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EVALUATING THE EFFICIENCY OF SOME HERBICIDES IN CONTROLLING WEEDS OF NEWLY PLANTED AND ESTABLISHED ALFALFA

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Abstract

In order to control weeds of alfalfa in the south of Alborz province, a randomized complete block experiment with four replications was conducted in the fields of Iranian Research Institute of Plant Protection located in Meshkindasht, Karaj, during the crop year of 2014-2016. The experimental treatments were one-time application of herbicides including EPTC (5 lit/ha), Metribuzin (750 g/ha), 2,4-DB (3 and 3.5 lit/ha), Bentazon (3 lit/ha) and Imazethapyr (0.5 and 1 lit/ha) on newly planted and established alfalfa, as well as control treatments without weed control and control treatments with manual weeding in all weed seasons. The results showed that the application of herbicides had a significant effect on the weed control efficacy and dry weight of alfalfa; so that, the weed control efficacy were significantly reduced with the application of herbicide treatments. One-time spraying with 2,4-DB (3.5 lit/ha) had a suitable weed control performance. One-time spraying with Metribuzin and Imazethapyr (1 lit/ha) could reduce the dry weight of weeds by 96 and 92% in the first harvest, 89 and 86% in the second harvest. Imazethapyr and EPTC herbicides did not harm alfalfa and significantly increased its yield. Although Metribuzin had an effective performance in controlling weeds, it caused plant burning and damage in the first harvest. One-time spraying with Imazethapyr (1 lit/ha and 0.5 lit/ha) had the highest dry weight yield. These treatments were able to increase the dry weight of alfalfa by 28 and 32% in the first harvest, 22 and 31% in the second harvest. Therefore, due to weed control efficiency and increased yield, it is recommended to apply one-time spraying with Imazethapyr herbicide (1 lit/ha).

Keywords; herbicide, fresh weight, dry weight, alfalfa.

Introduction

Alfalfa hay is the third most valuable cash crop in the Iran [10] and is the most widely cultivated forage legume worldwide [2]. Additionally, the overall value of alfalfa hay is further enhanced by its essential contributions, as feed and forage, to livestock production (i.e., milk, meat, textiles). As crop production acreage and the availability of resources for management continue to decline, it is important to maximize yield and nutritive value of all alfalfa production as much as possible to meet the agricultural needs of producers, farmers, ranchers, livestock managers, and industry personnel, especially in light of the need to increase food production globally to meet the needs of an increasing population and climate change [3,4]. Managing weeds is a critical and ever-present component of successful alfalfa production. While weeds that emerge during the initial seeding stages of alfalfa typically have the greatest effect by competing for light, water, space, and nutrients, late-season weeds that populate established alfalfa fields can have a significant influence on yield through continued competition for resources throughout the remaining and following growing seasons [5,6]. Additionally, the presence of annual and perennial weeds at any time can lower forage nutritive value, reduce stand longevity caused by premature plant loss or reduction, increase the incidence of disease and insect damage, and create detrimental harvesting issues [7–9]. Perennial weed populations are especially difficult to control in perennial crops, like alfalfa, because management practices have to address seed production and vegetative reproductive structures that allow the plant to survive from season to season. Simple perennial weeds, like plantain (Plantago spp.), have a hearty root system that allows the plant to die back and survive during non-ideal environmental conditions, proctoring tissue regrowth and re-establishment once conditions become ideal again [10,11]. Broadleaf plantain (Plantago major L.) and buckhorn plantain (Plantago lanceolata L.) are particularly difficult-to-control weeds whose infestations are widespread in alfalfa fields throughout the western U.S. [10,11]. Weed management of these simple perennial weeds must focus primarily on injury to the root system; however, it is difficult for herbicide active ingredients to move effectively enough within the entire plant to injure a hearty root system located deep within the soil [10]. Similarly, the use of selective herbicides to control broadleaf weeds, like plantain, in a broadleaf crop, like alfalfa, further complicates any effective management. As a result, there are

only a few registered herbicide active ingredients, such as glyphosate (pre-plant burndown or Roundup® Ready systems), 4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB amine), and 2-methyl-4-chlorophenoxyacetic acid (MCPA) that have been reported to cause injury to plantain in alfalfa fields [5,9]. Currently there are no herbicides labeled for use in alfalfa that will control plantain without multiple applications across several seasons [11,12]. Additionally, the broadleaf herbicide active ingredients labeled for use in alfalfa have never been evaluated for late-season broadleaf perennial weed control in dormant-season alfalfa. Furthermore, the continued use of these select few herbicide active ingredients to manage a specific population of weeds, like plantain in alfalfa, over time, can lead to the development of weed population shifts and herbicide resistance in the target weeds [13,14]. As a result, research to evaluate the effectiveness of newly registered herbicides with different active ingredients is greatly warranted for control of plantain in alfalfa. The active ingredient in Sharpen® is saflufenacil [N'-[2-chloro-4-fluoro-5-(3-methyl-2,6-dioxo-4-(trifluoromethyl)-3,6-dihydro-1(2H) pyrimidinyl)benzoyl]-N-isopropyl-N-methylsulfamide], which causes plant cell membrane damage and eventually plant death by inhibiting the production of protoporphyrinogen-oxidase (herbicide group 14 [16–18]). Specifically, saflufenacil can offer contact burn-down control of annual broadleaf weeds such as black nightshade (Solanum nigrum L.) and Palmer amaranth (Amaranthus palmeri S. Watson) [16,17,19], and perennial broadleaf weeds including, but not limited to, field bindweed (Convolvulus arvensis L.) and dandelion (Taraxacum o_cinale Weber ex Wigg) during limited (dormant) season growth of alfalfa [15,20]. Saflufenacil has yet to be studied as a potential herbicide option for broadleaf and buckhorn plantain control in alfalfa fields. The objectives of this study were to (1) compare the weed control against commercially available herbicide standards under open space conditions, and (2) evaluate the effects on alfalfa yield reduction resulting against commercially available herbicide products. Should results indicate that herbicides provides acceptable control on broadleaf and equivalent crop safety compared to the commercial standards, actions will be taken to include plantain as a target weed in the most up-to-date product labels.

Materials and methods

This study was conducted in freshly planted and established alfalfa fields of Iranian Research Institute of Plant Protection located in Meshkindasht, Karaj (51° east longitude and 35° 48´ north latitude) with an elevation of 1320 m above sea level and an average rainfall of 250 mm, during the crop year of 2014-2016. Some physical and chemical properties of the soil of the experimental location are given in Table 1.

The experiment was performed in a randomized complete block design with 4 replications and the treatments included were one-time application of herbicides including EPTC (5 lit/ha), Metribuzin (750 g/ha), 2,4-DB (3 and 3.5 lit/ha), Bentazon (3 lit/ha) and Imazethapyr (0.5 and 1 lit/ha) on newly planted and established alfalfa, as well as control treatments without weed control and control treatments with manual weeding in all weed seasons. The dosage of each herbicide is given in Table 2.

Table 1- Soil physicochemical properties of the experimental location

Dept (cm)	EC (ds/m)	Ph	K_2O (mg/kg)	P_2O_5 (mg/kg)	Organic carbon (%)	Soil texture
0-30	1.50	7.2	205	4.1	0.1	Sandy loam

Table 2- Characteristics of herbicide treatments applied in the experiment

Common Name	Trade Name	Application Rate	Formulation	(a.i.g/ha)	Company
EPTC	Eradicane	5(l/h)	82% EC	4100	Stauffer, USA
Metribuin	Sencorc	750 (g/ha)	70% WP	525	Bayer, Germany
2,4-DB	Butress	3(l/ha)	42.3% EC	1296	Nufarm, Australia
2,4-DB	Butress	3.5 (l/ha)	42.3% EC	1480	Nufarm, Australia
Bentazone	Bazagran	3(l/ha)	48% SL	1440	BASF, Germany
Imazethapyr	Pursuit + Citogate	0.5 (l/ha) + 200 (ml/ha)	10% SL	50	BASF, Germany
Imazethapyr	Pursuit + Citogate	1 (l/ha) + 200 (ml/ha)	10% SL	100	BASF, Germany

One- and two-time spraying treatments (first time) were performed on freshly planted alfalfa in autumn 2014. At this stage, EPTC was sprayed before planting alfalfa and mixed with soil (2014.10.14), Metribuzin was sprayed after planting and before alfalfa emergence (2014.11.01) and 2,4-DB, Bentazone and Imazethapyr were applied when alfalfa had a 10 - 15 cm height suring the 3^{rd}-4^{th} leaf growth stage of weeds (2014.12.16) (Table 3). In addition, the second spraying of the two-time spraying was performed in the winter of 2014; at a stage when six months had passed since the establishment of alfalfa; so that, the treatments of EPTC and biosin

herbicides were applied before alfalfa regrowth and weed growth (2015.03.04) and irrigation was done immediately. Spraying with 2,4-DB, Bentazone and Imazethapyr herbicides was performed after alfalfa regrowth and 3rd-4th leaf growth stage (2015.03.04) (Table 3). It is worth noting that in this experiment, the first three harvests after spraying on freshly planted alfalfa (one-time sprayed) and the first three harvests after the second time spraying were evaluated.

To perform the experiment, a field with a history of weed infestation was selected. Planting field preparation consisted of semi-deep plowing and two times vertical disking. Each experimental unit (plots) had a 6 m long and 2 m wide. The distance between the plots and blocks was 1 m and 2 m, respectively. Seed sowing was done by hand on (2014.10.14). The cultivars were Hamedani and the amount of seed used was 50 kg/ha. Irrigation was flooded depending on the needs of the plant during the growing season; so that, irrigation was done once every five to seven days in the warm season, and every two to three weeks in the cold season. The application of herbicide treatments was done using a backpack sprayer with a constant pressure of Elegance 18 plus, equipped with a 8002 nozzle with a double pressure and a spray volume of 350 lit water/ha. The measured traits included density, dry weight of weeds and their control percentage during three consecutive harvests after the spraying treatments. Density and dry weight of weeds in different harvests were measured in a 0.5× 0.5 m^2 frame. Weed samples were carefully weighed after harvesting and drying at 75 °C for 48 hours. Weed control efficacy (WCE) was calculated by Equation 1 (Baghestani et al., 2007):

Equation (1) $$WCE = (A - B/A) \times 100$$

where, A and B are the measured density or dry weight of the weeds in the control and spraying treatments, respectively. The dry weight of alfalfa and the percentage of forage changes during the three harvests were also determined in an area of 4 m^2. The percentage of changing dry weight of alfalfa was calculated using Equation 2:

Equation (2) $$\% \text{ Yield} = 100 \times C/D$$

where, YIELD is the percentage of alfalfa yield changes; C and D are the dry weight of alfalfa in the spraying treatments and control, respectively. Statistical analysis was done using SAS 9.1 and mean comparison was performed using Duncan's multiple range test at 5% level.

Result and Discussion

The ANOVA results of the density and dry weight of weeds in different harvests showed that herbicide treatments had significant effects ($p \leq 0.01$) on the mentioned traits (Table 3).

Table 3- ANOVA results of the density and dry weight of weeds in different alfalfa harvests

Sources of variation	df	(Mean of Squares)			
		Number of weed		Dry weight of weed	
		First harvest	Third harvest Second harvest	First harvest	Third harvest Second harvest
Replication	3	116.44^{ns}	153.97^{ns}	6.50^{ns}	110.14^{ns}
Treatment	7	907.11**	749.94**	1100.50**	1567.83**
Error	21	48.55	87.06	39.76	81.88
(CV%)		8.94	11.77	7.99	11.90

ns and **: non-significant and significant at 1% of probability levels, respectively.

The herbicides significantly reduced the density and dry weight of weeds in all three harvests. The comparison of the effectiveness of herbicides on newly planted alfalfa showed that Imazethapyr (1 lit/ha) was most effective in reducing weed density in different harvests. This treatment was significantly different from other treatments in terms of the first and second harvests; however, it was in the same statistical group with 2,4-DB (3.5 lit/ha) in the third harvest. On the other hand, Imazethapyr (1 lit/ha) had the highest control efficiency in different harvests in two-times spraying treatments on planted alfalfa and was in the same statistical group with 2,4-DB (3.5 lit/ha in second harvest).

Comparison of one- and two-time spraying treatments showed that one- and two-time application of Metribuzin and Imazethapyr (1 lit/ha) in different harvests of newly planted and established alfalfa was more desirable than other treatments in reducing weed density. However, the most desirable treatments in terms of reducing weed

density in different harvests were the one- and two-time application of Metribuzin. These treatments were able to reduce weed density by 96% in the first harvest, 87 and 85% in the second harvest, respectively compared to the control (Table 4).

Table 4- The effect of herbicide treatments on weed dry weight, the density and control efficacy of weeds in different alfalfa harvests

Treatments	First harvest		Second harvest	
	g/m^2	%	g/m^2	%
Metribuzin	56	96	54	92
Imazethapyr 1	37	89	32	86
Imazethapyr 0.5	32	69	26	65
2,4-DB 3.5	33	66	29	65
Bentazon	61	65	54	64
2,4-DB 3	38	64	36	60
EPTC	40	44	33	36

The results of herbicide treatments' effects on the dry weight of weeds also showed that Imazethapyr (1 lit/ha) was more desirable than other herbicide treatments in different harvests in terms of one-time spraying treatments on freshly planted alfalfa, which had a significant difference with other treatments. In terms of two-time spraying treatments on established alfalfa, Imazethapyr (1 lit/ha) was better than the other in reducing dry weight of weeds; however, it was in the same statistical group with other herbicide treatments in the first and second harvests in terms of weed control efficacy (Table 4).
One- and two-time application of Imazethapyr (1 lit/ha) on newly planted and established alfalfa had better results than other treatments in reducing weed weight in different harvests. However, one- and two-time application of Imazethapyr (1 lit/ha) had the best efficiency in reducing dry weight of weeds in different harvests. So that, these treatments were able to reduce the dry weight of weeds by 98 % in the first harvest, 96 % in the second harvest, respectively compared to the control. In contrast, the lowest efficiency in reducing dry weight of weeds was observed in the one-time application of Bentazon, which reduced the dry weight of weeds by 93 and 91% in the first, second respectively, compared to the control (Table 4). Given that the ability of alfalfa to compete with weeds in the first harvest is weaker than in the next harvests (Wilson & Burgener, 2009), it seems that the effect of using herbicides along with improving the competitiveness of alfalfa due to the establishment and development of its aerial parts in next harvests are the possible reasons of reduction of weed infestation in the second and third harvests. In this regard, the effect of herbicides in reducing the density and dry weight of alfalfa's weeds had been proven in various studies (Meighani et al., 2010).

Dry weight of Alfalfa:
The ANOVA results showed that the treatments had a significant effect ($P \leq 0.01$) on the dry weight of alfalfa in the first, second and third harvests (Table 5).

The results of the effect of herbicide application in the first alfalfa harvest showed that the effect of treatments on the dry weight of alfalfa was significantly different; so that, one-time spraying of Imazethapyr (1 lit/ha) on freshly planted alfalfa resulted in the highest dry weight of alfalfa (7.89 tons per hectare) compared to the control. Application of Imazethapyr (1 lit/ha) increased the dry weight by 31% in the first harvest compared to the control. The results of effect of herbicide treatments on the dry weight of freshly planted and established alfalfa in the second and third harvests were similar to the first harvest; so that, the Imazethapyr treatments (1 lit/ha) resulted in highest dry weight. Damage to alfalfa due to the use of herbicides in these two harvests decreased and the dry weight of forage increased. In addition, the effect of herbicide damage on freshly planted and established alfalfa in was completely eliminated the third harvest and even the dry weight of forage increased compared to the control (Table 6). These results indicated that alfalfa was able to replace its damaged parts in the second and third harvests through regeneration and production of lateral leaves and compensate for the damage caused by the use of herbicides. In this regard Wilson & Burgener (2009) reported that the intense weed competition with alfalfa in the first harvest reduced the forage content but after the establishment of alfalfa, the amount of forage increased.

Table 5- ANOVA results of alfalfa dry weight in different harvests

Sources of variation	df	(Mean of Squares)				
		Dry weight of weed				
		First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest
Replication	3	169065.29*	62762.17^{ns}	99894.80^{ns}	1910893.28**	14947.25^{ns}

Treatment	7	528121.05 **	505537.31 **	606117.72 **	108767.53 *	132735.31 **
Error	21	54193.18	69044.56	72059.67	40579.05	44676.87
(CV%)		16.06	10.55	11.95	10.13	19.81

ns and **: non-significant and significant at 1% of probability levels, respectively.
In total, based on the results of increased dry weight of forage in different harvests of freshly planted (one time spraying) and established (two time spraying) alfalfa and considering the effectiveness of herbicides in controlling weeds in different harvests and no damage to alfalfa, the most desirable treatments were the two- and one- time spraying application of Imazethapyr (1 lit/ha), respectively.

Table 6- Effects of herbicide treatments on the alfalfa's dry weight and percentage of weight changes in different harvests

Treatments	First harvest		Second harvest	
	g/m^2	%	g/m^2	%
Metribuzin	713	21.6	3669	27.5
Imazethapyr 1	927	28.2	3983	32.1
Imazethapyr 0.5	887	22.5	3981	31.7
2,4-DB 3.5	925	12.7	3792	18.1
Bentazon	886	20.8	3791	28.1
2,4-DB 3	912	6.9	3794	15.8
EPTC	784	20.3	3659	29.3

Conclusion

According to the results of weed control and dry weight of alfalfa, 2,4-DB (3.5 lit/ha) had a good weed control performance, however it is not recommended to be used in Alborz province due to the plant burning and damage in the first harvest. In contrast, Imazethapyr (1 lit/ha) can be introduced as the most desirable herbicide treatment due to its optimal efficiency in weed control and lack of damage to alfalfa. In addition, one time spraying of Imazethapyr (1 lit/ha) is recommended in terms of environmental issues and health quality of forage.

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