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EFFICACY OF DIFFERENT HERBICIDES ON WEED CONTROL, GROWTH INDICES AND FORAGE YIELD IN ALFALFA (*MEDICAGO SATIVA* L.)

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Abstract - In order to investigate the chemical management in alfalfa newly planted, an experiment in a randomized complete block design with four replications was conducted in the research farm of Iranian Research Institute of Plant Protection located in Meshkindasht, Iran (2014-2016). Treatments includes EPTC (5 l/ha), Metribuzin (750 g/ha), 2,4-DB (3 and 3.5 l/ha), Bentazon (3 l/ha) and Imazethapyr (0.5 and 1 l/ha) on newly planted and established alfalfa, as well as control treatments without weeds control and with manual weeding during alfalfa growth season. The results revealed that the most effective herbicides to decrease the broadleaf weeds density were Metribuzin (99 and 97% in the first and second cuttings, respectively) and Imazethapyr (1 l/ha) (91 and 90% in the first and second cuttings, respectively). The lower effect was related to EPTC application (44 and 36% in the first and second cutting, respectively). As regards the the effects on narrow-leaf weeds density the highest herbicides efficiency was related to EPTC (100% in both cuttings), Metribuzin (87 and 91% in the first and second cuttings, respectively), Imazethapyr (1 l/ha) (81 and 90% in the first and second cuttings, respectively). In conclusion, Imazethapyr application (1 l/ha) was more suitable than other herbicides.

Keywords: Imazethapyr, Metribuzin, Fresh and dry matter of alfalfa, LAI.

Introduction

Alfalfa (*Medicago sativa* L.) is the most important forage plant in terms of yield and nutritional value. The high protein along with low lignin content made it one of the strategic plants in the world. Alfalfa plays an important role in providing the required meat and milk as well as in soil fertility improvement. Alfalfa fields protect the soil from wind erosion. In areas where row crops have damaged the soil, alfalfa is commonly used to improve soil stabilization (Karimi, 2005). Alfalfa with the highest area under cultivation among forage plants (653000 hectares) in Iran, has a special place (Agricultural Statistics, 2011). Alfalfa has a slow germination and establish slowly, but it produces excellent cover and a lot of biomass after the first establishment (Arregi et al., 2001). Alfalfa is a perennial plant that can be productive for several years under suitable conditions, but it often decreases in quantity and quality after 2 to 3 years due to weed infestation (Mousavi, 2001). An accurate estimate of weed damage in forage plant fields is not available. However, studies have shown that the most weed damage in alfalfa production is related to the first cutting and is mainly done by winter weeds (Zand et al., 2007). Simmons et al. (1995) stated that if weeds are left, they reduce yield and weaken alfalfa, and in more severe cases, cause alfalfa death. Also, high weed competition can reduce alfalfa density and replant seeds in newly planted alfalfa fields. Thus, one of the effective methods to maintain production potential is weed

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management (Zand et al., 2007). Various methods are used to control alfalfa weeds (Bryan et al., 2011). Although the use of herbicides is effective to control weeds in many cases, there are environmental concerns about their use in terms of human health and soil and water pollution. The type, dose and method of herbicide application and the climate of the region are effective on the rate of weed control, and factors such as weed species, weed growth stage, and herbicide cost depend on crop growth stage (Arregi, 2001; Curran et al., 1999).

The type of weeds depends on the region and its climatic conditions. In general, annual weeds are dominating in the first year. Over time, perennial weeds gradually dominate due to harvesting operations and the inability to produce seeds of annual plants (Mousavi, 2001). The most common alfalfa weeds include: *Setaria viridis* (L.) P. Beauv, *Amaranthus retroflexus* L., *Tragopogon dubius* Scop, *Plantago major* L., *Convolvulus arvensis* L., *Rumex acetosa* L., *Rhaponticum repens* L (Hidalgo)., *Jacobaea vulgaris* Gaertn, *Cuscuta* spp., *Echinochloa crus-galli* (L.) P/Beauv, *Geranium robertianum* L., *Pelargonium* spp., *Sonchus asper* L., *Euphorbia* spp, *Sonchus arvensis* L., *Capsella bursa-pastoris* (L.) Medik, *Echium amoenum* Fish.& C.A.Mey, *Salvia officinalis* L., *Polygonum* spp.

Darwent et al. (1997) stated that the effectiveness of Imazethapyr herbicide in alfalfa production (about 60%) was significant on wild mustard, *C. arvensis*, *Chenopodium album* L., *A. retroflexus.* Imazethapyr herbicide (1.5 l/ha) caused alfalfa dwarfism, Imazethapyr + Bentazone caused yellowing and dwarfism in alfalfa (Mousavi et al., 2010). Faqih et al. (1998) by examining the effect of several herbicides on alfalfa weeds in East Azerbaijan showed that the application of Bentazone (3 and 5.2 l/ha) and Metribozin (1000 and 700 g/ha) had significant effect on broadleaf weeds compared to control. Tonks et al. (1991) investigated the effects of Bentazone and 2,4-DB herbicides on alfalfa and reported that Bentazone did not reduce alfalfa height and yield in the first cutting, but 2,4-DB reduced alfalfa yield in the first cutting. The aim of this study was to evaluate the effectiveness of different herbicides on weed control, alfalfa forage yield as well as growth indices such as cumulative dry matter and leaf area index in newly planted alfalfa characterized by slow growth.

Material and Method

The present study was conducted from 2014 to 2016 in the Iranian Research Institute of Plant Protection located in Meshkindasht, Iran, with a geographical location of 51° longitudes, 35° 48′ latitude and 1320 m a.s.l. The average annual rainfall was 250 mm during the mentioned crop year. The experiment was conducted with 9 treatments in a randomized complete block design with 4 replications. Experimental treatments included: one-time application of herbicides including EPTC (5 l/ha), Metribuzin (750 g/ha), 2,4-DB (3 and 3.5 l/ha), Bentazon (3 l/ha) and Imazethapyr (0.5 and 1 l/ha) on newly planted and established alfalfa, as well as control treatments without weeds control and control treatments with manual weeding during alfalfa production season. The characteristics of each herbicide is given in Table 1.

Table 1. Characteristics of herbicide treatments applied in the experiment

Common Name	Trade Name	Application Rate	Formulation	a.i.* (g/ha)	Time of consumption	Company
EPTC	Eradicane	5 (l/h)	82% EC	4100	Before alfalfa sowing and mixed with soil	Stauffer, USA
Metribuzin	Sencor	750 (g/ha)	70% WP	525	After sowing and before alfalfa emergence	Bayer, Germany
2,4-DB	Butress	3 (l/ha)	42.3% EC	1296	Early weed growth	Nufarm, Australia
2,4-DB	Butress	3.5 (l/ha)	42.3% EC	1480	Early weed growth	Nufarm, Australia
Bentazone	Bazagran	3 (l/ha)	48% SL	1440	Early weed growth	BASF, Germany
Imazethapyr	Pursuit + Citogate	0.5 (l/ha) + 200 (ml/ha)	10% SL	50	Early weed growth	BASF, Germany
Imazethapyr	Pursuit + Citogate	1 (l/ha) + 200 (ml/ha)	10% SL	100	Early weed growth	BASF, Germany

*Active ingredient.

Alfalfa was planted on Novembner 13th, 2014. Alfalfa seeds of Hamedani cultivar at a rate of 50 kg/ha after mixing with wind sand on both sides of the ridges (in two rows in each ridge) were distributed manually. The distance between the ridges was 50 cm. Irrigation was considered as leakage and weekly intervals. To determine the effect of herbicides on weeds, 45, 30 and 60 days after application of post-emergence herbicides, weed sampling using fixed square (50 × 50 cm) was performed. Flixweed, wild mustard, wild barley, yellow alfalfa, blue mustard and fine leaved fumitory were observed in the experimental plots. Finally, the percentage compared to the control was calculated for the effect of different herbicides. Weed samples were carefully weighed after harvesting and drying at 75 °C for 48 hours. Also, in order to evaluate the treatments on alfalfa yield and its growth indices at regular intervals during the second harvest (first year), sampling including fresh matter, dry matter and leaf area index was performed. 50 × 50 cm square were selected for each plot and harvested in a destructive manner, and then the leaf area index was measured using a Leaf Area Meter. Then all alfalfa shoots were dried and weighed at 72 °C for 48 hours in the oven to determine the dry matter.

Statistical analysis of data with SAS (version. 9.4) and comparison of means was performed using the least significant difference test (LSD).

Gaussian equation was used to fit the leaf area index data applying the following formula (Eq. 1)

$$a = exp\left(-0.5*\left(\frac{x-x0}{b}\right)^2\right)*Y \qquad \text{Eq. 1}$$

In which a: maximum leaf area index, b: slope of the curve, x_0= maximum leaf area per mentioned day.

The sigmoid equation was used for cumulative dry matter:

$$y = \frac{a}{1+\exp(-b(x-x0))} \qquad \text{Eq. 2}$$

In which a: maximum dry matter, b: slope of the curve, x_0: time to reach 50% of dry matter.

In relation to the correlation of the observed and predicted values, the coefficient of determination (R^2) as well as Root Mean Square Error (RMSE) was used.

Results and Discussion

Weed density and dry matter

The results of percentage reduction of weed density and dry matter in the first cutting showed that the effect of herbicides was different in total weed density reduction. Application of Metribuzin (97.71%) and Imazethapyr (1 liter per hectare) (89.95%) had the highest density reduction percentage compared to the control, and there was no significant difference with manual weeding treatment (Table 2). The results also showed that the application of 2,4-DB herbicide at 3 and 3.5 l/ha were not significantly different from bentazone, EPTC and Imazethapyr at 0.5 l/ha (Table 2).

Table 2. Effects of the treatments on the percentage of reduction of weed density and dry matter compared to the control: first cutting. Values within a column followed by same letter are not significantly different at LSD.

Treatments	Density reduction compared to control			Dry matter reduction compared to control		
	Narrow leaf	Broad broadleaf	Total	Narrow leaf	Broad broadleaf	Total
EPTC	99.73a	44.28d	67.00b	99.68a	40.41d	56.30d
Metribuzin	87.51a	99.16a	97.71a	95.72a	99.06a	98.15d
2,4-DB (3 l/ha)	47.91bc	66.62c	65.38b	62.97b	68.19c	67.92c
2,4-DB (3.5 l/ha)	41.66c	75.59bc	69.94b	50.45b	75.59c	69.51c
Bentazon	38.54c	76.27bc	63.40b	61.63b	67.38c	66.11c
Imazethapyr (0.5 l/ha)	52.08bc	79.37bc	70.75b	70.21ab	81.24bc	78.91b
Imazethapyr (1 l/ha)	81.25ab	91.66ab	89.95a	97.69a	91.21ab	93.97a
Manual weeding	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a

Table 3. Effects of the treatments on the percentage of reduction of weed density and dry matter compared to the control: second cutting. Values within a column followed by same letter are not significantly different at LSD.

Treatments	Density reduction (%)			Dry matter reduction (%)		
	Narrow leaf	Broad broadleaf	Total	Narrow leaf	Broad broadleaf	Total
[1] EPTC	99.94a	36.84c	68.26b	99.86a	28.49d	51.50c
Metribuzin	91.66ab	97.91a	95.83a	99.37a	98.19a	98.72a
[2] 2,4-DB (3 l/ha)	71.04abc	62.23b	71.06b	85.57ab	70.31bc	74.34b
2,4-DB (3.5 l/ha)	61.79bc	69.73b	72.46b	57.33bc	85.12ab	75.52b
Bentazon	60.41c	71.83b	66.96b	51.84c	54.77c	54.56c
Imazethapyr (0.5 l/ha)	72.91bc	63.13b	69.17b	78.71abc	52.74c	59.52c
Imazethapyr (1 l/ha)	90.62ab	90.18a	90.22a	92.71a	95.20a	93.83a
Manual weeding	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a

[1] thiocarbamates S-ethyl dipropylthiocarbamate; [2] 4-(2,4-dichlorophenoxy) butyric acid.

The highest percentage of weeds dry matter reduction (total dry matter of weeds) was related to Imazethapyr at 1 l/ha (97.93%) and Metribuzin (98.15%). The lowest effect was obtained by EPTC (56.30%) (Table 2).

The lowest percentage of weeds total dry matter reduction in the second cutting was related to Imazethapyr (0.5 l), EPTC and Bentazone (59, 54 and 51%, respectively) compared to the control (Table 3). Also, there was no significant difference between 2,4-DB herbicides at 3 and 3.5 l/ha (reduction percentage were 74 and 75%, respectively). Among the used herbicides, the highest reduction percentage was related to Metribuzin and Imazethapyr (98% and 93%, respectively). In Metribuzin and Imazethapyr treatments, weed density and growth were very low (Table 3).

Raoofi and Alebrahim (2017) reported that the application of Imazethapyr and Bentazone herbicides provided better control of alfalfa weeds, especially Flixweed. The results of Moyer and Acharya (2006) also showed that the application of Metribuzin was effective to control the broadleaf weeds such as dandelion, flixweed, priestly bag and narrow-leaved weeds such as Bromus and Poa. Also, the results of Sheaffer and Wyse (1982) indicated that Metribuzin at 1.1 kg/ha controlled weeds such as Bromus, Kochia, Salsola, flixweed and wild lettuce. Malik et al. (1993) also revealed that the application of Imazethapyr herbicide at 0.2 kg/ha led to the control of dandelion weed in alfalfa, but was not satisfactory in controlling *Cirsium arvense* L. According to the research of Mesbah and Miller (2005), the use of Imazethapyr resulted in 35% reduction in weed control when the height of the *C. arvense* was 15 cm. Pacanoski et al. (2017) reported that the highest percentage of weed control was related to the use of Metribuzin (98.4%), Pronamide (91.8%) and Imazethapyr (93.1%), and alfalfa yield was similar to the manual weeding treatment.

Fresh and dry forage yield of alfalfa: first cutting

Mean comparison of fresh matter in the first cutting in newly cultivated alfalfa showed that the highest fresh matter (5942 g/m^2) was obtained with manual weeding, without significant differences with Imazethapyr at 1 l/ha (5652 g/m^2) and 2,4-DB herbicide at 3.5 l/ha (5660 g/m^2). The lowest alfalfa fresh matter in the first cutting was related to Metribuzin application (3589 g/m^2). Also, the alfalfa fresh matter was obtained 3842 g/m^2 without weeds control. The fresh matter of alfalfa with application of EPTC was not significantly different from 2,4-DB herbicide (3 l/ha) and Imazethapyr (0.5 l/ha) (Figure 1). Dry matter of alfalfa in the first cutting was affected by different herbicide treatments and the results showed that the application of herbicides such as Imazethapyr and 2,4-DB (3.5 l/ha) was not significantly different with manual weeding treatment. On the other hand, the application of Metribuzin was related to the lowest alfalfa dry matter, and there were no significant differences between weed and control treatments. According to the percentage of weed control in Metribuzin herbicide application, fresh and dry matter of alfalfa had the lowest amount and the reason for this reduction could be the severe effects of burning and inhibitory effects on alfalfa with Metribuzin application. Finally, application of Imazethapyr herbicide, was related to the highest fresh and dry matter of alfalfa in the first cutting due to proper weed control (Figure 1).

Fresh and dry forage yield of alfalfa: second cutting

Comparison of the fresh and dry matter of alfalfa showed that it had more fresh and dry matter in the second cutting than the first cutting in all treatments (Figure 2). The highest fresh matter of alfalfa (8359 g/m^2) was obtained with manual weeding treatment, which did not differ significantly from 2,4-DB (3 and 3.5 l/ha) and Imazethapyr (0.5 l/ha). The lowest alfalfa fresh matter was obtained with Metribuzin (5720 g/m^2) and control treatment with weeds (6160 g/m^2), respectively (Figure 2).

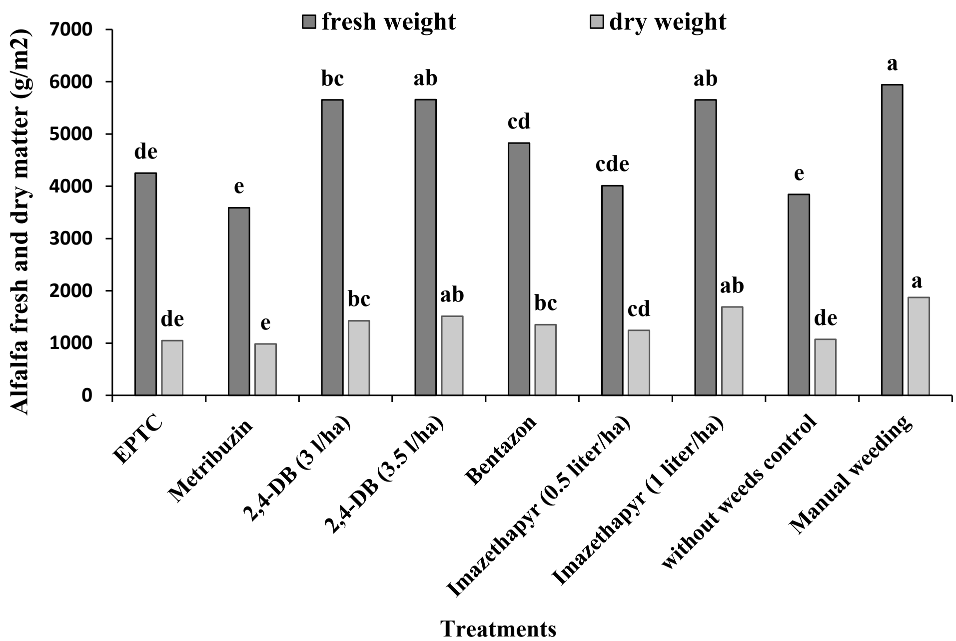

Figure 1. Effect of treatments on fresh and dry matter of newly cultivated alfalfa in the first cutting. Columns followed by same letter are not significantly different at LSD.

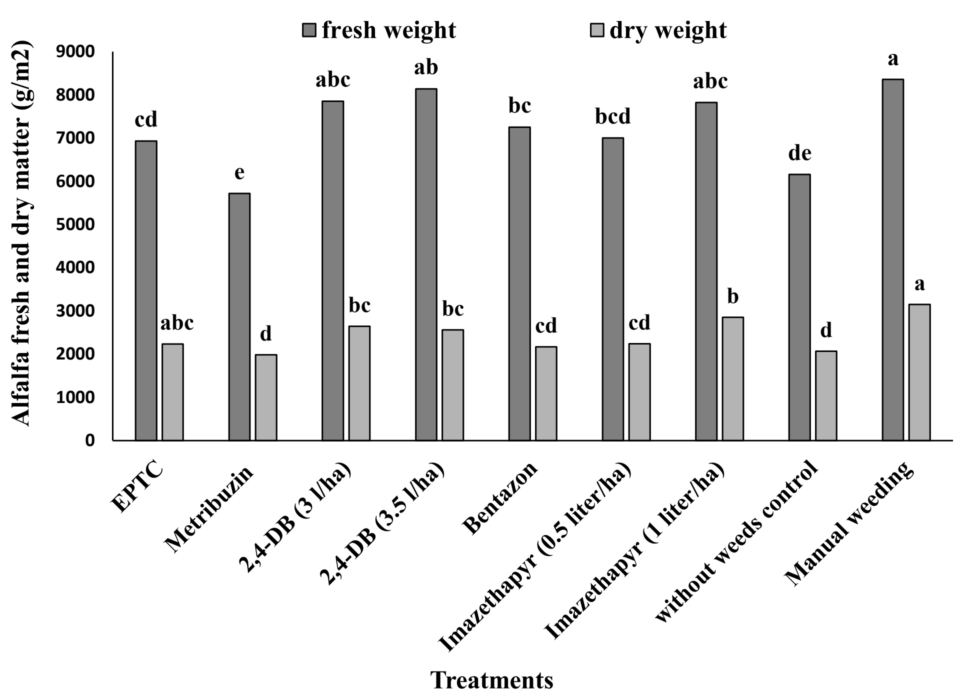

Figure 2. Effect of treatments on fresh and dry matter of newly cultivated alfalfa in the second cutting. Columns followed by same letter are not significantly different at LSD.

The results showed that the highest dry matter (3152 g/m^2) and the lowest one (2069 g/m^2) were obtained in the manual weeding and without weeds control treatments, respectively. Imazethapyr herbicide treatment (1 l/ha) had the highest dry matter (2851 g/m^2) after manual weeding treatment (Figure 2). The results of Wilson (1997) showed that the application of Metribuzin (1.1 kg/ha) resulted in no alfalfa phytotoxicity, but with increasing herbicide at a rate of 7.1 kg/ha, alfalfa burn increased and reduced the dry matter yield. The results of Pacanoski et al. (2017) showed that the percentage of dry matter reduction in the first cutting in 2009, 2008 and 2010 years was 49%, 51% and 53%, respectively, due to the competition between weeds and alfalfa. The presence of weeds confirms the importance of weed control in forage plants, especially alfalfa.

The trend of alfalfa growth (g/m2 d.m.) in the different treatments showed that the rate of growth was slow until two weeks after the first cutting (Figure 3).

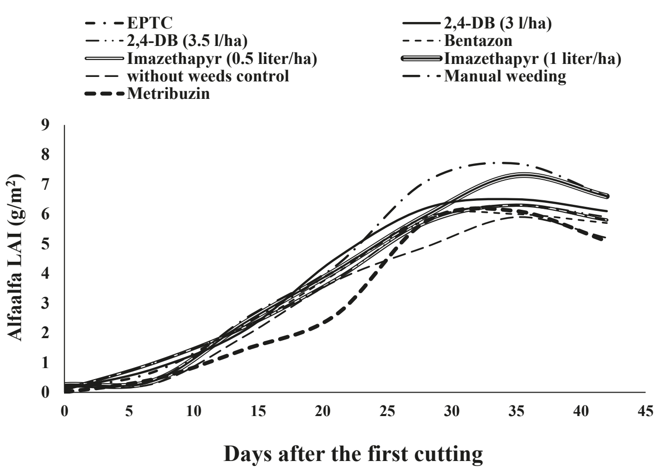

Figure 3. Effect of treatments on alfalfa dry matter trend of in the second cutting.

Dry matter increased rapidly and linearly until about 30 days after the first cutting. After that, dry matter growth slowly increased until the beginning of the second cutting, when it reached its maximum value. The results showed that the highest cumulative dry matter (3170 g/m^2) was obtained in manual weeding. After that, 2,4-DB (3.5 l/ha) and Imazethapyr (1 l/ha) with 2702 and 2784 g/m^2 had the highest cumulative dry matter, respectively. Among the treatments, the lowest cumulative dry matter (2137 g/m^2) was estimated in control, and then in Metribuzin treatment (2281 g/m^2). On the other hand, the 50% of the maximum cumulative dry matter was reached in manual weeding after 20.24 days from the first cutting. This time was 20.19 and 19.66 days for 2,4-DB (3.5 l/ha) and Imazethapyr (1 l/ha), respectively (Table 4).

The results showed that the maximum alfalfa cumulative dry matter had the highest value in Imazethapyr and 2,4-DB herbicides, and manual weeding treatments due to better weed control. Low alfalfa dry matter yield was obtained from weed control with Metribuzin treatment. The reason is related to the inhibitory effects of Metribuzin on newly planted alfalfa that lead to non-uniformity of emergence and density, with a consequent reduction of cumulative dry matter. It should be noted that the response of alfalfa cultivars to the Metribuzin herbicide may be different (Pacanoski et al., 2017).

Leaf area index (LAI)

Alfalfa LAI changes in different treatments had three main stages. The first stage, in which the changes were low and continued about a week after first cutting. The trend after this stage showed that the LAI increased linearly about 30 days after first cutting. As shown in Figure 4, the maximum LAI was obtained approximately 35 days after first cutting. After this stage, the downward slope showed that the LAI decreased due to senescence until the beginning of the second cutting (Figure 4).

Table 4. Estimation of Fitting Parameters of alfalfa cumulative dry matter in the second cutting.

Treatments	Upper limit±SE	Slope±SE	T_{50}±SE	R^2	RMSE
EPTC	2346.88±66.71	5.85±0.47	21.29±0.69	0.99	57.87
Metribuzin	2281.02±166.64	7.33±1.05	24.34±1.62	0.98	88.84
2,4-DB (3 l/ha)	2672.78±50.02	4.95±0.32	20.16±0.40	0.99	53.97
2,4-DB (3.5 l/ha)	2702.98±43.98	4.48±0.28	20.19±0.33	0.99	51.05
Bentazon	2340.64±56.91	5.48±0.43	19.96±0.53	0.99	56.92
Imazethapyr (0.5 l/ha)	2406.55±73.70	5.53±0.51	21.41±0.65	0.98	67.12
Imazethapyr (1 l/ha)	2784.65±50.81	4.84±0.32	19.66±0.39	0.98	57.25
Control with weeds	2137.21±56.59	5.60±0.43	22.01±0.55	0.97	49.07
Manual weeding	3170.26±58.06	5.43±0.32	20.24±0.40	0.99	57.68

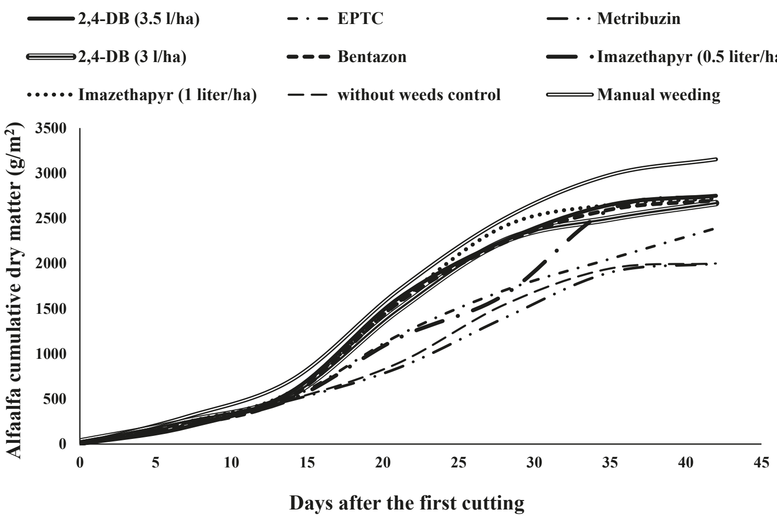

Figure 4. Effect of treatments on alfalfa LAI trend in the second cutting.

The results indicated that the highest LAI (7.74, 7.35 and 7.13 reached 33.90, 35.31 and 34.63 days after the first cutting) was obtained in manual weeding, Imazethapyr (1 l/ha) and 2,4-DB (3.5 l/ha) treatments, respectively. The lowest LAI equal to 5.09 was obtained in control treatment without weeds control (Figure 4). Lemaire et al. (2005) showed that there is a significant correlation between LAI and shoot nitrogen content.

Conclusion

The use of herbicides EPTC, Bentazone and Imaztapir (0.5 l/ha) had a weaker weed control while the Metribuzin and Imazethapyr had the best weed control. On the other hand, the results showed that although Metribuzin was successful in controlling weeds, but it led to alfalfa burning and non-uniform emergence, which led to a decrease in alfalfa forage yield. In general, according to the results, the use of Imazethapyr herbicide is more suitable than other herbicides.

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