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Evaluation of post-emergence herbicides to control weeds of newly planted sainfoin (*Onobrychis sativa*)

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Abstract

Sainfoin (*Onobrychis sativa)* is an important forage crop thanks to both high yield and proper compatibility to environmental stress such as drought and nutrient deficiency. Weed competition, especially in newly planted seedling of sainfoin, could cause great yield reduction in forage plant's quantity and quality. A field experiment was conducted during 2010 to 2011, to determine proper herbicide treatments for weed control in sainfoin. Seven weed-control treatments, along with weed infested (WI) and weed-free (WF) controls in three replications were arranged in a randomized complete block design. Weed control treatments included bentazone (1920g a.i.ha^{-1}), bentazone (1440g a.i.ha^{-1}), bentazone (1440g a.i.ha^{-1}) plus an adjuvant (tween 80), bentazone (1440g a.i.ha^{-1}) plus an adjuvant (ammonium sulphate), imazethapyr (100g a.i.ha^{-1}), imazethapyr (75g a.i.ha^{-1}), imazethayr (75g a.i.ha^{-1}) plus an adjuvant (ammonium sulphate). Results showed that bentazone and imazethapyr in high dosage as well as in low rates plus an adjuvant (tween 80 or ammonium sulphate) have a good efficiency in weed control. Bentazon herbicide is much more efficient compared to imazethapyr in weed control of sainfoin. Application of low dosage bentazon in combination with adjuvants was shown to be more effective in controling noxious weeds like purslane. However, due to sainfoin biomass loss after applying these treatments, imazethapyr (75g a.i.ha^{-1}) is introduced as the best treatment to control weed and improve yield in newly planted sainfoin.

Keywords: Sainfoin, weed control, forage yield, imazethapyr, bentazone.
Abbreviations: WF_Weeds free in all growing season, WI_Weeds infested in all growing season.

Introduction

Sainfoin (*Onobrychis sativa*) is a native Iranian forage legume receiving great deal of attention due to both its high yield and its adaption to wide varieties of environmental conditions. Sainfoin is serves as a forage crop in arid regions due to its deep roots, drought and pest resistance, and potential to prevent soil erosion (Majidi and Arzani, 2004). However, sainfoin often suffers from yield loss caused by weed competition especially during its early growing stages in the first year of planting. No serious weeds management program is designed for sainfoin production. Since most forage plants and especially sainfoin are planted in high density and close row spacing, mechanical and manual weed control in these crops may not be satisfying. Application of herbicides in legume forage including sainfoin production is found to be very suitable method for weed management (Keyan and Adak, 2006). While herbicides are used in new integrated weed management programs, to optimize herbicide dosages is stressed emphatically. (Duke et al., 2002; Dayan et al., 1999; Singh et al., 2005; Kim et al., 2006). Adjuvants can enhance herbicide effectiveness and decrease their application rate, in particulare to control broadleaf weeds (Kirkwood, 1993; Abouziena et al., 2009). Adjuvants are not pesticides, but they can increase herbicide efficiency. (Kirkwood, 1993; Bellinder et al., 2003; Abouziena et al., 2009). Application of bentazon at 50% and 75% label rates have been shown to provide effective control in some crops e.g. soybeans (zia Hoseini, 1999), mitigating costs and potential off-target effects (Aghajani, 1999). To the best of our knowledge, There is not any scientific research concerning weed control of in sainfoin. As a result of low sainfoin growth rate with weeds in early months after planting, the present research was aimed to find the best post emergence herbicide treatment to control weeds in sainfoin and 2- to reduce herbicide dosage using proper adjuvant.

Results

Weed species control

P. oleracea

At the first sampling, herbicides did not significantly influence *P. oleracea*'s height, although in the second sampling, it was affected by herbicides (Table 2 and Table 3). Herbicide treatments also lowerd biomass of *P. oleracea* in both sampling. The results of means sepration (Table 4) in the first sampling (15 days) demonstrate that the various combination of bentazon imposed great impact on the reduction weight of *P. oleracea* (from 91% to 96 %). Among all treatments, bentazon herbicide (1440g a.i.ha^{-1}) along with Tween 80 showed 96 % efficiency on reducing dry matter of *P. oleracea* compare to control treatment. The various imazethapyr treatments signifi-

Table 1. Herbicides and their dosages applied in 3-4 leaves of sainfoin to weeds control in sainfoin production.

Treatments
Bentazon (1440 g a.i.ha^{-1})
Bentazon (1920 g a.i.ha^{-1})
Bentazon (1440 g a.i.ha^{-1}) in mixture with tween 80 at level of 0.25%
Bentazon (1440 g a.i.ha^{-1}) in mixture with ammonium sulfate at level of 2%
Imazethapyr (75 g a.i.ha^{-1})
Imazethapyr (100 g a.i.ha^{-1})
Imazethapyr (75 g a.i.ha^{-1})in mixture with ammonium sulfate at level of 2%
Weeds free in all growing season (WF)
Weeds infested in all growing season (WI)

cantly differed in weedy controls; however, their effect was 24% to 65% less than bentazon treatments. In the second sampling, one month after herbicide application, bentazon was introduced the most effective herbicide to control of *P. oleracea*. The bentazon 1920g a.i.ha^{-1} and bentazon 1440 g a.i.ha^{-1} along with amonium sulfate compare to weed infested treatment had 98% and 99% of *P. oleracea* control respectively. Imazethapyr affected it trivially, however the highest rate was recorded to imazethapyr 75g a.i.ha^{-1} along with ammonium sulfate (60.9) and also there was a significant vary between it and weedy control treatment (Table 5). Imazethapyr 100g a.i.ha^{-1} caused the least reduction of *P. oleracea* height and imazethapyr 75g a.i.ha^{-1} along with ammonium sulfate led to the least percentage of *P. oleracea* control in first and second samplings respectively. Given to literatures, *P. oleracea* is more tolerance to ALS inhibitor herbicides such as imazethapyr, but herbicides inhibiting photosynthesis as bentazon are found to be more effeicient in controling these weeds. Previous researches have confirmed that *P. oleracea* is resistant to some chemical herbicides like 2,4-D (Zhang et al., 1997). Moreover, finding of the present research are in line with previous result repoting positive effects of adjuvants on improving the efficiency of bentazon . The mixture of adjuvants with bentazon improved control efficiency of *Xanthium strumarium* and *Solanum nigrum* weeds (Abouziena et al., 2009). Application of adjuvants accompany with herbicide allows to improveing weeds control to much extent. In this approach the minimal dosage of herbicide varies according to type of assisting ingredient, type of weeds and the stage of weed growth (Bellinder et al., 2003).

A. retroflexus

Both bentazon and imazethapyr reduced the height and dry matter of *A. retrof*lexus in first and second sampling (Table 2 and Table 3). Given to results of first step (15 days after spraying herbicides), weed free treatment, bentazon at 1440g a.i.ha^{-1} rate, imazethapyr at 75g a.i.ha^{-1} rate along with ammonium sulfate imposed the highest influence on reduced height of *A. retrofexus* compare to weed infested treatment (Table 4). Bentazon at 1920g a.i.ha^{-1} rate effectively eliminated *A. retroflexus*, so that bentazon at 1920 g a.i.ha^{-1} rate caused 81% control of *A. retroflexus* compared to weed infested treatment (Table 4).

In the second sampling (30 days after herbicide spraying), imazethapyr at 75g a.i.ha^{-1} rate in combination with ammonium sulfate and weed free treatment caused the highest efficiency in reducing *A. retroflexus* height. Although, bentazon at 1920g a.i.ha^{-1} rate and bentazon at 1440g a.i.ha^{-1} rate along with imazethapyr in mixture with ammonium sulphate efficiently reduced height and growth of *A. retroflexus* (Table 5). *A. retroflrxus* dry matter was significantly reduced when Imazethapyr at 100g a.i.ha-1 rate was applied in a way that this treatment could stint *A. retroflexus* growth to 86% in comparison to weed infested treatment and could be fall into same level as weed infested treatment.Least control of *A. retroflexus* was attribute to bentazon 1440g a.i.ha^{-1} without any mixture about 39% and bentazon 1440g a.i.ha^{-1} in combination with tween 80 about 43%, showing negligible difference to those in weed infested treatment. These results imply to effectiveness of an adjuvant, such as tween 80, when it is mixed to bentazon (Abouziena et al., 2009). *A. retroflexus* as one of annual weed compete to crop on water and nutrient and especially light (Rafael et al., 2001). Santos (1997) pointed out that this plant overcomes medium height plants through rising its height to absorbing light, resulting in low dry matter in neighboring plants. In this research it was found that most of treatment caused substantial low height of *A. retroflexus* and subsequently low interference with sainfoin.

C. arvensis

The effect of herbicides on *C. arvensis*'s height and dry matter was shown to be significant at 15 days after herbicide treatment (Table 2) but in the second sampling there was no significant difference (Table 3). According to mean sepration of traits (Table 4), in the first step of sampling, bentazon at 1920 and 1440g a.i.ha^{-1} along with ammonium sulfate and imazethapyr 75g a.i.ha^{-1} alone and also in combination with ammonium sulfate controled *C. arvensis* efficiently. Different treatment of bentazon and imazethapyr at 75g a.i.ha^{-1} rate, alone or in combination with ammonium sulfate, showed satisfying weed control (it about 66 to 97 percent). Getting through Table 5, it is clear that in the second sampling (30 days after application of treatments) different herbicides did not varied significantly in term of height and percentage of control of *C. arvensis*. As it can be seen, both of these herbicides could not control perennial weeds such as *C. arvensis*. This species has an extended root system. However, most of foliar and soil applied herbicides cannot control it.

Table 2. Analysis of variance (Mean squares) of herbicide treatments effects on reduction of dry weight and height of weeds in 15 days after treatments applied.

C. arvensis		*A. retroflexus*		*P. oleracea*		Others weeds	Total weeds
Dry weight loss	Height (cm)	Dry weight loss	Height (cm)	Dry weight loss	Height (cm)	Dry weight loss	Dry weight loss
4037.84**	695.66**	3836.13**	120.35**	4240.93**	110.64^{ns}	3969.61**	388.9

NS,*, ** indicate significance at 5% and 1% level, respectively

Table 3. Analysis of variance (Mean squares) of herbicide treatments effects on reduction of dry weight, height of weeds and crop biomass in 30 days after treatments applied.

C. arvensis		*A. retroflexus*		*P. oleracea*		Others weeds	Total weeds	Crop
Dry weight loss	Height	Dry weight loss	Height (cm)	Dry weight loss	Height (cm)	Dry weight loss	Dry weight loss	Biomass
2848.4^{ns}	554.5^{ns}	2718.7*	393.65**	3922.86**	144.51*	3126.9**	58.09**	42427.30*

NS,*, ** indicate significance at 5% and 1% level, respectively

Only phloem mobile herbicides such as glyphosate effectively controlled this weed (Jensen et al., 1999).

Other types of weeds

As it can be seen in Tables 2 and 3, among different treatments to reduce weeds dry matter, both sampling dates varied significantly. Bentazon and imazethapyr treatments reduced other weeds weight from 73 to 100 % compared to weed infested treatment (Table 4). Imazethapyr (100g a.i.ha^{-1}) and bentazon (1920g a.i.ha^{-1}) and bentazon (1440g a.i.ha^{-1}) along with tween 80, bentazon (1440g a.i.ha^{-1}) along with ammonium sulfate encounter 100 % reduction in weeds biomass compared to weedy treatment. In 30 days after herbicide spraying, the efficiency of the most of treatment to control other types of weeds was satisfying, and only imazethapyr treatment (75g a.i.ha^{-1}) in combination with ammonium sulfate was shown to be inefficient than weed free.

Crop biomass

The result of analysis of variance (Table3) showed that herbicide treatment had a significant impact on sainfoin dry matter in the first harvest. Figure 1 shows that the biomass of sainfoin in weed free treatment was recorded the highest among other treatment. Also it has demonstrated that hand weeding from planting to first harvesting caused 10% increase in sainfoin dry matter accumulation when compared to weed treatment. imazethapyr (75g a.i.ha^{-1}) alone or in combination with ammonium sulfate and also imazethapyr (100g a.i.ha^{-1}) had the highest efficiency among other herbicide treatment. Bentazon treatment showed lower efficiency in increasing of crop biomass in comparison with imazethapyr treatments. This result suggested that although bentazon herbicide efficiency controls some weeds like purslane and pigweed (Table 4 and 5), finally it couldn't increase sainfoin forage crops as much as imazethapyr. Although we didn't observe any phytotoxicity symptoms on sainfoin after application of bentazon, probably bentazon had a trivial negative effect on growth suppression of sainfoin. As a result sainfoin has to spend more energy to regrowth and finally cannot reach to its maximum potential growth.

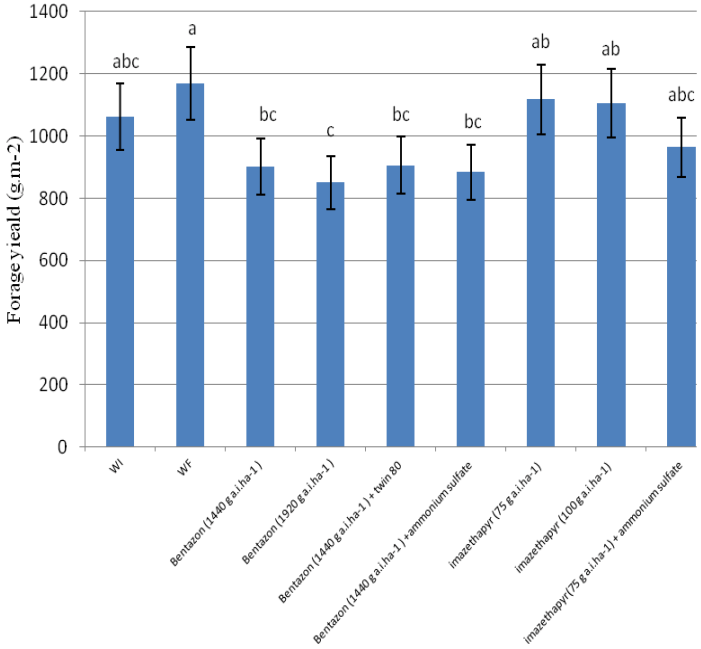

Fig 1. Effect of different treatments of herbicides on forage yield of newly planted sainfoin. For more information about treatments refer to Table 1.

Materials and Methods

Site description

Field experiment was carried out during 2010 to 2011 at the research farm of agriculture collage of Isfahan University of Technology, Isfahan, Iran. The farm is located in the Lavark region of Najaf Abad County at latitude 32° 32´ North and longitude 52 ° 22´ East and an elevation of 1630m above sea level. This area has a dry climate with a mild winter and a hot, dry summer (Khajehpour, 2004). Average rainfall and annual temperature were 150.9 mm and 15.2 centigrade degree, respectively. The soil texture was clay-loam with bulk density 1.4 g.cm^{-1} and pH of 7.59.

Table 4. Effects of different treatments on height and biomass reduction of weeds in 15 days after herbicides application.

Treatment	Purslane height (cm)	Purslane biomass loss (%)	Amarant height (cm)	Amarant biomass loss (%)	Morninglory height (cm)	Morninglory biomass loss (%)	Biomass loss of other weeds (%)
Bentazon (1440 g a.i.ha^{-1})	11.33 ^{a}	91.12 ^{a}	10.24 ^{b}	58.99^{ab}	4.58^{c}	97.38 ^{a}	73.86 ^{a}
Bentazon (1920 g a.i.ha^{-1})	13.83 ^{a}	91.04 ^{a}	13.44 ^{ab}	81.77 ^{ab}	18.44 ^{bc}	89.91 ^{a}	100^{a}
Bentazon (1440 g a.i.ha^{-1}) & towin 80	5.53 ^{a}	96.32 ^{a}	18.72 ^{ab}	0.92 ^{c}	34.52 ^{ab}	62.66 ^{a}	100^{a}
Bentazon (1440 g a.i.ha^{-1}) & Sulphate amunium	5.41 ^{a}	94.52 ^{a}	16.66 ^{ab}	32.80^{bc}	6.33 ^{c}	98.50 ^{a}	100^{a}
Imazethapyr (75 g a.i.ha^{-1})	16.60 ^{a}	65.12 ^{b}	12.44 ^{ab}	76.73 ^{ab}	8.14 ^{c}	66.67 ^{a}	86.75 ^{a}
Imazethapyr (100 g a.i.ha^{-1})	18.52 ^{a}	31.09^{c}	15.30 ^{ab}	75.37 ^{ab}	34.80 ^{ab}	19.08^{b}	100^{a}
Imazethapyr (75 g a.i.ha^{-1}) & Sulphate amunium	15.73 ^{a}	24.83^{c}	10.47^{b}	66.98^{ab}	9 ^{c}	88.89 ^{a}	100^{a}
Weed infested	21.35a	0d	22.31a	0c	40.02a	0b	0b
Weed free	5.33a	98.37a	5.66 c	100a	9c	100a	100a

Mean within columns or rows with the same letters are not significantly different at 5% level.

Table 5. Effects of different treatments on height and biomass reduction of weeds in 30 days after herbicide application.

Treatment	Purslane height (cm)	Purslane biomass loss (%)	Amarant height (cm)	Amarant biomass loss (%)	Morninglory height (cm)	Morninglory biomass loss (%)	Biomass loss of other weeds (%)
Bentazon (1440 g a.i.ha^{-1})	17.33^{abc}	98.04 ^{a}	38.81 ^{ab}	39.71 ^{bc}	20 ^{a}	89.1 ^{a}	78.06 ^{a}
Bentazon (1920 g a.i.ha^{-1})	5.66 ^{c}	98.71 ^{a}	24.62 ^{bc}	66.10 ^{ab}	23.53 ^{a}	65.91 ^{a}	71.76 ^{a}
Bentazon (1440 g a.i.ha^{-1}) & towin 80	11.41^{abc}	97.58 ^{a}	22.35 ^{bc}	43.70 ^{abc}	26.93 ^{a}	33.33 ^{a}	100^{a}
Bentazon (1440 g a.i.ha^{-1}) & sulphate amunium	5.33 ^{c}	99.07 ^{a}	24.61 ^{bc}	60.50 ^{ab}	9.03 ^{a}	81.79 ^{a}	100^{a}
Imazethapyr (75 g a.i.ha^{-1})	19.42 ^{ab}	53.40 ^{abc}	14.24 ^{c}	84.49 ^{ab}	22.39 ^{a}	70.76 ^{a}	93.33 ^{a}
Imazethapyr (100 g a.i.ha^{-1})	20.86 ^{a}	24.35 ^{bc}	14.50 ^{c}	86.66 ^{ab}	21.98 ^{a}	66.72 ^{a}	100 ^{a}
Imazethapyr (75 g a.i.ha^{-1}) & sulphate amunium	17.27^{abc}	60.91 ^{ab}	11.40 ^{c}	82.51 ^{ab}	0 ^{a}	100 ^{a}	55.05 ^{b}
Weed infested	23.68^{a}	0^{c}	42.56 ^{a}	0 ^{c}	47.91 ^{a}	0^{a}	0^{b}
Weed free	7.46^{bc}	66.67^{ab}	11.66 ^{c}	93.95 ^{a}	9.53 ^{a}	46.27 ^{a}	100^{a}

Experimental design and herbicide treatments

Treatments were assigned randomly to blocks in field in 3 replications. Treatments included seven herbicide treatment of weed control (using bentazon and imazethapyr alone or plus adjuvant, see table 1 for rates and application details), and two check treatments (weed free or weed infested). Seedbed preparation includes deep plowing with a moldboard plough, followed by twice vertically disking. The crop was planted on September 1 in 2010 at density 80 plants per meter square with 50cm row spacing. Each plot included four rows 5 m long. The furrow irrigation method was applied weekly until the sainfoins' plant's physiological maturity. An electrical back sprayer (MATABI) fitted with flat fan nozzles (Goizper S Cooperative Company, Guipuzcoa, Spain) operated at a pressure of 240 kPa delivering a volume rate of 250 L ha^{-1} was used. Herbicide treatments were conducted in 3-4 leaf stage of sainfoin. In weed free check treatment hand weeding was carried out weekly all over the growing season. Weeds infested were occurring naturally in the experimental plots. To determine weed control treatments efficiency, Weeds sampling were done using a 0.5x0.5 m^2 quadrate. The numbers of weeds in one day before herbicides treatments and also in 15 and then 30 days after that were recorded. The samples were transferred to the laboratory and after measuring their height, they were dried at 75 degree for 48 h.

Weed flora

The weed species observed in experimental plots included *Amaranthus retroflexus*, *Portulaca oleracea*, *Convolvulus arvensis*, *Sorghum halepens*, *Echinochloa crus-gali*, *Sonchus oleraceus.* The first three species were dominant weed species in all experimental plots.

Statistical analysis

Weed control efficiency (WCE) was calculated using this equation:

$$WCE = \frac{\text{Weight or density of weeds in untreated plots} - \text{Weight or density of weeds in treated plots}}{\text{Weight or density of weeds in untreated plots}}$$

Analysis of variance was done by SAS (statistical Analysis software). The means sepration was done using LSD tests.

Conclusion

As a whole, bentazon herbici**d**e in combination with adjuvants efficiency controlled sainfoin weeds compare to imazethapyr. Application of bentazon in low dosage in combination with adjuvants found to be more effective in controling noxious weeds like purslane. However, due to sainfoin biomass loss after applying these treatments, Imaztapier (75g a.i.ha^{-1}) in known as the best treatment to control weeds and subsequently to improved yield in sainfoin..

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