

# Herbicidal efficacy and selectivity of imazethapyr for weed control in alfalfa (*Medicago sativa* L.) in Sudan

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## **Abstract:**

*Alfalfa, or lucerne (Medicago sativa L.), is a perennial and an important leguminous forage crop worldwide. A field trial was conducted at Shambat Research Station Farm, Khartoum, Sudan, during the 2014/2015 and 2015/2016 winter seasons to evaluate the activity and selectivity of the herbicide (imazethapyr) for weed control in alfalfa. The herbicide imazethapyr at 57.1, 76.2, 95.2, and 114.3 g a.i./ha was applied at sowing and 3 weeks later. The most prevailing weed species were Brachiaria eruciformis (Sm) Grieseb, Cyperus rotundus L., Ipomoea sp., and Tribulus terrestris. The herbicide imazethapyr, at all rates, irrespective of application time, gave good to excellent control (78–98%) of broad-leaved weeds. However, its activity against grasses was poor. All herbicide treatments significantly reduced weed biomass in comparison to the untreated control. All herbicide treatments were selective to the crop. Competing weeds reduced total dry matter yield by 36% in both seasons. Imazethapyr at all rates, irrespective of application time, resulted in total dry matter yield comparable to that of the weeded control.*

**Keywords:** alfalfa lucerne, weed control, imazethapyr

## **1. Introduction**

Alfalfa (*Medicago sativa* L.), also known as lucerne, is recognized as one of the most valuable leguminous forage crops worldwide. It provides highly nutritious feed for livestock due to its rich composition of proteins, minerals, vitamins, and fiber (Reddy *et al.*, 2014; Richter *et al.*, 2017). The increasing global demand for livestock products has led to a parallel rise in the need for high-quality fodder crops. Consequently, the cultivated area of alfalfa in Sudan has been expanding steadily, especially in the central and northern regions where production potential is highest. The crop is commonly grown under both traditional and modern farming systems.

A wide range of weed species—annual and perennial, grasses and broad-leaved, as well as parasitic plants—infest alfalfa fields, competing directly with the crop for light, nutrients, water, and space (Mesbah and Miller, 2005; Yang *et al.*, 2018). Without effective control, weeds can cause significant reductions in yield and forage quality (Green and Legleiter, 2018). Traditionally, hand weeding has been the main weed management practice in Sudan, but this approach, while reliable, is labor-intensive, slow, and costly.

Previous studies have shown that several herbicides can be applied effectively and safely for weed management in alfalfa (Cudney and Adams, 1993; McCordick *et al.*, 2008; Wilson and Burgener, 2009; Idris *et al.*, 2015). However, limited research has been conducted on chemical weed control in Sudanese alfalfa production systems. Therefore, this study aimed to evaluate the efficacy and selectivity of the herbicide (imazethapyr) for controlling weeds in alfalfa.



## 2. Related Work

Several studies have investigated the effectiveness of different weed management strategies in alfalfa (*Medicago sativa L.*) across diverse environmental and agronomic conditions. Beck *et al.* (2020) examined the efficacy of various herbicides for the control of *Perennial Plantago* species and evaluated their effects on alfalfa yield and injury. Their findings indicated that herbicide selectivity plays a crucial role in maintaining crop safety while ensuring effective weed suppression. Cudney and Adams (1993) similarly found that using 2,4-DB amine greatly improved weed control in seedling alfalfa without causing serious damage to the crop, which helped the crop establish itself more quickly.

Green and Legleiter (2018) wrote a full extension guide that stressed the importance of using a mix of chemical, mechanical, and cultural methods to control weeds. They stressed the need for pre- and post-emergence herbicides and proper crop rotation to keep both annual and perennial weeds under control in a way that lasts.

Technological advances have also contributed to modern weed management in alfalfa. Yang *et al.* (2022) demonstrated that conventional neural networks (CNNs) can effectively detect weeds growing in alfalfa fields, opening new opportunities for precision and site-specific weed control through artificial intelligence.

In Sudan, Idris *et al.* (2021) conducted a comparative analysis of Fusilade Forte (fluazifop-p-butyl), Agroharm (haloxyfop-p-methyl), and Oraselect (clethodim) for post-emergence weed management, affirming that clethodim formulations achieved enhanced control and crop safety under the unique conditions of Sudan.

McCordick, *et al.* (2008) investigated establishment systems for glyphosate-resistant alfalfa and discovered that the adoption of herbicide-tolerant varieties facilitated flexible weed management and improved stand establishment. In a similar vein, Wilson and Burgener (2009) compared glyphosate-tolerant and conventional alfalfa systems, concluding that transgenic alfalfa confers superior weed control efficiency, reduced production costs, and increased yields during the establishment phase.

Mesbah and Miller (2005) examined the management of Canada thistle (*Cirsium arvense*) in established alfalfa seed production fields. Their findings indicated that the application of selective herbicides at the appropriate growth stage significantly diminished thistle infestation without compromising alfalfa seed yield. Furthermore, Pacanoski *et al.* (2017) reported that metribuzin, imazethapyr, and pronamide delivered effective control when administered to dormant alfalfa, ensuring both broad-spectrum weed suppression and high crop tolerance.

Reddy *et al.* (2014) highlighted the significance of biofertilizers and biofungicides in sustainable agriculture, positing that their integration with chemical weed control could enhance soil health and mitigate environmental risks.

The use of these herbicides — clethodim, imazethapyr, fluazifop, and glyphosate — has been proven to work very well for weed control in many different areas or environments around the world.

## 3. Methodology

A field trial was conducted during the 2014/2015 and 2015/2016 winter seasons at Shambat Research Station Farm (Latitude 15° 39' N and Longitude 32° 31' E). The soil composition was characterized as a heavy clay type with a pH of 8.5. The experiment site was disc ploughed, harrowed, and ridged and then divided into plots of 9.6 m<sup>2</sup> each. Alfalfa (cv. Higazi) was sown on both sides of the ridge at a seed rate of 23.8 kg/ha. The sowing date was the last and second week of November in the first and second seasons, respectively. Irrigation was administered at intervals of 7 to 10 days. The herbicide imazethapyr 10% SL at 57.1, 76.2, 95.2, and 114.3 g a.i./ha was applied at sowing and 3 weeks later. Herbicide treatments were sprayed by a knapsack sprayer at a volume rate of 285.7 l/ha. Weeded and unweeded control treatments were included for comparison. In the weeded plots, weeds were

hand-removed at 15, 30, and 45 days after sowing, whereas the unweeded treatment was kept weedy for the whole growing season. Treatments were arranged in a randomized complete block design with three replications. Visual observations of the phytotoxicity of herbicide treatments on the crop were made periodically.

**Data Collection:**

**Weeds:**

The effects of herbicide treatments on weeds were assessed by counting total and individual weed species at 4 and 8 weeks after herbicide application. This was done by placing a 1 x 1 m quadrat in each plot at random. Weeds inside each quadrat were identified, and total and individual weed species were calculated. Percentage control of grassy and broad-leaved weeds was calculated relative to the unweeded treatment. Weeds in a 1 - m<sup>2</sup> area from each plot were cut 75 days after sowing, air-dried, and weighed.

Weed control was calculated as percentage according to the following equation:

$$Control \% = \frac{Number\ of\ weeds\ in\ untreated\ plot - number\ of\ weeds\ in\ treated\ plot}{Number\ of\ weeds\ in\ untreated\ plot} \times 100$$

**Crop:**

Alfalfa was initially harvested at first bloom, in the second week and the first week of February in the first and the second seasons, respectively; the following second and third harvests were at 25-day intervals from the initial cutting. The whole plot was harvested to record the fresh weight of alfalfa. Forage samples of 0.5 kg from each plot were dried and weighed to determine the dry alfalfa yield. Data collected were subjected to the analysis of variance, and means were separated for significance using Duncan’s Multiple Range Test (DMRT) at 0.05 using M-Stat Software Program.

**4. Result Discussion**

**Effect on weeds:**

In both seasons, the most dominant weed species were *Brachiaria eruciformis*, *Cyperus rotundus*, *Echinochloa colona*, *Ipomoea spp.*, and *Tribulus terrestris*. During the first season, the total weed count in the unweeded control reached 305 and 187 plants m<sup>2</sup> at 4 and 8 weeks post-herbicide application, respectively. Of the total weed species, 32-72% comprised grassy weeds, while the remainder consisted of broad-leaved varieties. imazethapyr, applied at all rates regardless of timing, demonstrated remarkable efficacy, achieving an impressive control rate of 80-98% against broad-leaved weeds. Conversely, the same herbicide exhibited limited effectiveness against grassy weeds (Table 1).

**Table 1:** Effects of herbicide imazethapyr treatments on weed control (Season, 2014/2015)

Treatments	Herbicide rate (g a.i./ha)	(% ) Weed control			
		Grasses		Broadleaved	
		4WAA	8WAA	4WAA	8WAA
Imazethapyr*	57.1	56	53	85	80
Imazethapyr*	76.2	50	45	91	92
Imazethapyr*	95.2	53	25	98	83
Imazethapyr*	114.3	50	56	90	80
Imazethapyr**	57.1	35	32	83	80
Imazethapyr**	76.2	38	37	93	89

Imazethapyr**	95.2	37	0	86	80
Imazethapyr**	114.3	38	13	89	85
Weeded control	-	100	100	100	100
Unweeded control	-	0	0	0	0

WAA = weeks after application of herbicide.

\*and \*\* = applied at sowing and 21 days after sowing, respectively.

In the second season, the total number of weeds in the unweeded control was recorded at 202 and 146 plants m<sup>2</sup> at 4 and 8 weeks after herbicide application, respectively. Within this total, 46-76% were grasses, with the remainder being broad-leaved species. Imazethapyr, at all application rates, provided good to excellent control (78-92%) of broad-leaved weeds, this finding is consistent with the observations made by Pacanoski and Vereš (2017), who reported that the efficacy of herbicides in controlling weeds ranged from 91.8% for pronamide to 98.4% for metribuzin at a dosage of 1.0 kg\*ha<sup>-1</sup> in 2008, with efficacy values spanning from 93.1% for imazetapyr to 97.3%., yet similarly displayed inadequate activity against grassy weeds (Table 2). All herbicide treatments significantly diminished weed biomass in comparison to the untreated control (Table 2).

**Table 2:** Effects of herbicide imazethapyr treatments on weed control and weed biomass (Season, 2015/2016)

Treatments	Herbicide rate (g a.i./ha)	% Control 4WAA	Grass % Control 8WAA	Grass % Control 4WAA	Broadleaf % Control 8WAA	Weed biomass (g/m <sup>2</sup> )
Imazethapyr*	57.1	52	14	82	78	40.97 a
Imazethapyr*	76.2	32	41	92	80	53.03 a
Imazethapyr*	95.2	53	49	85	81	40.10 a
Imazethapyr*	114.3	52	14	87	84	36.60 a
Imazethapyr**	57.1	37	37	80	84	55.50 a
Imazethapyr**	76.2	0	0	81	80	44.47 a
Imazethapyr**	95.2	35	35	79	87	44.83 a
Imazethapyr**	114.3	38	38	80	90	32.30 a
Weeded control	-	100	100	100	100	29.30 a
Unweeded control	-	0	0	0	0	133.73 b
+SE						28.159
%CV						39.68

\*and \*\* = applied at sowing and 21 days after sowing, respectively.

Values followed by the same letter (s) are not significantly different according to DMRT.

**Effect on crop:**

In both seasons, all herbicide treatments showed no visual injury symptoms on the crop. The treated plants had vigorous growth, indicating that the herbicide treatments were selective for alfalfa. Uncontrolled weed

proliferation diminished the total fresh weight yield of alfalfa by 39% and 36% in the first and second seasons, respectively, relative to the weeded control (Tables 3 and 4).

**Table 3:** Effects of herbicide imazethapyr treatments on fresh weight yield of alfalfa (Season, 2014/2015).

Treatments	Herbicide rate (g a.i./ha)	Fresh weight yield (ton/fed)			Total fresh yield (ton/ha)
		1st cut	2nd cut	3rd cut	
Imazethapyr*	57.1	16.3 a	15.1 a	14.2 ab	45.6 a
Imazethapyr*	76.2	16.6 a	16.8 a	15.8 a	49.0 a
Imazethapyr*	95.2	15.6a	15.6 a	5.8 ab	45.6 a
Imazethapyr*	114.3	14.9 a	14.2 ab	13.9 ab	43.0 a
Imazethapyr**	57.1	15.4 a	12.2 ab	14.2 ab	42.0 a
Imazethapyr**	76.2	13.7 a	13.2 ab	13.7 ab	40.6 a
Imazethapyr**	95.2	15.6 a	15.4 a	14.9 a	45.9 a
Imazethapyr**	114.3	15.1 a	13.7 ab	13.7 ab	42.7 a
Weeded control	-	16.3 a	14.6 ab	13.9 ab	44.9 a
Unweeded control	-	8.6 b	9.6 b	9.6 b	27.6 b
<b>SE<sub>±</sub></b>		<b>1.464</b>	<b>1.560</b>	<b>1.450</b>	<b>4.154</b>
<b>CV%</b>		<b>16.8</b>	<b>19.0</b>	<b>18.2</b>	<b>16.75</b>

\*and \*\* = applied at sowing and 21 days after sowing, respectively.

Values followed by the same letter (s) are not significantly different according to DMRT.

**Table 4:** Effects of herbicide imazethapyr treatments on fresh weight yield of alfalfa (Season, 2015/2016).

Treatments	Herbicide rate (g a.i./ha)	Fresh weight yield (ton/ha)			Total fresh yield (ton/ha)
		1st cut	2nd cut	3rd cut	
Imazethapyr*	57.1	11.3 ab	14.6 a	15.4 d	41.0 ab
Imazethapyr*	76.2	13.4 ab	14.9 a	15.1 cd	43.4 ab
Imazethapyr*	95.2	13.0 ab	16.8 a	16.1 bcd	45.8 a
Imazethapyr*	114.3	14.9 ab	19.4 a	17.5 abc	51.8 a
Imazethapyr**	57.1	12.5 ab	15.6 a	15.1 cd	43.2 ab
Imazethapyr**	76.2	12.7 ab	16.3 a	15.8 bcd	44.9 a
Imazethapyr**	95.2	13.4 ab	18.5 a	15.6 abc	47.5 a
Imazethapyr**	114.3	13.9 ab	18.2 a	18.0 ab	49.7 a
Weeded control	-	14.9 ab	17.5 a	16.8 ab	49.2 a
Unweeded control	-	4.3 b	11.5 a	15.4 e	31.4 b
<b>SE<sub>±</sub></b>		<b>1.922</b>	<b>1.174 Ns</b>	<b>1.514</b>	<b>4.078</b>

CV% 26.94 12.22 16.18 15.62

\*and \*\* = applied at sowing and 21 days after sowing, respectively. Ns = non significant differences. Values followed by the same letter (s) are not significantly different according to DMRT.

Competing weeds reduced total dry matter yield by 36% in both seasons (Tables 5 and 6). In season 2014/2015, all herbicide treatments tested significantly increased total alfalfa dry and fresh weight yields, compared to the unweeded control (Tables 3 and 5). In both seasons, the herbicide imazethapyr at all rates, irrespective of application time, resulted in total dry matter yield comparable to that of the weeded control (Tables 5 and 6). It is evident from the results that most of the herbicide treatments used significantly increased total alfalfa dry and fresh weight yields, compared to the untreated control. These results have shown that early control of weeds by herbicides enables the crop to maximize the use of the available resources.

**Table 5:** Effects of herbicide imazethapyr treatments on dry matter yield of alfalfa (Season, 2014/2015).

Treatments	Herbicide rate (g a.i./ha)	Dry matter yield (ton/ha)			Total Dry matter (ton/ha)
		1st cut	2nd cut	3rd cut	
Imazethapyr*	57.1	4.1 a	4.7 a	3.6 a	11.8 a
Imazethapyr*	76.2	3.8 a	3.8 ab	3.8 a	11.5 a
Imazethapyr*	95.2	3.6 a	3.8 ab	3.1 ab	10.6 a
Imazethapyr*	114.3	1.4 a	1.3 ab	1.4 ab	10.1 a
Imazethapyr**	57.1	3.8 a	2.9 ab	3.8 a	10.8 a
Imazethapyr**	76.2	3.4 a	3.1 ab	3.6 a	10.1 a
Imazethapyr**	95.2	3.6 a	3.6 ab	3.8 a	11.0 a
Imazethapyr**	114.3	3.6 a	3.4 ab	3.6 a	10.3 a
Weeded control	-	3.6 a	3.4 ab	3.6 a	13.0 a
Unweeded control	-	1.9 b	2.4 b	2.5 b	7.0 b
<b>SE±</b>		<b>0.340</b>	<b>0.434</b>	<b>0.290</b>	<b>0.838</b>
<b>CV%</b>		<b>16.7</b>	<b>22.1</b>	<b>14.28</b>	<b>13.8</b>

\*and \*\* = applied at sowing and 21 days after sowing, respectively. Values followed by the same letter (s) are not significantly different according to DMRT.

**Table 6:** Effects of herbicide imazethapyr treatments on dry matter yield of alfalfa (Season, 2015/2016).

Treatments	Herbicide rate (g a.I./ha)	Dry matter yield (ton/fed)			Total Dry matter (ton/ha)
		1st cut	2nd cut	3rd cut	
Imazethapyr*	57.1	3.1 a	3.1 bcd	3.6 a	9.8 ab
Imazethapyr*	76.2	3.6 a	3.1 bcd	3.6 a	10.3 a
Imazethapyr*	95.2	3.6 a	3.6 abc	3.8a	10.8 a
Imazethapyr*	114.3	3.8 a	3.6 abc	4.3 a	11.8 a
Imazethapyr**	57.1	3.6 a	2.9 cd	3.6 a	10.1 a

Imazethapyr**	76.2	3.6 a	3.1 bcd	3.8 a	10.6 a
Imazethapyr**	95.2	3.6 a	3.8 ab	3.8 a	11.3 a
Imazethapyr**	114.3	3.8 a	3.8 ab	4.3 a	11.8 a
Weeded control	-	3.8 a	3.6 abc	3.8 a	11.3 a
Unweeded control	-	1.2 b	2.4 d	3.6 a	7.2 b
<b>SE<sub>t</sub></b>		<b>0.504</b>	<b>0.233</b>	<b>0.403 Ns</b>	<b>0.910</b>
<b>CV%</b>		<b>26.14</b>	<b>12.34</b>	<b>18.15</b>	<b>15.06</b>

\*and \*\* = applied at sowing and 21 days after sowing, respectively. Ns = non significant Values followed by the same letter (s) are not significantly different according to DMRT.

The significant reduction in both fresh and dry matter yields of alfalfa under unweeded conditions emphasizes the strong competitive ability of the associated weed flora for essential resources such as light, nutrients, and moisture. Conversely, herbicide treatments enhanced crop performance by minimizing early weed competition, allowing alfalfa plants to achieve better growth and higher biomass accumulation.

The absence of visible injury symptoms on alfalfa plants confirms that imazethapyr is selective and safe for use in alfalfa fields. These findings are consistent with previous studies reporting that early-season weed control is crucial for maximizing yield potential in forage legumes (Cudney and Adams, 1993; Mc Cordick *et al.*, 2008; Wilson and Burgener, 2009; Idris *et al.*, 2015). Therefore, the use of imazethapyr, particularly in integrated weed management programs, can be a valuable component for sustainable alfalfa production in regions where broad-leaved weeds dominate.

## 5. Conclusion

Imazethapyr proved to be effective and selective for weed control in alfalfa under Shambat condition Sudan. All application rates (57.1–114.3 g a.i./ha) provided good to excellent control of broad-leaved weeds. The herbicide showed limited activity against grassy weeds such as *Brachiaria eruciformis*.

All herbicide treatments significantly reduced weed biomass compared with the untreated control. Alfalfa plants exhibited no visible injury, confirming crop selectivity. Weed competition reduced total dry matter yield by about 36% in both seasons. Imazethapyr treatments produced yields comparable to the weed-free control.

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## فعالية مبيد الأعشاب إيمازيتابير وانتقائيته في مكافحة الأعشاب الضارة في البرسيم ( *Medicago sativa* L ) في السودان

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### الملخص:

البرسيم الحجازي، (*Medicago sativa* L.) محصول علقي بقولي معمر وهام عالمياً. أجريت تجربة حقلية في مزرعة محطة شمبات للأبحاث، الخرطوم، السودان، خلال موسمي الشتاء 2014/2015 و 2015/2016 لتقييم فعالية وانتقائية مبيد الأعشاب (إيمازيتابير) في مكافحة الأعشاب الضارة في البرسيم الحجازي. استخدم مبيد الأعشاب إيمازيتابير بتركيزات 57.1، 76.2، 95.2، و 114.3 غرام من المادة الفعالة/هكتار عند الزراعة وبعد ثلاثة أسابيع. وكانت أكثر أنواع الأعشاب الضارة انتشاراً هي *Brachiaria eruciformis* (Sm) Grieseb.، و *Cyperus rotundus* L.، و *Ipomoea sp.*، و *Tribulus terrestris*. أظهر مبيد الأعشاب إيمازيتابير، بجميع تركيزاته وبغض النظر عن وقت استخدامه، فعالية جيدة إلى ممتازة (78-98%) في مكافحة الأعشاب عريضة الأوراق. مع ذلك، كانت فعاليته ضد الأعشاب النجيلية ضعيفة. وقد أدت جميع معالجات مبيدات الأعشاب إلى انخفاض ملحوظ في الكتلة الحيوية للأعشاب مقارنةً بالعينة الضابطة غير المعالجة. وكانت جميع معالجات مبيدات الأعشاب انتقائية للمحصول. وخفضت الأعشاب المنافسة إجمالي محصول المادة الجافة بنسبة 36% في كلا الموسمين. وأدى استخدام إيمازيتابير، بجميع تركيزاته وبغض النظر عن وقت استخدامه، إلى محصول مادة جافة إجمالي مماثل لمحصول العينة الضابطة المعالجة.

**الكلمات المفتاحية:** البرسيم الحجازي، مكافحة الحشائش، إيمازيتابير.