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Ability of Adjuvants in Enhancing the Performance of Pinoxaden and Clodinafop Propargyl Herbicides against Grass Weeds

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ABSRTACT

Adjutants' ability in enhancing the performance of herbicides is a major priority in adjuvant research. To identify an appropriate adjuvant for pinoxaden and clodinafop propargyl herbicides against littleseed canarygrass (*Phalaris minor* Retz.), common wild oat (*Avena fatua* L.) and ryegrass (*Lolium temulentum* L.), three separate experiments were conducted under greenhouse conditions. In all experiments treatments consisted of five doses of pinoxaden and two doses of each of the three commercial formulations of clodinafop propargyl (Topik, Behpik & Karent), with and without the adjuvants Adigor, Citogate, Citohef and Volk. Performance of all herbicides increased with enhancing their concentrations against the tested plants except for clodinafop propargyl in case of wild oat. The addition of Volk (followed by Adigor) had the highest effect on pinoxaden efficacy against ryegrass and littleseed canarygrass, supporting the idea that either Volk or Adigor solubilizes the cuticular waxes thus facilitating their uptake. Adding Volk and Adigor had the highest and lowest influence on pinoxaden performance against wild oat, respectively. Totally, the adjuvant receptivity for pinoxaden was higher than for clodinafop propargyl. Between the two surfactants, Citogate was more effective than Citohef in enhancing the efficacy of pinoxaden against ryegrass and littleseed canarygrass, while, Citohef was more effective in increasing the efficacy of pinoxaden against wild oat.

Key words: adjuvant, clodinafop propargyl, littleseed canarygrass, pinoxaden, ryegrass, wild oat.

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INTRODUCTION

Winter wheat is one of the most important cereals in Iran. Annual grasses such as ryegrass, littleseed canarygrass, and wild oat reduce yield through competing for resources such as water, nutrient and light (Baghestani *et al*., 2007). The acetyl coenzyme-A carboxylase (ACCase) inhibiting herbicides, are the most effective and widespread method to control the above-mentioned weeds in Iran (Baghestani *et al*., 2008) which might result in evolution of resistance in grasses due to high selective pressure imposed by this group of herbicides (Devine & Shimabukuro, 1994). Moreover, environmental side-effects due to high usage of the ACCase inhibitors are probable (Rashed-Mohassel *et al*., 2010). A solution to the above-mentioned negative impacts of continuous application of ACCase herbicides is to use adjutants and/or surfactants. These chemical compounds decrease the application dose of herbicides (Sharma & Singh, 2000). Adjuvants (e.g. methylated seed oils (Sharma & Singh, 2000) and surfactants (Rashed-Mohassel *et al*., 2009)) can reduce the surface tension of spray solution; thereby increase the chance of spray droplets to sit on the plant surface. Moreover, they can increase the droplets spread on leaf surface and enhance the foliar activity of post-emergence herbicides (Rashed-Mohassel *et al.*, 2009) due to an increase in the infiltration rate of the active ingredient into the cuticular waxes. There are many factors that affect the suitability of an adjuvant (Green & Foy, 2000; Zolinger, 2000). Based on their type, adjuvant can directly/indirectly affect the formulations efficacy-related factors including atomization, deposition, retention, absorption and translocation (Zabkiewicz, 2000). Many researchers have stated that adjuvant performance depends on the interaction among herbicide, adjuvant and plant surface characteristics (Bunting *et al*., 2004a ;Rashed-Mohassel *et al.,* 2010).

The objective of the present research was to test and determine the ability of four different adjuvants in increasing the performance of pinoxaden and clodinafop propargyl against ryegrass, little seed canarygrass, and wild oat.

MATERIALS AND METHODS

Plant Materials

The seeds of ryegrass, little seed canarygrass, and wild oat were obtained from The Department of Weed Research at Iranian Plant Protection Research Institute, Tehran. The seeds were placed in Petri dishes in an incubator at alternating temperatures of 20/15°C and relative humidity of 45/65% under 16/8 hour light and dark cycle. After germination, six seedlings with uniform radical length (8-10 mm) were selected and planted 1 cm deep in 1.5 L plastic pots that were filled with a mixture of soil, peat, vermiculate, and sand (3:2:2:2 *v/v/v/v*). The pots were placed and kept in a greenhouse with a light/dark period of 16/8 hour at 25/15°C. A lamp was used to supply additional light and extend the day length. The plants were irrigated every three days and thinned to four per pot at one-leaf stage.

Chemicals, Treatments and Measurements

Separate experiments were established for each weed species in a completely randomized design with a factorial arrangement of treatments and six replications. Factor *A* was different herbicides including Pinoxaden EC 10% at 30, 40, 50, 60 and 70 g a.i. ha^{-1}, and three commercial formulations of clodinafop propargyl EC 8% including Topik, Behpik and Karent, each at 48 and 64 g a.i. ha^{-1} applied against ryegrass, littleseed canarygrass, and wild oat. Factor *B* was using and not-using herbicides with the following adjuvants: (*i*) Adigor (a methylated seed oil, 44.8 % methylated rapeseed oil and 28.2 % ethoxylated alcohols, Syngenta, Switzerland); (*ii*) Citogate (a non-ionic surfactant, 100% alkylarylpolyglycol ether, Zarnegaran Pars Company, Karaj, Iran); (*iii*) Citohef (a non-ionic surfactant, 100% alkylarylpolyglycol ether, Hef Chemicals Company, Semnan, Iran); and (*iv*) Volk (petroleum oils, 80% EC, 800 g a.i. L^{-1} petroleum oils, associated with 200 g a.i. L^{-1} emulsifier, Melli Agrochemical Company, Alborz Industrial City, Ghazvin, Iran). All adjuvants were applied at 2 % (*v/v*). Herbicides were sprayed at three- to four-leaves stage by using a sprayer equipped with a Flat-fan nozzle, delivering 300 L spray solution ha^{-1} at 250 kPa. Thirty days after spraying, the number of survived plants per pot was recorded and the fresh and dry (dried at 70°C for 48 hours) above-ground biomass in each pot were measured. In addition, two days prior to harvest, assessment of visual weed control was conducted according to European Weed Research Council (EWRC) scoring on a scale of 1 to 9 representing 100%, 99-98%, 97-95%, 94-90%, 89-82%, 81-70%, 69-55%, 54-30% and 29-0.00% injury, respectively (Sandral *et al.*, 1997). The data was subjected to analysis of variance using the GLM procedure in SAS (SAS Institute Inc., 2000). A physical slicing was performed due to significant interaction between experimental factors. Mean comparisons were performed using Duncan Multiple Range Test (DMRT) set at 0.05.

RESULTS AND DISCUSSION

Experiment 1: Ryegrass

Results (Tables 1 to 4) showed that all commercial formulations of clodinafop propargyl had greater effects on reducing the fresh (Table 1) and dry (Table 2) weights of ryegrass when applied without adjuvants compared with those of pinoxaden. In contrast, the addition of the adjuvants increased the foliar activity of pinoxaden more than that of clodinafop propargyl formulations ($P < 0.05$). This indicated that adjuvant receptivity for pinoxaden was higher than that for clodinafop propargyl. The addition of Volk and Citohef had the highest and the lowest effects on performance of pinoxaden, respectively. It is possible to rank the tested adjuvants as Volk > Adigor > Citogate > Citohef in their decreasing ability to enhance the efficacy of pinoxaden. Petroleum oils such as Volk and methylated seed oils such as Adigor probably disrupt and solubilize cuticular waxes (Zabkiewicz, 2000) and

consequently, facilitate the penetration of the active ingredient (McMullan & Chow, 1993). The benefits of using these oils (e.g. Volk & Adigor) rather than surfactants (e.g. Citogate & Citohef) in enhancing the foliage activity of herbicides have been well documented in other studies (Bunting *et al*., 2004a; Ramsdale & Messersmith, 2002; Bunting *et al*., 2004b; Rashed-Mohassel *et al*. 2010). Sharma and Singh (2000) reported that an increase in the penetration of the active ingredient through softening or disrupting the cuticular waxes is a more effective factor than decreasing the surface tension of spray droplets in improving the foliar activity of glyphosate on *Bidens frondosa* and *Panicum maximum*. Therefore, the foliar activity of the pinoxaden might be increased due to the ability of either Volk or Adigor to soften or disrupt the cuticular waxes. Unlike pinoxaden, the addition of the adjuvants to clodinafop propargyl formulations did not significantly affect their performance. Nonetheless, Volk had the highest influence on improving the foliar activity of clodinafop propargyl formulations. Citohef application led to an insignificant antagonistic effect on the foliar activity of clodinafop propargyl formulations resulting in a decrease in performance of all formulations of this herbicide. The mortality of ryegrass plants was improved with an increase in concentration of pinoxaden especially when applied with adjuvants (Table 4). The mortality of ryegrass plants did not change in none of clodinafop propargyl formulations when applied with Adigor, Citohef, and Volk. However, Citogate led to a significant increase in survival of ryegrass plants (Table 3).

Experiment 2: Little Seed Canarygrass

Results (Tables 5-8) indicated that the foliar activity of herbicides was improved with increasing the concentration of pinoxaden. Pinoxaden at high concentrations (> 50 g a.i ha^{-1}) caused complete weed control (Table 8) and showed greater efficacy than all clodinafop propargyl formulations when used without adjuvants. The performance of pinoxaden was enhanced significantly ($P < 0.05$) when adjuvants were added. Adigor and Volk had the highest effect while Citogate and Citohef showed the lowest effect on pinoxaden performance. The addition of adjuvants to pinoxaden at 40 g a.i. ha^{-1} led to complete littleseed canarygrass control (Table 8). All adjuvants increased performance of clodinafop propargyl formulations against this weed. The application of adjuvants did not have any positive effect on formulations Behpik and Karent. In case of Topik formulation, however, Citogate and Citohef had the highest, and Adigor and Volk had the lowest effects on performance of this herbicide. Therefore, these results emphasize the dependency of adjuvant performance on herbicide properties and plant species as previous studies also stated (Johnson *et al*., 2002; Rashed-Mohassel *et al*., 2010). The data from this experiment showed that the number of surviving littleseed canarygrass plants increased when the adjuvants were added to clodinafop propargyl formulations (Table 7). However, all adjuvant-added clodinafop propargyl formulations showed

superior performance in reducing the fresh and dry weight of little seed canarygrass (Table 5 & 6). According to the EWRC index, all clodinafop propargyl formulations acted weaker than pinoxaden either with (> 30 g a.i. L^{-1}) or without (> 40 g a.i. L^{-1}) the adjuvants (Table 8). This indicates that the adjuvants are likely to improve the penetrability of the active ingredient (Johnson *et al*., 2002) which provides an opportunity to reduce herbicide application dose (Zabkiewicz, 2000).

Experiment 3: Wild Oat

Increasing pinoxaden concentration up to 60 g a.i. ha^{-1} enhanced its weed control efficacy (Table 12). This herbicide controlled weeds completely at higher does. All adjuvant enhanced the efficacy of pinoxaden in decreasing the fresh (Table 9) and dry (Table 10) weights of wild oat. Volk was the most effective adjuvant as its addition to pinoxaden at 30 g a.i. ha^{-1} led to complete control of wild oat, while higher herbicide dose was needed for other adjuvants to achieve complete weed control. It was clearly indicated that pinoxaden has a vigorous receptivity for adjuvant which might be related to weaker penetration of pinoxaden into wild oat leaf when applied without adjuvant. This can be a reason for why pinoxaden is being sold with a particular adjuvant (Adigor). However, the results from the present experiment indicated that the addition of Adigor had the lowest influence on pinoxaden performance among adjuvants. Generally, the adjuvants could be ranked as Volk being the most effective adjuvant followed by Citohef, Citogate, and Adigor. Based on the available literature (Singh & Mack , 1993; Kocher & Kocur, 1993), it seems that the tested adjuvants led to more cuticular penetration and stomata infiltration and subsequently, allowed better pinoxaden absorption and translocation. The efficacy of clodinafop propargyl formulations did not change significantly by increase in their concentration and all treatments resulted in complete control of wild oat (Table 12). Rashed-Mohassel *et al*., (2009) reported similar result that the Topik formulation of clodinafop propargyl at 48 and 64 g a.i. ha^{-1} showed no significant difference in wild oat (*Avena fatua* L.) control ability. This finding can be related to high sensitivity of wild oat plant to clodinafop propargyl and/or high efficacy of this herbicide in controlling wild oat. Moreover, the addition of the adjuvants did not have any positive effect on efficacy of the three formulations of clodinafop propargyl against wild oat (Table 12).

Overall, our study showed that although Citogate and Citohef chemical characteristics and formulations are similar (non-ionic surfactants, 100% alkylarylpolyglycol ether) but they differ in their performance. In experiments 1 and 2, Citogate was more an effective adjuvant in enhancing the efficacy of pinoxaden against ryegrass and littleseed canarygrass, while in experiment 3, Citohef acted better in increasing the efficacy of pinoxaden against wild oat. These results indicated that the differences in leaf surface micromorphology can affect the efficacy of an adjuvant as previously shown in other studies (Collins & Helling, 2002; Sanyal *et*

al., 2006). In other words, the efficacy of an adjuvant also depends on species.

Table 1. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on ryegrass fresh weight.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Fresh weight (g)				
Pinoxaden	30	2.22 a**	0.63 a	0.71 ab	1.19 a	0.29 bcde
Pinoxaden	40	2.19 a	0.34 cd	0.69 ab	0.46 cd	0.00 e
Pinoxaden	50	1.34 b	0.00 e	0.13 cd	0.42 cd	0.00 e
Pinoxaden	60	1.24 b	0.00 e	0.00 d	0.00 e	0.00 e
Pinoxaden	70	0.00 d	0.00 e	0.00 d	0.00 e	0.00 e
Clodinafop propargyl (Topik)	48	0.46 dc	0.52 ab	0.87 a	0.97 ab	0.55 bc
Clodinafop propargyl (Topik)	64	0.41 d	0.20 d	0.00 d	0.88 ab	0.59 bc
Clodinafop propargyl (Behpik)	48	0.81 bc	0.43 cb	0.40 bc	0.76 bc	0.59 b
Clodinafop propargyl (Behpik)	64	0.26 cd	0.29 d	0.23 cd	0.18 de	0.65 a
Clodinafop propargyl (Karent)	48	0.58 bdc	0.46 b	0.68 ab	0.41 cd	0.25 cde
Clodinafop propargyl (Karent)	64	0.62 bdc	0.21 d	0.28 cd	0.79 bc	0.16 ed

* All adjuvants were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 2. Effects of pinoxaden or three commercial formulations of clodinafop propargyl applied with and without adjuvants* on ryegrass dry weight.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Dry weight (g)				
Pinoxaden	30	0.27 cb**	0.12 a	0.11 b	0.17 a	0.05 a
Pinoxaden	40	0.22 cd	0.03 d	0.09 a	0.06 de	0.00 c
Pinoxaden	50	0.16 b	0.00 e	0.02 cd	0.04 ef	0.00 c
Pinoxaden	60	0.02 cd	0.00 e	0.00 d	0.00 g	0.00 c
Pinoxaden	70	0.00 f	0.00 e	0.00 d	0.00 g	0.00 c
Clodinafop propargyl (Topik)	48	0.06 ef	0.08 bc	0.06 bc	0.14 bc	0.06 a
Clodinafop propargyl (Topik)	64	0.05 ef	0.05 bc	0.00 d	0.12 ab	0.04 b
Clodinafop propargyl (Behpik)	48	0.08 de	0.04 c	0.06 bc	0.10 ab	0.04 a
Clodinafop propargyl (Behpik)	64	0.05 ef	0.09 bc	0.03 cd	0.02 gf	0.01 a
Clodinafop propargyl (Karent)	48	0.07 ef	0.03 c	0.07 b	0.05 c	0.05 b
Clodinafop propargyl (Karent)	64	0.90 a	0.03 bc	0.04 cd	0.11 d	0.04 b

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 3. The number of the survived plants of ryegrass after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Survived plants (plant pot^{-1})				
Pinoxaden	30	3.75 a**	2.00 a	2.00 a	2.50 a	1.00 b
Pinoxaden	40	3.25 a	1.00 b	1.50 ab	1.00 c	0.00 c
Pinoxaden	50	2.00 b	0.00 c	1.00 c	1.00 c	0.00 c
Pinoxaden	60	1.75 bc	0.00 c	0.00 d	0.00 d	0.00 c
Pinoxaden	70	0.00 d	0.00 c	0.00 d	0.00 d	0.00 c
Clodinafop propargyl (Topik)	48	1.00 c	1.00 b	1.50 abc	1.00 c	1.00 b
Clodinafop propargyl (Topik)	64	1.00 c	1.00 b	0.00 d	1.00 c	1.00 b
Clodinafop propargyl (Behpik)	48	1.25 bc	1.00 b	1.50 abc	1.00 c	1.00 b
Clodinafop propargyl (Behpik)	64	1.00 c	1.00 b	1.00 c	1.00 c	1.00 b
Clodinafop propargyl (Karent)	48	1.00 c	1.00 b	1.25 c	1.00 c	1.00 b
Clodinafop propargyl (Karent)	64	1.50 bc	1.00 b	1.00 c	1.00 c	1.00 b

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 4. Percent control of ryegrass by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvant*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Control (%)				
Pinoxaden	30	22.50 d**	83.75 d	76.25 cd	55.00 d	90.00 b
Pinoxaden	40	32.50 d	92.50 b	92.50 ab	91.25 a	100 a
Pinoxaden	50	71.25 c	100 a	92.50 ab	91.50 a	100 a
Pinoxaden	60	77.50 c	100 a	100 a	100 a	100 a
Pinoxaden	70	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Topik)	48	81.25 bc	85.00 c	77.50 cd	67.50 c	82.50 c
Clodinafop propargyl (Topik)	64	95.50 ab	90.00 bc	100 a	76.25 bc	88.75 bc
Clodinafop propargyl (Behpik)	48	68.00 c	70.00 e	73.75 d	68.75 c	75.00 d
Clodinafop propargyl (Behpik)	64	93.75 ab	91.25 bc	93.75 ab	93.75 a	86.25 bc
Clodinafop propargyl (Karent)	48	76.00 cd	87.50 cd	82.50 bcd	75.50 bc	87.50 bc
Clodinafop propargyl (Karent)	64	88.00 ab	100 a	90.00 abc	87.50 ab	92.50 b

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 5. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on littleseed canarygrass fresh weight.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Fresh weight (g)				
Pinoxaden	30	3.04 a**	0.00 d	1.17 a	0.46 a	0.00 d
Pinoxaden	40	1.82 b	0.00 d	0.00 b	0.00 c	0.00 d
Pinoxaden	50	0.00 e	0.00 d	0.00 b	0.00 c	0.00 d
Pinoxaden	60	0.00 e	0.00 d	0.00 b	0.00 c	0.00 d
Pinoxaden	70	0.00 e	0.00 d	0.00 b	0.00 c	0.00 d
Clodinafop propargyl (Topik)	48	0.12 cd	0.18 a	0.17 b	0.11 b	0.15 a
Clodinafop propargyl (Topik)	64	0.09 d	0.23 a	0.11 b	0.11 b	0.15 a
Clodinafop propargyl (Behpik)	48	0.13 cd	0.10 b	0.16 b	0.11 b	0.14 ab
Clodinafop propargyl (Behpik)	64	0.12 cd	0.08 bc	0.09 b	0.07 b	0.14 ab
Clodinafop propargyl (Karent)	48	0.14 cd	0.10 b	0.15 b	0.07 b	0.09 c
Clodinafop propargyl (Karent)	64	0.13 cd	0.05 cd	0.09 b	0.06 b	0.10 bc

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 6. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvant* on littleseed canarygrass dry weight.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	G a.i. ha^{-1}	Dry weight (g)				
Pinoxaden	30	0.40 a**	0.00 e	0.24 a	0.60 a	0.00 d
Pinoxaden	40	0.24 b	0.00 e	0.00 e	0.00 c	0.00 d
Pinoxaden	50	0.00 d	0.00 e	0.00 e	0.00 c	0.00 d
Pinoxaden	60	0.00 d	0.00 e	0.00 e	0.00 c	0.00 d
Pinoxaden	70	0.00 d	0.00 e	0.00 e	0.00 c	0.00 d
Clodinafop propargyl (Topik)	48	0.04 c	0.05 b	0.05 c	0.04 b	0.06 a
Clodinafop propargyl (Topik)	64	0.04 c	0.10 a	0.05 cd	0.05 b	0.05 ab
Clodinafop propargyl (Behpik)	48	0.05 c	0.03 d	0.05 c	0.04 b	0.05 ab
Clodinafop propargyl (Behpik)	64	0.04 c	0.05 bc	0.03 d	0.03 b	0.05 ab
Clodinafop propargyl (Karent)	48	0.05 c	0.04 cd	0.05 c	0.02 bc	0.04 b
Clodinafop propargyl (Karent)	64	0.05 c	0.00 e	0.03 cd	0.02 bc	0.03 c

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 7. The number of survived plants of littleseed canarygrass after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Survived plants (plant pot^{-1})				
Pinoxaden	30	4.75 a**	0.00 c	3.50 a	1.25 bc	0.00 b
Pinoxaden	40	4.50 a	0.00 c	0.00 c	0.00 c	0.00 b
Pinoxaden	50	0.00 e	0.00 c	0.00 c	0.00 c	0.00 b
Pinoxaden	60	0.00 e	0.00 c	0.00 c	0.00 c	0.00 b
Pinoxaden	70	0.00 e	0.00 c	0.00 c	0.00 c	0.00 b
Clodinafop propargyl (Topik)	48	1.75 cd	1.50 b	2.25 ab	2.70 a	2.75 a
Clodinafop propargyl (Topik)	64	0.75 e	1.00 bc	1.25 bc	0.75 bc	2.00 a
Clodinafop propargyl (Behpik)	48	1.50 cd	2.25 a	3.00 a	1.75 ab	2.00 a
Clodinafop propargyl (Behpik)	64	1.00 cd	1.00 bc	1.50 b	1.75 ab	2.25 a
Clodinafop propargyl (Karent)	48	1.00 e	1.75 b	2.50 ab	2.00 ab	2.50 a
Clodinafop propargyl (Karent)	64	1.25 e	1.50 b	1.50 b	1.75 ab	2.25 a

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 8. Percent control of littleseed canarygrass by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Control (%)				
Pinoxaden	30	22.50 c**	100 a	47.50 d	83.75 bc	100 a
Pinoxaden	40	23.75 c	100 a	100 a	100 a	100 a
Pinoxaden	50	100 a	100 a	100 a	100 a	100 a
Pinoxaden	60	100 a	100 a	100 a	100 a	100 a
Pinoxaden	70	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Topik)	48	61.25 b	81.25 b	66.25 bcd	60.00 d	60.00 b
Clodinafop propargyl (Topik)	64	87.50 a	86.25 ab	83.75 ab	91.25 ab	72.50 b
Clodinafop propargyl (Behpik)	48	55.50 b	58.75 c	60.00 cd	73.75 cd	71.25 b
Clodinafop propargyl (Behpik)	64	55.50 b	85.00 ab	78.75 bc	78.75 bc	71.25 b
Clodinafop propargyl (Karent)	48	86.25 a	72.50 b	67.50 bc	73.75 cd	60.00 b
Clodinafop propargyl (Karent)	64	70.00 b	76.25 b	78.75 bc	77.50 bc	70.00 b

* All adjuvant were added at 0.2 % (*v/v*).
****** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 9. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on wild oat fresh weight.

Herbicides	Rate g a.i. ha^{-1}	No adjuvant	Adigor	Citogate	Citohef	Volk
		Fresh weight (g)				
Pinoxaden	30	49.12 a**	9.05 a	3.26 a	0.50 a	0.00 a
Pinoxaden	40	26.54 b	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	50	4.85 c	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	60	4.29 c	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	70	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 10. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on wild oat dry weight.

Herbicides	Rate g a.i. ha^{-1}	No adjuvant	Adigor	Citogate	Citohef	Volk
		Dry weight (g)				
Pinoxaden	30	6.52 a**	0.99 a	0.31 a	0.03 a	0.00 a
Pinoxaden	40	3.23 b	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	50	0.60 c	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	60	0.32 cd	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	70	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 11. The number of survived plants of wild oat after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	wild oat (plant pot^{-1})				
Pinoxaden	30	5.00 a**	1.00 a	0.75 a	0.25 a	0.00 a
Pinoxaden	40	2.00 b	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	50	0.50 c	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	60	0.50 c	0.00 b	0.00 b	0.00 a	0.00 a
Pinoxaden	70	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Topik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Behpik)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	48	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a
Clodinafop propargyl (Karent)	64	0.00 d	0.00 b	0.00 b	0.00 a	0.00 a

* All adjuvant were added at 0.2 % (*v/v*).
** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

Table 12. Percent control of wild oat by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

Herbicides	Rate	No adjuvant	Adigor	Citogate	Citohef	Volk
	g a.i. ha^{-1}	Control (%)				
Pinoxaden	30	15.00 c**	89.50 b	78.25 b	95.50 a	100 a
Pinoxaden	40	56.25 b	100 a	100 a	100 a	100 a
Pinoxaden	50	93.25 a	100 a	100 a	100 a	100 a
Pinoxaden	60	92.75 a	100 a	100 a	100 a	100 a
Pinoxaden	70	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Topik)	48	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Topik)	64	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Behpik)	48	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Behpik)	64	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Karent)	48	100 a	100 a	100 a	100 a	100 a
Clodinafop propargyl (Karent)	64	100 a	100 a	100 a	100 a	100 a

* All adjuvant were added at 0.2 % (*v/v*).
****** Treatment means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Duncan's Multiple Range test.

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چکیده

توانایی مویان‌ها در افزایش کارکرد علف کش ها از اواویت های اصلی تحقیقات در زمینه مویان محسوب می شود . به منظور شناسایی مویان‌های مناسب برای علف کش های پینوکسادن و کلودینافوپ پروپارژیل برای کنترل علف های هرز علف قناری (*Phalaris minor* Retz.)، یولاف وحشی (*Avena fatua* L.) و چچم (*Lolium temulentum* L.)، سه آزمایش گلخانه ای جداگانه صورت پذیرفت. در تمامی آزمایش ها تیمارها شامل پنج غلظت پینوکسادن و دو غلظت از هر یک از سه فرمولاسیون تجاری کلودینافوپ پروپارژیل یعنی تاپیک، بهپیک و کارنت، با و بدون کاربرد مویان های آدیگور، سیتوگیت، سیتوهف و ولک بودند . نتایج حاصل از آزمایش نشان داد که با افزایش غلظت علف کش، کارایی هر دو علف کش در کنترل علف های هرز، به ج ز علف کش کلودینافوپ پروپارژیل بر روی یولاف وحشی، افزایش پیدا کرد . کاربرد ولک بیشترین تاثیر مثبت را روی کارایی علف کش پینوکسادن در کنترل علف های هرز چچم و علف قناری داشت که در تایید این مطلب ا ست که مویان های ولک و آدیگور کوتیکول مومی برگ را در خود حل کرده و بدین سان جذب آنها افزایش می یابد . همچنین، کاربرد ولک و آدیگور به ترتیب بیشترین و کمترین تاثیر را بر روی کارایی علف کش های پینوکسادن در کنترل یولاف وحشی داشت . در مجموع، تمایل علف کش پینوکسادن برای جذب مویان بیشتز از علف کش کلودینافوپ پروپارژیل بود. همچنین، مویان سیتوگیت در مقایسه با سیتوهف تاثیر بیشتری در افزایش کارایی علف کش پینوکسادن در برابر علف های هرز چچم و علف قناری داشت درحالیکه سیتوهف در افزایش کارایی پینوکسادن در برابر علف هرز یولاف وحشی موثرتر بود.

کلمات کلیدی: مواد افزودنی، کلودینافوپ پروپارژیل، علف قناری، پینوکسادن، چچم، یولاف وحشی.