00% and between 56.25% and 95.00% during the harvest period. Karkanis et al. (2022) stated that herbicides were 90% effective on *S. halepense* compared with the weed-infested treatment. The effects of herbicides on the dry weight of *S. halepense* are given in Table 7.

Table 7. *Variance analysis and effects of treatments on S. halepense dry weight.*

	Year 2022		**Year 2023**		**Average**	
Treatments	**Dry Weight (g m^{-2})**	**Effect (%)**	**Dry Weight (g m^{-2})**	**Effect (%)**	**Dry Weight (g m^{-2})**	**Effect (%)**
Q+H	15,00±3,53c	91,56	16,25±6,88c	89,84	15,62±5,03c	90,75
Q	26,75±5,96c	84,95	21,25±8,00c	86,72	24,00±6,57c	85,79
H	37,50±6,61c	78,90	25,00±7,35c	84,38	31,25±4,84c	81,50
P	21,25±4,26c	88,05	17,50±3,22c	89,06	19,37±3,28c	88,53
Mowing	77,50±11,08b	56,40	62,75±6,12b	60,78	70,12±6,77b	58,48
Weddy	177,75±9,04a	0,00	160,00±10,80a	0,00	168,87±4,87a	0,00
Mean	59,29±12,11		50,45±11,06		54,87±11,43	
F	73,622		57,800		121,993	
p- value	,000		,000		,000	

Means with the same letter do not differ significantly at the 0.05 significance leve
Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

In the study, the lowest *S. halepense* dry weights were recorded in the plots where herbicides were applied consistently over two years, with all herbicides falling into the same statistical group. . The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. In the study, the lowest *S. halepense* dry weights were obtained in the plots where herbicides were used in both years, and all herbicides were in the same statistical group. The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. The highest dry weight of *S. halepense* was obtained in the weedy control plots (first year = 177.75 g/m^2 and second year = 160 number/m^2), which were in a single statistical group (Table 7). Karkanis et al. (2022) determined the lowest dry weight of *S. halepense* as 7.7 g/m^2. It was determined that the herbicides used in the study caused a 99.8% decrease in the dry weight of *S. halepense*.

Effect of herbicides on alfalfa yield and yield components

The herbicides utilized in the study displayed significant effects on alfalfa growth parameters across both years. They notably increased plant height (first year: F=321.165, p<0.000; second year: F=92.907, p<0.000), fresh weight (first year: F=267.599, p<0.000; second year: F=98.141, p<0.000), and hay weight (first year: F=559.992, p<0.000; second year: F=135.533, p<0.000) with statistical significance (p<0.01) at the 1% level, as shown in Table 8.

Table 8. *Variance analysis and effects of treatments on alfalfa biomass and height.*

Treatment	**Year 2022**			**Yeae 2023**			**Average**		
	Plant height	**Fresh Weight ($g\ m^{-2}$)**	**Dry Weight ($g\ m^{-2}$)**	**Plant height**	**Frewsh Weight ($g\ m^{-2}$)**	**Dry Weight ($g\ m^{-2}$)**	**Plant height**	**Fresh Weight ($g\ m^{-2}$)**	**Dry Weight ($g\ m^{-2}$)**
Q+H	82,03±,30a	3.509,33±10,84a	911,73±5,12a	79,93±,78a	3457,50±21,74a	881,25±11,96a	80,98±,49a	3483,41±7,43a	896,49±6,20a
Q	81,08±,37ab	3.438,27±20,77ab	883,23±4,56b	79,80±,99a	3447,50±28,68a	886,25±11,43a	80,43±,59a	3442,88±10,25ab	884,74±6,86ab
H	80,83±,07c	3.354,02±5,28bc	864,65±1,82c	80,75±,96a	3455,00±20,61a	876,75±9,86a	80,43±,52a	3404,50±10,64ab	870,70±5,14b
P	80,68±,06bc	3.301,90±8,69c	852,02±2,77c	80,35±,98a	3374,50±12,12a	882,00±11,88a	80,01±,50a	3338,20±10,37b	867,00±5,22b
Mowing	78,85±,11d	3.210,25±60,84d	849,25±7,96d	74,07±,67b	2625,00±149,30b	728,00±11,28b	74,46±,34b	2668,12±102,78c	738,62±6,89c
Weedy	77,45±,81e	3.105,68±49,68e	782,82±9,65e	58,45±,99c	1887,50±42,69c	502,50±20,56c	60,95±,86c	1996,59±10,96d	517,65±8,57d
Mean	80,15±1,34	3.319,91±105,71	857,28±27,03	75,56±1,69	3041,16±126,34	792,79±29,88	76,21±1,51	3055,62±115,45	795,87±28,25
F	321,165	267,599	559,992	92,907	98,141	135,533	185,951	195,878	503,956
p- value	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Means with the same letter do not differ significantly at the 0.05 significance leve
Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

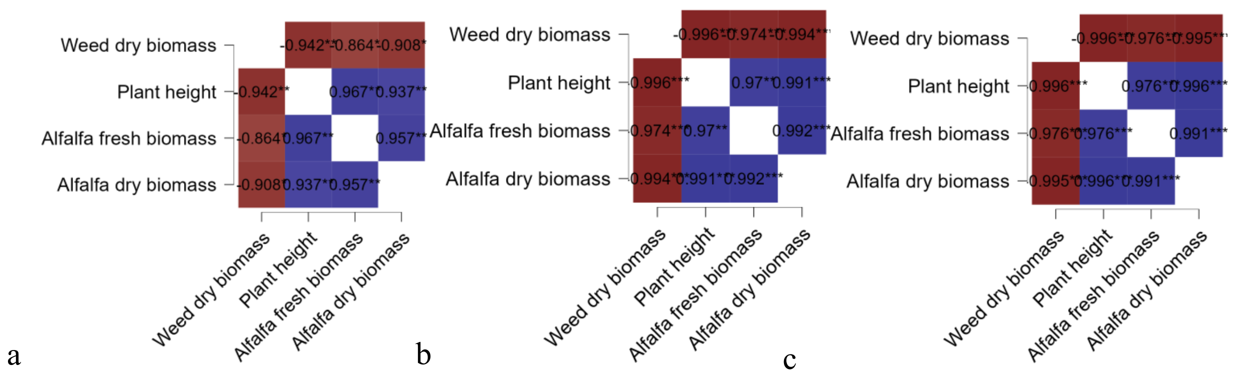
In both years of the study, the highest alfalfa plant height was obtained in Q+H (first year: 82.03 cm and second year: 79.93 cm) parcels. In both years of the study, the lowest plant height was obtained in the weedy control plots (Table 8). Çoruh and Tan (2016) determined the average alfalfa plant height between 41.3 cm and 47.9 cm. Harmanlıoğlu (2019) determined the average alfalfa plant height between 55.75 cm and 84.83 cm. The average height of alfalfa plants ranged from 66.7 to 80.2 cm according to Keskin et al. (2020b).

Among the applications, the highest fresh alfalfa weights were recorded in the Q+H plots (first year: 3,509.33 kg/da and second year: 3,457.50 kg/da). In both years of the study, the lowest alfalfa fresh weight was obtained in the weedy control plots (Table 8). Harmanlıoğlu (2019) determined alfalfa fresh weights between 5.125 kg/da and 7.389 kg/da. Cosgrove and Barrett (1987) stated that herbicides were not effective on alfalfa yield. Arregui et al. (2001) reported that some of the herbicides they used increased alfalfa yield, some did not, and some damaged alfalfa. Temme et al. (1979) stated that alfalfa seeding alone using herbicides is beneficial for weed control in alfalfa and that the feed produced in this way will increase the performance of farm animals. The highest values of dry weights were obtained in Q+H parcels in both years (first year: 911.73 kg/da and second year: 881.25 kg/da). The herbicides used at the end of both years of the study were in the same statistical group. The lowest alfalfa dry weight was obtained in the weedy control plots, which were in a single statistical group in both years (Table 8). Cosgrove and Barrett (1987) reported that total feed efficiency did not change with herbicide applications. Arregui et al. (2001) reported that some of the herbicides they used increased alfalfa yield, some did not, and some damaged alfalfa. In their study in different locations, Kostov and Pacanoski (2006) determined that the lowest alfalfa yield was in weedy control plots (1,143 kg/ha and 1,914 kg/ha), while the highest alfalfa yield was 2,891 kg/ha and 2,720 kg/ha. Çoruh and Tan, (2016). They determined alfalfa dry weights between 776 kg/da and 946 kg/da. In his study, Harmanlıoğlu (2019) determined alfalfa hay weights between 1,878.86 kg/da and 1,349.30 kg/da. Keskin et al. (2020b) found fresh yield between 3966.0 and 6180.4 kg da-1, and dry yield between 979.7 and 1586.7 kg da-1. Temme et al. (1979) stated that alfalfa seeding alone using herbicides is beneficial for weed control in alfalfa and that the feed produced in this way will increase the performance of farm animals. Differences in alfalfa yield values are affected by factors such as alfalfa variety, growing region, and climatic conditions. In our studies with the studies mentioned above, the similarities and differences between alfalfa yield and yield elements depend on the alfalfa variety, growing conditions and climate. due to variation from region to region.

Multivariate analysis of the parameters and the applications

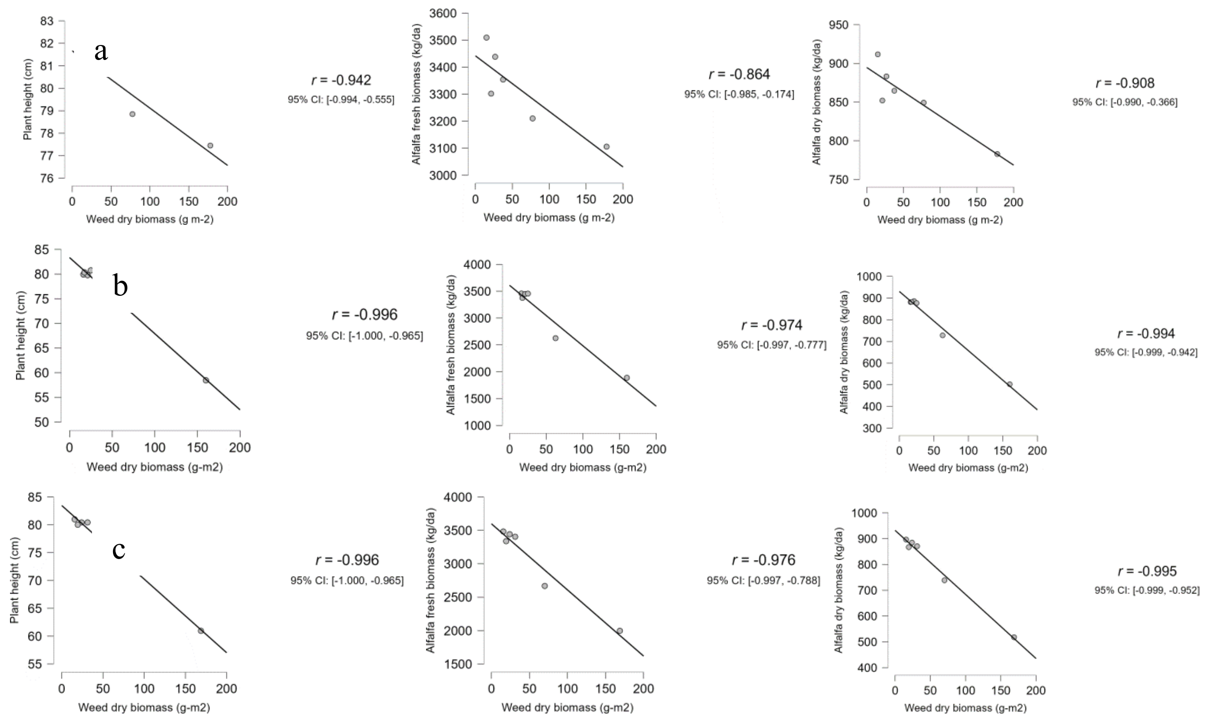
In addition to one-way analysis of variance, the mean values obtained were subjected to multiple statistical analyses to visualize the magnitude, correlations, and estimated parameters associated with independent processes. Since weed dry weights are critical issues considered in agricultural/non-agricultural fields, we discussed their relationships with other parameters. In this context, advanced analyzes such as correlation coefficient, heat map clustering, network graph analysis and principal component analysis were performed on the average values of the variables in the study.

In the current study, as discussed in the multivariate statistical analysis section, weed dry weight is negatively correlated with coefficients ranging from -0.864 to -0.942 in the first year: -0.864 to -0.942, in the second year: -974 to -996, and the average of both years is between -976 and -996. Based on the average of both years in the study, weed dry weight, plant height (r= -0.996, p<0.000), fresh weight (r=-976, p<0.000), dry weight (r=-995, P=0.000).) parameters showed a negative correlation and was statistically significant (Figure 2, Figure 3).



a: Year 2022, b: Year 2023, c: Average

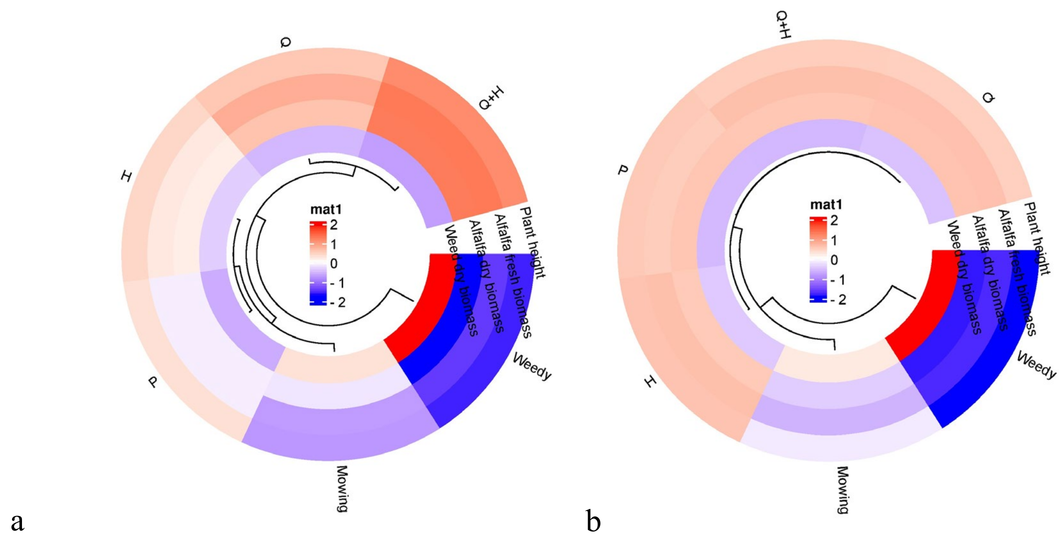
Figure 2. *Correlation analysis of estimated parameters*

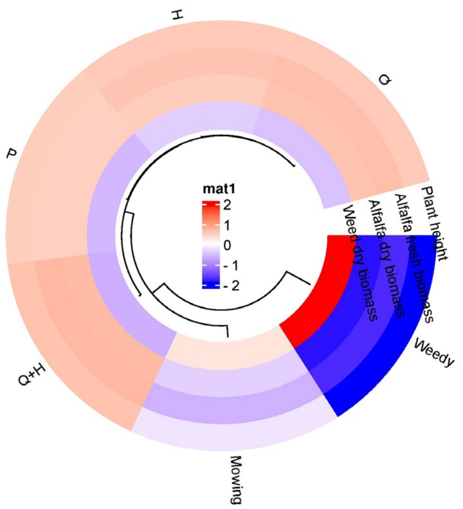


a: Year 2022, b: Year 2023, c: Average

Figure 3. *Correlations between weed dry weight and other parameters*

Heat map clustering is clearly distinguished by separating dependent and independent variables into two main clusters with a color range (+2 to -2; red to blue) indicating the resulting values (Figure 4). Among the main clusters, a single cluster contained a weed control plot. The results obtained from heat map clustering showed that it was effective in controlling weeds, although the herbicides used in the study were different.



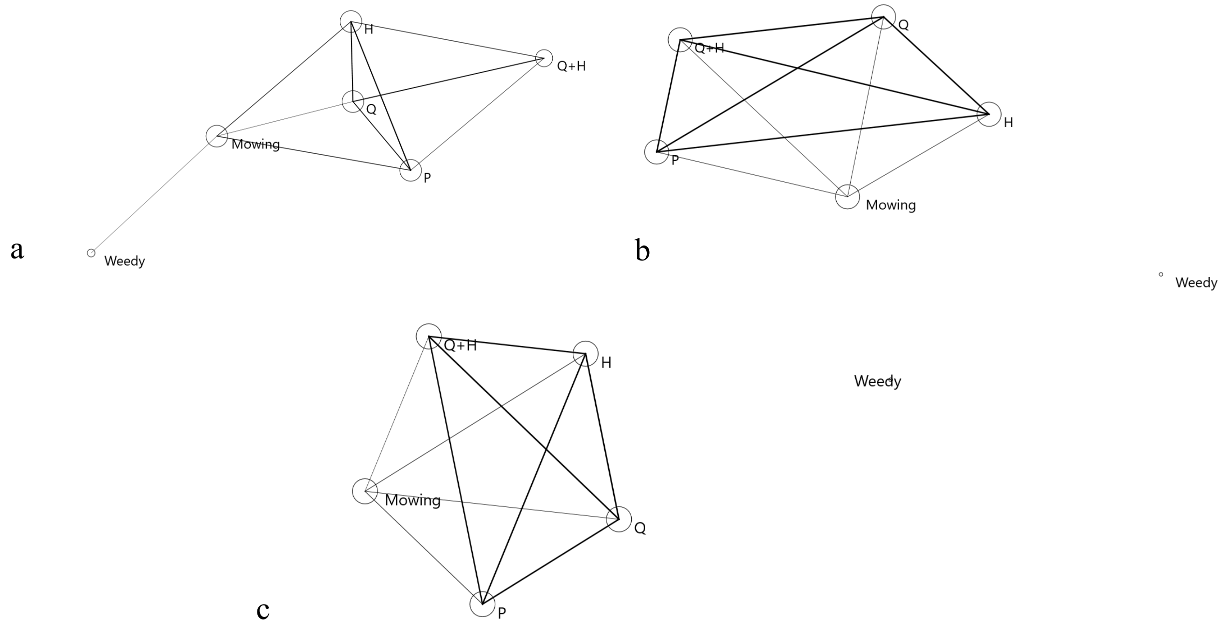


c

a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 4. *Heat map of parameters corresponding to applications*

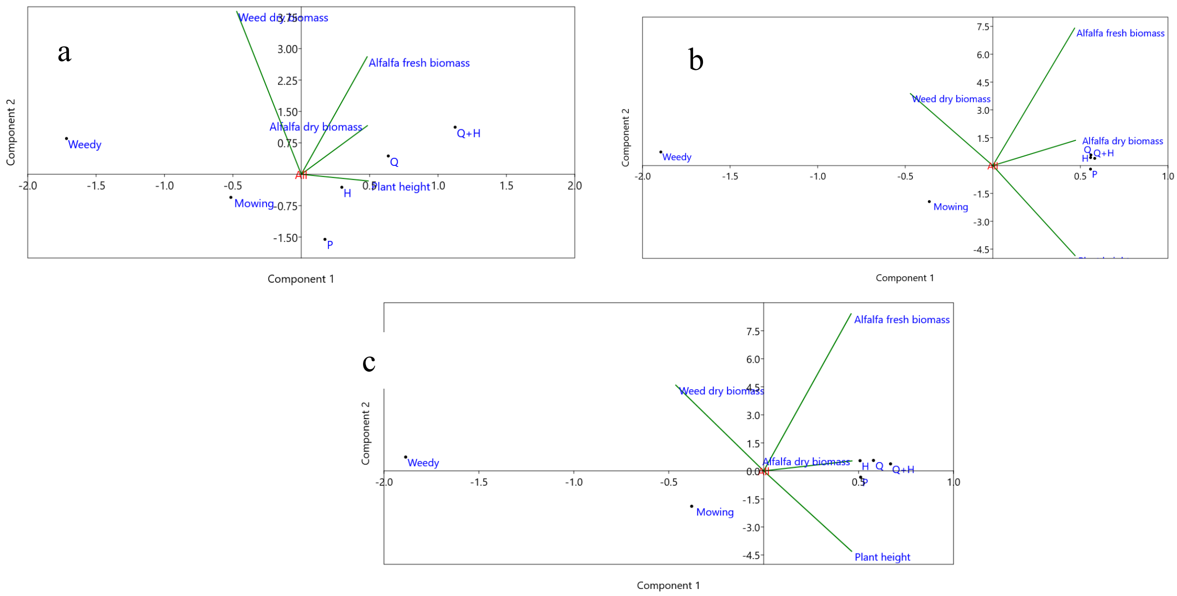
To consolidate the effects of the trials/treatments on alfalfa, a network graph analysis was also conducted to determine the relationship between treatments based on their effects/performance on agronomic traits and weed dry weights (Figure 5). The nodes along the lines represent the extent of the relationships, with thinner or lighter lines indicating weaker connections and thicker lines indicating stronger relationships. Consistent with heat map clustering, a clear separation emerged. In this analysis, the weedy control group was partially associated with mowing in the first year, but was not associated with any practice in the second year and when the average of both years was taken. Other practices are interrelated to a certain degree.



a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 5. *Network graph analysis of applications*

To describe the rate of variation, the dry and fresh weights of alfalfa and the dry weight of weeds were distributed over a biplot pair (Figure 6). Accordingly, in the first year, the first two components (PC1: 94.70% and PC2: 3.60%) accounted for 98.30% of the variability of the original data, and in the second year, (PC1: 98.97% and PC2: 0.91%).) explained 99.88% of the variability of the original data and on average (PC1: 99.13% and PC2: 0.76%) explained 99.89% of the variability of the original data. Such a high variance explained clearly shows that principal component analysis can be used successfully to evaluate the impact of estimated parameters together with applications. At the end of both years, the first component (PC1), mowing (with -0.75 points), weed control (with -3.75 points) groups were negatively related, while Q+H (with 1.33 points), Q (It is positively related to (with a score of 1.15), H (with a score of 1.01) and P (with a score of 1.01). In addition, in both years when the study was conducted, "weed dry weight" was negative in the first year (with -0.48 points), in the second year (with -0.50 points) and based on the average of both years (with -0.50 points). While other parameters were found to be positively related.



a: Year 2022, b: Year 2023, c: Average, Q: Quizalofop-p-ethyl, H: Haloxyfop (R) methyl ester, P; Propaquizafop, Q+H: Quizalofop-p-ethyl+ Haloxyfop

Figure 6. Principal component analysis of parameters and applications

Advanced analyzes such as correlation, heat map clustering, hierarchical clustering, network plot analysis and principal component analysis performed on the average values of the variables in the study support the analysis of variance. In general, the effects and the relationships between the applications and the parameters are clearly stated.

CONCLUSION

The purpose of this study was to have a look at the frequency and density of *S. halepense* in alfalfa production areas in Iğdır province and the control possibilities of herbicides with different active ingredients against this weed. In the study, at the end of both years, the frequency of *S. halepense* in alfalfa cultivation areas in Iğdır province was determined as 92.25% and its density was 48.15 plants/m^2. The effects of the herbicides used in the study on *S. halepense* were similar in both years. The effects of herbicides on S. halepsense were low in the first assessment, but high effect rates were determined in the second assessment. At the end of both years, herbicide efficacy was found to be greater than 95% on *S. halepense*. In the study, the lowest *S. halepense* dry weights were obtained in the plots where herbicides were used in both years, and all herbicides were in the same statistical group. The effect rates of the herbicides used in the study on *S. halepense* dry weight at the end of two years varied between 81.50% and 90.75%. As a result, the herbicides used were effective on *S. halepense* and caused an increase in alfalfa yield. Management of *S. halepense* requires not only the use of herbicides, but also the adoption of modified crop management practices, including improved tillage. Certain effective methods can be used in conjunction with herbicides. Further research is essential to develop comprehensive, long-term strategies that integrate both chemical and non-chemical approaches for sustainable control of this troublesome weed species..

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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