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Evaluation of herbicide options for control of invasive annual ground cherry (*Physalis divaricata* D.Don.) in corn

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Evaluation of herbicide options for control of invasive annual ground cherry (*Physalis divaricata* D.Don.) in corn

Abstract: Annual ground cherry (*Physalis divaricata*) is an invasive weed in farmlands located in western Iran, but there is little information on effective options for its management, particularly in corn. Greenhouse and field studies were conducted to evaluate the performance of herbicide options consisting of mesotrione + s-metolacholor + terbuthylazine, bromoxynil + MCPA, foramsulfuron + iodosulfuron, 2,4-D + MCPA, rimsulfuron and nicosulfuron + rimsulfuron alone and in combination with ammonium sulphate (AMS) and citogate for *Ph. divaricata* control in corn. In the greenhouse study, only Mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA mixture provided satisfactory control of *Ph. divaricata* among the evaluated herbicides. In field study, each of mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA efficiently suppressed *Ph. divaricata*. Nevertheless, bromoxynil + MCPA had higher efficacy so that applying 75% of its recommended dose resulted in more than 80 % control of *Ph. divaricata*. Considering both greenhouse and field studies, mesotrione + s-metolacholor + terbuthylazine as well as bromoxynil + MCPA were found to be suitable options for *Ph. divaricata* in corn. Results also suggest the need of adding of AMS to improving weed control by these herbicides, particularly in bromoxynil + MCPA.

Key words: ammonium sulphate; annual ground cherry; weed control

Ovrednotenje herbicidov primernih za nadzor invazivnega himalajskega volčjega jabolka (*Physalis divaricata* D.Don.) v posevku koruze

Izvleček: Enoletnica, himalajsko volčje jabolko (*Physalis divaricate* D. Don.) je invaziven plevel na kmetijskih zemljiščih zahodnega Irana, a le malo je znanega o možnostih njegovega zatiranja, še posebej v koruzi. Za ovrednotenje učinka herbicidov za zatiranje tega plevela v koruzi so bili v rastlinjaku in v poljskem poskusu uporabljeni herbicidi v naslednjih kombinacijah: mezotrion + s-metolaklor + terbutilazin, bromoksinil + MCPA, foramsulfuron + iodosulfuron, 2, 4-D + MCPA, rimsulfuron in nikosulfuron + rimsulfuron posamično ali v kombinaciji z amonijevim sulfatom (AMS) in citogatom. V rastlinjaku je bila za nadzor plevela izmed preiskušenih herbicidov zadostna samo mešanica herbicidov kot so mezotrion, s-metolaklor, terbutilazin in bromoksil, MCPA. V poljskem poskusu je uporaba mešanic herbicidov kot so mezotrion, s-metolaklor, terbutilazin ali bromoksil in MCPA učinkovito zatrla plevel. Mešanica bromoksila in MCPA je imela večjo učinkovitost in je pri odmerku 75 % od priporočene doze zavrla rast plevela za 80 % v primerjavi s kontrolo. Glede na poskusa v rastlinjaku in na polju je mešanica herbicidov kot so mezotrion, s-metolaklor, terbutilazin, bromoksinilin MCPA primerna za nadzor tega plevela v koruzi. Rezultati nakazujejo tudi potrebo po dodatku amonijevega sulfata za izboljšanje nadzora plevelov s temi herbicidi, še posebej pri mešanici bromoksinila in MCPA.

Ključne besede: amonijev sulfat; himalajsko volčje jabolko; uravnavanje plevelov

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1 INTRODUCTION

Over the last decade, annual ground cherry (*Physalis divaricata* L.) has increasingly become one of the noxious and invasive annual weed of summer crops in Iran (Nosratti et al., 2017). Originating from India, *Ph. divaricate* D. Don. has been adapted to diverse agro-ecological conditions in Iran (Nosratti et al., 2016). It is now a weed of national significance in Iran, with highly infestations found in corn. Despite applied control measures, average yield loss due to weeds in corn farms of Kermanshah province has been reported to be higher than 17 % (Sabeti et al., 2013). Sugar beet, potato, tomato, and other summer crops, are grown especially in western parts of Iran (Alam et al., 2011).. *Physalis divaricata* is very competitive because of its fast growth and large canopy. For instance, Alam et al. (2013) found that presence of only one individual plant of *Ph. divaricata* in square meter resulted in 34 % reduction in root yield of sugar beet. In Iranian farmlands, particularly those of Kermanshah and Lorestan provinces, *Ph. divaricata* is now one of the five most troublesome corn weed. It is especially compatible to corn, where there is free gape between corn rows during early growth stages greatly favor its growth (Murphy et al., 1996). This weed species has the potential to reduce the yield of several main crops and interfere with their harvest. For example, reductions of 10 and 14 % in corn yield have been reported with *Ph. divaricata* at densities of 8 and 16 plants m^{-2}, respectively (Sabeti et al., 2019). In addition, the presence of sticky ingredients in its berries causes harvest problems. Applying herbicide is the predominant weed management option in Iranian fields, particularly in corn. So far, 11 herbicides belonging to different groups of modes of action are available for corn growers in Iran (Zand et al., 2009a). When compared with other developed countries, the number of herbicides for use in Iranian corn fields are lower than those are in other countries (Zand et al., 2009b). The lack of herbicide variation by narrowing spectrum of target weed species may has resulted in increasing the population of *Ph. divaricata* (Alam et al., 2011). In addition, almost all of the commercially available herbicides for use in corn are applied as POST (Zand et al., 2006), which may let some weed species escaping the common herbicide application (Mortimer, 1997). In addition, the efficacy of commonly used corn herbicides on *Ph. divaricata* is not known because little effort has been devoted to investigating chemical control of this weed in corn. Therefore, the main aim of this research was to characterize the reaction of *Ph. divaricata* to applying registered herbicides in Iran.

2 MATERIALS AND METHODS

2.1 GREENHOUSE EXPERIMENT

The Research was conducted at Greenhouse of Kermanshah Agricultural and Natural Resources Research and Education Center during March and April of 2017. This trial was conducted to evaluate the response of *Ph. divaricata* to herbicides listed as follows: mesotrione + s-metolacholor + terbuthylazine, bromoxynil + MCPA, foramsulfuron + iodosulfuron, 2, 4-D+MCPA, rimsulfuron and nicosulfuron + rimsulfuron, which applied alone or in combination with either AMS (2 % w/v) or citogate (1 % v/v). *Ph. divaricata* berries were collected from corn fields of Kermanshah province in the western Iran during October and November of 2016. Seeds were kept in paper bags at room temperature until the beginning of the greenhouse experiment. Seeds of annual ground cherry were sowed in l5-cm-diam pots filled with a silty clay loam soil (an average mixture of 42 % sand, 34 % silt, and 24 % clay). The organic matter content was 11 % and the pH 6.1. Plants were grown by sowing five seeds in each 4.5 l plastic pot. Pots watered as needed during the experiment. After emergence, seedlings were thinned to three uniform Annual ground cherry plants per pot. Greenhouse was operated at 30 °C day and 16 °C night temperatures and at l6-h photoperiod consisting of daylight supplemented with dummy light. Experiment was a randomized complete block (CRD) with four replicates and the whole of experiment was repeated twice. Herbicides were used with a backpack mechanical plot sprayer in 200 liters of water per hectare at 3 bar, using a single Teejet® XR8003 flat fan nozzle. Herbicides were applied at the 3-5 leaf growth stage (10 to 12 cm in height) of annual ground cherry with 25, 50, 75, 100 and 125 % of the recommended dose of six evaluated herbicides (Table 1).Forty-five DAT, *Ph. divaricata* plants were cut at the soil surface, placed in paper bags, and dried in an oven at 72 °C for 48 h, and the dry biomass of each individual pot was calculated as percentage of untreated control.

2.2 FIELD EXPERIMENT

In 2017, two separate field trials were conducted in Research Centers Mahidasht (34°26'N, 46°83'E; elevation: 1366 m a.s.l.; annual average temperature: 14.7 °C; annual average rainfall: 439.2 mm) and Eslamabad–e-Gharb (34°8'N, 47°26'E; elevation: 1346 m a .s. l.; annual

Table 1: Herbicide product, active ingredients, and application rates for herbicide treatments used for *Physalis divaricata* control in greenhouse and field studies

Trade name	Active ingredients	Rates kg ai or ae* ha^{-1}
Bromicide	Bromoxynil + MCPA	300 g a. i. ha^{-1} Bromoxynil + 300 g a. i. ha^{-1} MCPA
Lumax	Mesotrione + s-metolacholor + terbuthylazine	1500 g a.i. ha^{-1} s-metolachlor + 150 g a.i. ha^{-1} Terbuthylazine + 500 g a.i. ha^{-1} Mesotrione
Maister	Foramsulfuron + iodosulfuron	45 g a. i. ha^{-1} foram + 1.5 g a. i. ha^{-1} iod
U 46 Combi fluid	2,4-D + MCPA	540 g a. i. ha^{-1} 2,4-D + 472.5 g a. i. ha^{-1} MCPA
Titus	Rimsulfuron	10 g a. i. ha^{-1}
Utima	Nicosulfuron +rimsulfuron	93.75 g a. i. ha^{-1}

* ai: active ingredients, ae: acid equivalent which is applied for those pesticides that are acids

average temperature: 15 °C; annual average rainfall: 498.4 mm) to further investigation the response of *Ph. divaricata* to mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA. Because satisfactory control of *Ph. divaricata* was achieved only by using these two herbicides under greenhouse conditions, we selected them for further study in field conditions. The field soil in both locations was uniformly infested with high densities of *Ph. divaricata*. The soil type, physical and chemical characteristics in the experimental sites are shown in Table 2.

The experimental procedure for both locations was the same and corn (SC 703) seeds were sowed in mid-May at 75000 seeds ha^{-1} in 75-cm rows. Plot size for each treatment was 3 m wide by 10 m long and arranged in a randomized complete block design with four replications. Each test plot was divided into two parts in length. The upper part of each plot was not sprayed and was considered as a control for each plot separately and the lower part of the plot treatment was applied. When *Ph. divaricata* was between 10 and 12 cm height, 50, 75, and 100 % of the recommended dose of mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA (Table 1) with and without ammonium sulfate (AMS) (2 %) were applied using the described equipment in greenhouse study. A nontreated control was also included for comparison. In both experimental sites, arrangement of treatments was as factorial in a completely randomized block design with four replications. Visual weed control was recorded 15 and 30 DAT on a scale of 0 % to 100 %, with 0 % representing no control compared to nontreated plots and 100 % indicating plant death. At corn maturity, all aerial parts of living *Ph. divaricata* plants were harvested from 50 by 50 cm quadrate placed in each plot, then oven dried and above dry biomass of weeds was recorded.

2.3 DATA ANALYSIS

For both greenhouse and field studies, homogeneity of variance also was analyzed. However, no transformation of the data was needed; therefore, analyses were conducted on the untransformed data. For the greenhouse study, the data were pooled across runs because of lacking a significant run by treatment interaction and then subjected to ANOVA using SAS software (SAS Institute, Cary, NC, USA). Because field study was done at two locations, data analysis was conducted using the PROC MIXED procedure in SAS. The variance was partitioned into fixed effects of treatment and random effects of block, location, and location by treatment interaction. Fisher's Protected LSD ($p = 0.05$) was used for means separation.

Regression analysis was conducted on data obtained from greenhouse experiment using SigmaPlot software (version 12.0, SyStat Software, Inc., Point Richmond, CA,

Table 2: Physical and chemical properties of soil (0-30 cm depth) in the experimental sites

Site	O.C (%)	N (%)	P (ppm)	K (ppm)	Soil texture	PH	EC (ds m^{-1})
Mahidasht	0.77	0.08	7.4	280	Silty clay loam	7.8	0.84
Eslamabad–e-Gharb	0.63	0.06	8	240	Silty Clay Loam	7.7	0.55

USA). Above dry biomass of weeds reduction (%) resulting from different doses of herbicides in greenhouse studies were fitted to a functional three-parameter exponential model (Chauhan et al., 2006). The fitted model was as follows:

$$G\ (\%) = G_{max} / \left[1 + (X/ED_{50})^{Grate}\right]$$

G represents the weed dry biomass reduction (%) at herbicide concentration *X*, G_{max} is the maximum germination (%), ED_{50} is the herbicide concentration for 50 % reduction in above dry biomass of weeds, and G_{rate} indicates the slope.

3 RESULTS AND DISCUSSION

3.1 GREENHOUSE STUDY

Bromoxynil + MCPA and mesotrione + s-metolacholor + terbuthylazine applied at 25 % of the recommended herbicide dose provided 100 and 93.4 % control of annual ground cherry, respectively (Fig. 1). Based on the three-parameter logistic model results, the required concentration of different herbicides to reduce 50 % of the dry biomass of annual ground cherry varied greatly among herbicides when used with AMS, citogate and alone are presented in Table 3. AMS was more effective than citogate in enhancing performance of applied herbicides (Fig. 1).

The ED_{50} (the herbicide concentration for 50 % reduction in dry biomass) of all herbicide was significantly lower when compared with herbicide lonely (Table 3). The control of *Ph. divaricata* improved with increasing dosage of foramsulfuron + iodosulfuron and 2, 4-D (Fig. 1). However, only applying foramsulfuron + iodosulfuron at recommended dose resulted in significant control (84.6 %) of *Ph. divaricata* (Fig. 1). Similar to our results, Kudsk, (1989, 2002) found that very susceptible species can be controlled with less than half of recommended herbicide dose. Rimmsulfuron did not provide control percentages beyond 20 % even at recommended doses (Fig. 1). Mesotrione + s-metolacholor + terbuthylazine is a combination of three highly effective active, which recently has been registered for the control of weeds in Iranian corn fields (Zand et al., 2009a). Tański and Idziak (2009) reported that mesotrione + s-metolacholor + terbuthylazine was able to effectively control *Chenopodium album* L., *Echinochloa crus-galli* (L.) P.Beauv., *Amaranthus retroflexus* L., and *Solanum nigrum* L. in corn. In addition, Chikoye et al. (2009) showed that mesotrione + s-metolacholor + terbuthylazine provides satisfactory control of all main broad-leaved and grass weeds in corn. It has been well demonstrated that bromoxynil + MCPA controls a wide spectrum of broadleaved weeds in corn (Baghestani et al., 2014). Likewise, our results showed that either mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA were highly effective in controlling annual ground cherry. Although foramsulfuron + iodosulfuron, rimsulfuron, 2,4-D + MCPA, nicosulfuron, and foramsulfuron are known to control broadleaved weeds in corn (Vencill, 2002), but they had no or little effect on control of annual ground cherry in this study. Little weed control with mesotrione (30 %) and atrazine (8 %) was consistent with formerly reported results (Vencill, 2002). Generally, weed species responded to various herbicides inconsistently (Khan et al., 2003).

3.2 FIELD STUDIES

Based on the results of greenhouse study, commonly used herbicides are the most important factor in reducing the population of *Ph. divaricata* in corn field. Bromoxynil + MCPA and mesotrione + s-metolacholor + terbuthylazine, which provided optimum control of *Ph. Divaricata*, are not common herbicides often being used by corn growers across Iran, particularly in western provinces. Instead, 2, 4-D + MCPA, nicosulfuron, and foramsulfuron are more popular herbicide option for chemical weed control in corn (Baghestani et al., 2007). There are scarce reports on the response of *Ph. divaricata* to even the main generally used herbicides although such information would be very important for control this newly introduced weed in corn. There was an interaction between herbicide rate by location interaction for *Ph. divaricata* control 15 and 30 DAT. Therefore, the current control data are presented by separate locations.

Symptoms of mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA injury in *Ph. divaricata* were described by chlorosis and general growth reduction causing to final death. Herbicide symptoms were not visible until 15 DAT, the first ranking date on which control was recorded. Research conducted in Eslamabad-e-Gharb resulted in higher control of *Ph. divaricata* by either mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA at 15 and 30 DAT in comparison with Mahidasht observations (Table 4). Differences detected between two sites are likely due to the difference in climate conditions. Furthermore, results clearly

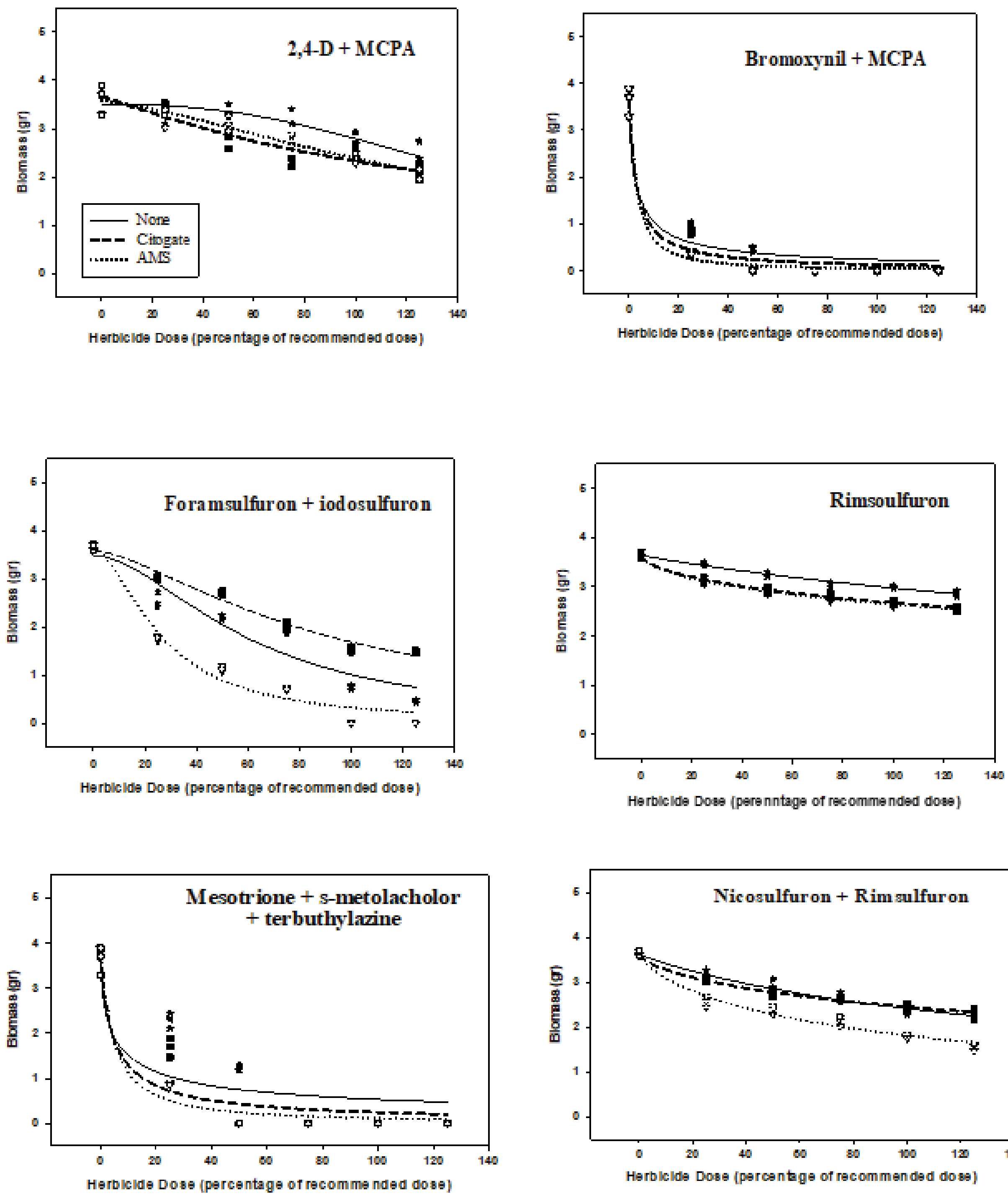

Figure 1: Response of *Physalis divaricate* following foliar applications of various doses of mesotrione + s-metolacholor + terbuthylazine, bromoxynil + MCPA, foramsulfuron + iodosulfuron, 2,4-D + MCPA, rimsulfuron and nicosulfuron + rimsulfuron applied alone and in combination with AMS and citogait. Data are replication of dry biomass reduction of weed, which are fitted to a 3-paramere logistic model

Table 3: Parameter estimates of the three-parameter sigmoid model fitted to dry biomass reduction of *Physalis divaricata* following foliar applications of various doses of different herbicides applied alone and in combination with AMS and citogate

Treatment	G_{max}*	* ED_{50}	G_{rate}*	RMSE	R^2
2,4-D+MCPA	3.51 (0.10)	173.13 (24.75)	2.47 (0.83)	0.24	0.76
2,4-D+MCPA +Citogate	3.68 (0.14)	167.21 (28.38)	1.05 (0.24)	0.25	0.83
2,4-D +MCPA +AMS	3.57 (0.09)	161.29 (15.20)	1.45 (0.26)	0.17	0.90
Bromoxynil + MCPA	3.66 (0.17)	3.00 (1.48)	0.76 (0.22)	0.30	0.95
Bromoxynil + MCPA +Citogate	3.64 (0.15)	3.00 (1.67)	0.94 (0.37)	0.26	0.96
Bromoxynil + MCPA +AMS	3.63 (0.08)	3.00 (1.48)	1.22 (0.67)	0.14	0.99
Foramsulfuron + iodosulfuron	3.48 (0.19)	61.00 (6.43)	1.80 (0.31)	0.34	0.91
Foramsulfuron + iodosulfuron + Citogate	3.60 (0.07)	91.74 (3.80)	1.47 (0.11)	0.12	0.97
Foramsulfuron + iodosulfuron + AMS	3.62 (0.13)	26.25 (2.36)	1.73 (0.21)	0.23	0.97
Rimsulfuron	3.64 (0.06)	508.82 (181.24)	0.92 (0.21)	0.12	0.85
Rimsulfuron + Citogate	3.63 (0.02)	534.32 (74.20)	0.60 (0.04)	0.05	0.98
Rimsulfuron + AMS	3.63 (0.03)	508.22 (70.41)	0.59 (0.04)	0.05	0.98
Mesotrione + s-metolacholor + terbuthylazine	3.83 (0.43)	5.00 (2.29)	0.61 (0.17)	0.74	0.75
Mesotrione + s-metolacholor + terbuthylazine + Citogate	3.71 (0.30)	5.00 (2.32)	0.88 (0.27)	0.52	0.87
Mesotrione + s-metolacholor + terbuthylazine + AMS	3.65 (0.14)	5.00 (2.85)	1.13 (0.45)	0.25	0.97
Nicosulfuron + rimsulfuron	3.63 (0.12)	215.50 (46.62)	0.89 (0.20)	0.21	0.84
Nicosulfuron + rimsulfuron + Citogate	3.63 (0.04)	306.51 (38.11)	0.64 (0.06)	0.07	0.97
Nicosulfuron + rimsulfuron + AMS	3.62 (0.07)	100.46 (8.14)	0.76 (0.08)	0.12	0.97

*G_{max} is the maximum germination (%), ED_{50} is the herbicide concentration for 50 % reduction in above dry biomass of weed, and G_{rate} indicates the slope

showed that as herbicide rate increased, *Ph. divaricata* control also increased. For both locations and regardless of adjuvant (AMS), bromoxynil + MCPA was more effective than mesotrione + s-metolacholor + terbuthylazine in the control of *Ph. divaricata* (Table 4).

There was a significant AMS by herbicide rate interaction on biomass reduction of annual ground cherry. However, treatment by location interaction was not significant. Hence, the biomass reduction data were pooled across the locations. Similar to the control data, *Ph. divaricata* control increased as herbicide rate increased with and without AMS (Table 5). Likewise, bromoxynil + MCPA reduced the biomass of *Ph. divaricata* more efficiently when compared to mesotrione + s-metolacholor + terbuthylazine (Table 5). Applying 75 % of the recommended dose of bromoxynil + MCPA provided more than 80 % control of *Ph. divaricata* regardless of AMS, but even the highest rate of mesotrione + s-metolacholor + terbuthylazine resulted in lower than 90 % control at 15 and 30 DAT. However, by utilizing complete dose of bromoxynil + MCPA plus AMS, *Ph. divaricata* control was 100 % at 30 DAT. Bromoxynil + MCPA is premixed and formulated herbicide that controls broadleaved weeds (Vencill 2002). Bromoxynil + MCPA can provide excellent suppression of some problematic weeds such as *Ambrosia artemisiifolia* L., *Abutilon theophrasti* Medik., *Capsella bursa-pastoris* (L.) Medik., *Polygonum convovulus* L., *Polygonum persicaria* L., *Sinapis arvensis* L., *Solanum* spp., *Thlaspi arvense* L., and *Xanthium strumarium* L. (Soltani et al., 2006); Sheibany et al., 2009). Their research found that using bromoxynil + MCPA as a POST-treatment can effectively control *Portulaca oleracea* L., *Convolvulus arvensis* L., *Amaranthus retroflexus, Chenopodium album* in corn. However, control of *Amaranthus blitoides* S.Wats. was not sufficient.

Zand et al. (2009b) showed that mesotrione + s-metolacholor + terbuthylazine is able to effectively control *P. oleracea, Ch. album, Setaria* spp.,_and *Hibiscus trionum* L.. However, the control of *Sorghum halepense* (L.) Pers. by this herbicide was poor (Zand et al., 2009b). Be-

Table 4: Effect of various doses of mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA herbicides on *Physalis divaricata* control 15 and 30 days after treatment (DAT) at Eslamabad and Mahidasht Research Centers

				%Control	
Location	Herbicide	Rate	Adjuvant	15 DAT	30 DAT
		% of Recommended herbicide dose			
Eslamabad-e-Gharb	Bromoxynil + MCPA	50	-	16.67 p	21.67 k
			AMS	36.67 m	40.67 i
		75	-	58.33 jk	71.67 e
			AMS	69.33 h	71.67 e
		100	-	79.33 de	94.00 b
			AMS	89.00 b	100.00 a
	Mesotrione + s-metolacholor + terbuthylazine	50	-	21.67 o	41.67 i
			AMS	36.00 m	48.33 h
		75	-	51.67 l	55.00 g
			AMS4	56.67 k	66.67 f
		100	-	61.00 ij	83.33 cd
			AMS	71.67 gh	100.00 a
Mahidasht	Bromoxynil + MCPA	50	-	22.00 o	35.00 j
			AMS	34.00 n	50.00 h
		75	-	73.00 gh	85.00 c
			AMS	78.00 ef	100.00 a
		100	-	87.00 bc	100.00 a
			AMS	100.00 a	100.00 a
	Mesotrione + s-metolacholor + terbuthylazine	50	-	33.00 n	40.00 i
			AMS	52.00 l	50.00 h
		75	-	70.00 h	70.00 ef
			AMS	75.00 fg	70.00 ef
		100	-	63.00 i	80.00 d
			AMS	83.00 cd	90.00 b

Means in a column with the same letter are not significantly different

tween the locations, bromoxynil + MCPA was found to be more effective in managing *Ph. divaricata* compared to mesotrione + s-metolacholor + terbuthylazine (Table 4 and 5). Based on the controlled weed by bromoxynil + MCPA, the results of current study are expected. The results of field surveys showed that the addition of AMS improve *Ph. divaricata* control by either mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA, especially at lower herbicide doses (Table 4 and 5). Collectively, AMS had higher ability in increasing the efficacy of bromoxynil + MCPA compared to mesotrione + s-metolacholor + terbuthylazine. For instance, addition of AMS to 50 % of label dose of bromoxynil + MCPA improved *Ph. divaricata* control by 10 % in comparison to herbicide alone while this value was negligible in the respect dose of mesotrione + s-metolacholor + terbuthylazine (Table 5). Adding AMS to 75 % recommended dose of bromoxynil + MCPA resulted in complete reduction of biomass of *Ph. divaricata* (Table 5).

The present results are in agreement with those of similar studies in which control of weeds was improved by adding AMS to various herbicides (Zollinger et al.,

Table 5. Effect of various doses of mesotrione + s-metolacholor + terbuthylazine and bromoxynil + MCPA herbicides on biomass of *Physalis divaricata* when data pooled over location

Herbicide	Rate	Adjuvant	Biomass reduction
	% of Recommended herbicide dose		% of untreated
Bromoxynil + MCPA	50	-	27.49 c
		AMS	38.39 c
	75	-	84.69 ab
		AMS	100.00 a
	100	-	100.00 a
		AMS	100.00 a
Mesotrione + s-metolacholor + terbuthylazine	50	-	35.18 c
		AMS	36.26 c
	75	-	67.99 b
		AMS	68.50 b
	100	-	72.99 b
		AMS	82.84 ab

Means with the same letter are not significantly different

2011; Tanveer et al., 2015). It has been well confirmed that the addition of AMS to herbicide tank mixture could improve the control of *A. theophrasti* by herbicides (Maschhoff et al., 2000; Young et al., 2003; Guza et al., 2002; Krausz et al., 1996). In addition, dust storm is a predominant phenomenon in western parts of Iran. Therefore, most likely the increasing of herbicide efficacy could be attributed to overcoming the adverse impact of dust particles on herbicide performance (Mathiassen et al., 1999; Zhou et al., 2006).

4 CONCLUSION

Results clearly showed that 2, 4-D + MCPA, rimsulfuron and nicosulfuron + rimsulfuron are not suitable options to control *Ph. divaricate* in corn. In conclusion, current study indicated that either mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA, particularly bromoxynil + MCPA can be used for successfully control of *Ph. divaricata* in corn. Furthermore, AMS was very efficient adjuvant in increasing the performance of mesotrione + s-metolacholor + terbuthylazine or bromoxynil + MCPA, against *Ph. divaricata.* These herbicides provide corn growers an herbicide options that can control *Ph. divaricata* and probably other weed species which are not affected by other regularly used herbicide options.

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