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Response of redroot pigweed (*Amaranthus retroflexus* L.) to tank mixtures of 2,4-D plus MCPA with foramsulfuron

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Abstract

Mixture of herbicides could help to control wide range of weed floras, postpone resistance to herbicides and reduce herbicides application. A greenhouse study was conducted to assess the effect of individual post-emergence application of 2,4-D plus MCPA in combination with foramsulfuron at two growth stages of redroot pigweed (*Amaranthus retroflexus* L.). Treatments comprised of untreated control and six rates (67.5, 202.5, 405, 607.5, 810 and 1012.5 g a.i. ha^{-1}) of 2,4-D plus MCPA, which applied alone or in combination with constant rate of 450 g a.i. ha^{-1} of foramsulfuron. Weeds were sprayed at two- to four- and four- to six-true leaf stages of redroot pigweed. Mixtures were appreciably more effective on redroot pigweed at 4-6 leaf stage compare to 2,4-D plus MCPA, when applied singly. So it is possible to use reduced rates of 2,4-D plus MCPA when combined. However, in 2-4 leaf stage, single application of 2,4-D plus MCPA had better effect compared to combination with foramsulfuron. It seems that at this growth stage of redroot pigweed common and restricted entrance routs of both herbicides have decreased the rate of herbicide absorption and translocation in mixture compared to using 2,4-D plus MCPA.

Keywords*:* combination, dose response curve, growth stage, regression model, sulfonylurea.
Abbreviations*:* 2,4-D- (2,4-dichlorophenoxy) acetic acid; a.i.- Active ingredient; ALS- Acetolactate synthase; DAT- Days after treatment; ED- Effective dose; Foramsulfuron- 1-(4,6-dimethoxypyrimidin-2-yl)-3-[2-(dimethylcarbamoyl)-5-formamidophenylsulfonyl] urea; MCPA- (4-chloro-2-methylphenoxy) acetic acid; POST- Postemergence; R- Relative potency.

Introduction

Evolution of weeds resistant to herbicides, economic aspects of application of chemicals, negative effects on the environment and the risk of food contamination have forced human to determine alternative weed management strategies. This will help to minimize herbicides application rate, resistance and costs for weed control (Coble, 1994). To date, musk thistle (*Carduus nutans* L.), Italian thistle (*Carduus pycnocephalus* L.), Canada thistle [*Cirsium arvense* (L.) Scop.], spreading dayflower (*Commelina diffusa* Burm. f.), field bindweed (*Convolvulus arvensis* L.), wild carrot (*Daucus carota* L.), globe fringerush [*Fimbristylis miliacea* (L.) Vahl], prickly lettuce (*Lactuca serriola* L.), and Indian hedge mustard (*Sisymbrium orientale* Torn.) have been reported as resistant weeds to 2,4-D (Heap, 2008). Two new 2,4-D resistant weed species have been reported in the last decade (Heap, 2008). Also, development of ALS-resistant weeds substantiates the use of non-ALS-inhibiting herbicides as a component of a mixture for broadleaf weed control (Manley et al., 1998; Ohmes and Kendig, 1999). Growth regulator herbicides like 2,4-D complements ALS-inhibitor herbicides for postemergence (POST) broadleaf weed control (Hart, 1997; Isaacs et al., 2002; Kalnay et al., 1995; Parks et al., 1995). Foramsulfuron is a sulfonylurea herbicide that has recently been registered for weed control in corn (Nurse et al., 2007). In Ontario, foramsulfuron is registered for application at a rate of 35 g a.i. ha^{-1} in eight-leaf stage of corn (OMAF, 2004). Susceptible plants are controlled through inhibition of the acetolactate synthase enzyme, preventing the production of branched-chain amino acids (Vencill, 2002). The registered rate of herbicides may be higher than the rate required for control of the most economically important weed species depending on location (Nurse et al., 2007). Also, in post-emergence programs, the use of herbicides at reduced doses is one of the most important tools to limit herbicide input into the environment based on Integrated Weed Management System (IWMS) (Swanton and Weise, 1991; Berti et al., 2001). Soltani et al. (2005) demonstrated that the herbicide flufenacet plus metribuzin applied at a rate of 670 g ha^{-1} (170 g ha^{-1} lower than registered rate) provided more than 90% control of redroot pigweed, common lambsquarters (*Chenopodium album* L.) and common ragweed (*Ambrosia artemisiifolia* L.) in soybean fields in southwestern Ontario. The determination of ‘‘minimum dose requirment for a satisfactory efficacy’’ (MDRE) requires dose–response studies for each ‘‘herbicide-weed species’’ under various environmental conditions (Kudsk and Kristensen, 1992; Jensen and Streibig, 1994; Rydahl, 1995). The reduction of doses with respect to the labeled is possible, but enough care is required to avoid escaping situations, where the presence of one unsusceptible weed species would hinder the overall effectiveness of weed control, as already observed with other herbicides (Covarelli and Pannacci, 2000). In such cases, it is necessary to use a mixture of herbicides (also at reduced doses) to improve the efficacy and broaden the weed control spectrum (Green and Streibig, 1993). Tank mixing two or more herbicides is a common practice that is increasingly used in most agronomic crops to control a wide spectrum of weeds, reduce production cost, and/or prevent the development of herbicide-resistant weeds (Zhang et al., 1995). Several studies have demonstrated the benefits of auxin-type herbicides combination with ALS inhibitor herbicides to enhance weed control. Preliminary research at Kansas State University with metsulfuron + 2,4-D tank mixes has shown good control of Palmer amaranth (*Amaranthus palmeri* S. Wats), redroot pigweed, velvetleaf (*Abutilon theophrasti* Medicus) and ivyleaf morningglory (*Ipomoea hederacea* (L.) Jacq.) (Regehr 1997). Brown et al. (2004) reported that application of Metsulfuron alone controlled 45 to 60% of ivyleaf morningglory and its controlling efficiency increased when metsulfuron was tank mixed with 2,4-D, dicamba, and fluroxypyr. Also, Metsulfuron applied alone controlled 68 to 79% of velvetleaf and its effect increased when metsulfuron was tank mixed with 2,4-D or fluroxypyr. Isaacs et al. (2006) observed synergistic relationship between 2,4-D and halosulfuron over the range of dosages when these herbicides mixed to control the common lambsquarters in corn. More researches conducted to determine effects of 2,4-D plus MCPA and foramsulfuron individually on redroot pigweed. In our knowledge no data exists to evaluate 2,4-D plus MCPA in combination with foramsulfuron on redroot pigweed. In this study 2,4-D plus MCPA was applied in the greenhouse in combination with foramsulfuron at two phenological stages to determine (1) if this combination provides better weed control and (2) if lower dose of 2,4-D plus MCPA for satisfactory control of redroot pigweed is sufficient than application of 2,4-D plus MCPA individually.

Materials and methods

Site description

An experiment was conducted in 2008 at the greenhouse of Agricultural Faculty of Ferdowsi University of Mashhad, Iran (Lat 36˚15' N, Long 59˚28' E; 985 m Altitude). In this experiment, effects of 2,4-D plus MCPA in combination with foramsulfuron on redroot pigweed was studied in different doses of 2,4-D plus MCPA. Redroot pigweed seeds after collecting from corn fields, placed in 11 cm diameter glass Petri dishes lined with a single layer of Wathman No.1 filter paper. Ten ml of KNO_3 solution (2 g L^{-1}) was added to each Petri dish. Petri dishes were transferred to a refrigerator at 8-9 °C in the dark for 1 week, then, placed in an incubator under a 20-10 °C and 45-65% relative humidity day/night with a 16-h photoperiod to germinate the seeds. Seeds were planted at 2 L-plastic pots after germination. Pots were placed in the greenhouse and seeds emerged and grown with temperatures maintained at 24/18°C day/night. Natural sunlight was supplemented with metal halide lamps producing 14 h of photoperiod. After emergence and development of the first true leaf, plants with uniform height were selected and thinned to four plants per pot for greenhouse studies. The soil texture was silt loam (19.8% sand, 20.1% clay, 58% silt, 4.1% organic matter and a pH of 6.7) and was sterilized at 180°C for 2.5 hours. No fertilizer was used and the soil moisture was kept at or near field capacity by watering.

Experimental design and treatments

The experiment was a randomized complete block design with four replications. Treatments consist of six rates (67.5, 202.5, 405, 607.5, 810 and 1012.5 g a.i. ha^{-1}) of 2,4-D plus MCPA SL 67.5% alone and tank mixing with foramsulfuron OD 22.5% at 450 g a.i. ha^{-1} at two- to four- and four- to six-true leaf stages of redroot pigweed. An untreated check was included for each growth stage. Herbicide applications for each stage analyzed separately. Herbicides were mixed to assess the compatibility and sedimentation before tank mixing. Plants were sprayed by greenhouse bench sprayer delivering 200 L/ha at 200 kPa utilizing a flat-fan spray nozzle. Five days after spraying, control percentages of plants were evaluated by visual rating. Visual observations were recorded every five days until 25 days after treatment (DAT). The scale used for percent injury ranged from 0 (no visible injury) to 100% (complete death) as approved by the Weed Science Society of America. All aboveground plant organs were cut 4 weeks after treatment from the soil surface and oven-dried at 70°C for 48 h and weighed.

Statistical analysis

Visual injury data were subjected to analysis of variance (ANOVA) using the PROC GLM procedure of SAS (Ver. 9.1, SAS Inst., Cary, NC, 2004, USA) and means of the treatments were separated using Fisher's protected LSD Test at $P \leq 0.05$. Analysis of variance and mean separations were performed after the percent injury data were normalized by arcsine square root transformation where it was required. Means of percent injury were compared on the transformed scale and were converted back to the original scale for presentation of results. The dose–response curves for each herbicide and stage were fitted simultaneously with the Four-Parameter Gompertz Model using the drc add-on package to the programme R:

$$f(x,(b,c,d,e)) = c + (d-c)\exp\{-\exp\{b(\log(x)-e)\}\} \quad \text{(Eq. 1)}$$

Where c and d denote the lower and upper limit of dry matter at highest and zero doses of 2,4-D plus MCPA, b is the relative slope around e, and the e parameter is denoted ED_{50} and it is the dose producing a response half-way between the upper limit d, and lower limit c. The ED_{50} parameter can be replaced by any ED level, so the selected model was used to estimate the dose of 2,4-D plus MCPA required to obtain 80 and 90% weed control when applied individually or in combination with foramsulfuron defined as ''MDRE'' (ED_{80} and ED_{90} values). The goodness-of-fit was assessed by graphical analyses of residuals and F-test for lack-of-fit (Ritz and Streibig, 2005). Also, optimal Box-Cox transform-both-sides approach was done to variance homogeneity of the response. Relative potency (R) is the parameter to display herbicide efficacy and was calculated by dividing ED_{50}, ED_{80} and ED_{90} of 2,4-D plus MCPA to its mixture with foramsulfuron, so that R=1 shows that adding foramsulfuron has not any effect on efficacy of 2,4-D plus MCPA, but R<1 and R>1 indicate that foramsulfuron combination decreases and increases efficacy of 2,4-D plus MCPA compare to its application alone, respectively. Relative potency was calculated as:

$$R = \frac{ED_{50,80,90(2,4-D+MCPA)}}{ED_{50,80,90(2,4-D+MCPA+Foramsulfuron)}} \quad \text{(Eq. 2)}$$

Results

Mixture and individual application of 2,4-D plus MCPA were more effective at recommended dose compared to minimum dose at both phenological stages of redroot pigweed (Two- to four- and four- to six-true leaf stage). Visual assessment showed that 607.5 g a.i. ha^{-1} of 2,4-D plus MCPA results in 90 percent control of redroot pigweed 10 days after treatment at two- to four-true leaf stage. While, this control of redroot

Table 1. Visual observations of redroot pigweed control percentage (5, 10, 15, 20 and 25 days after treatments) at two- to four-true leaf stage.

Treatments	Rate	Two- to four-true leaf stage		
		5 DAT[b] (10 DAT)	15 DAT (20 DAT)	25 DAT
	g a.i. ha^{-1}	% control		
None	0	0	0	0
2,4-D plus MCPA	67.5	20.25 f[a] (22.5 e)[c]	24.5 d (25.25 d)	26.5 e
2,4-D plus MCPA with Foramsulfuron	67.5+450	18.5 f (19.75 e)	21.75 d (23.5 d)	24.75 e
2,4-D plus MCPA	202.5	60 e (61.25 d)	63.75 c (66.25 c)	68.75 d
2,4-D plus MCPA with Foramsulfuron	202.5 + 450	57.5 e (62.5 cd)	68.75 bc (68.75 c)	67.5 d
2,4-D plus MCPA	405	67.5 de (70 cd)	73.75 bc (78.75 bc)	80 cd
2,4-D plus MCPA with Foramsulfuron	405 + 450	63.75 e (65 cd)	70.5 bc (72.5 bc)	78.75 c
2,4-D plus MCPA	607.5	83.25 bc (96.25 ab)	100 a (100 a)	100 a
2,4-D plus MCPA with Foramsulfuron	607.5 + 450	77.5 cd (78.75 c)	84 b (88.75 ab)	93.75 b
2,4-D plus MCPA	810	87 abc (96.5 ab)	100 a (100 a)	100 a
2,4-D plus MCPA with Foramsulfuron	810 + 450	92.75 a (92.75 ab)	96 a (100 a)	100 a
2,4-D plus MCPA	1012.5	91.25 ab (98.75 a)	100 a (100 a)	100 a
2,4-D plus MCPA with Foramsulfuron	1012.5 + 450	93 a (93.5 ab)	96.75 a (100 a)	100 a

[a] Means within each column followed by the same letter are not significantly different at the 0.05 probability level according to Fisher's protected LSD Test. [b] DAT: days after treatments.[c] Values in parentheses represent control 10 and 20 days after POST applications.

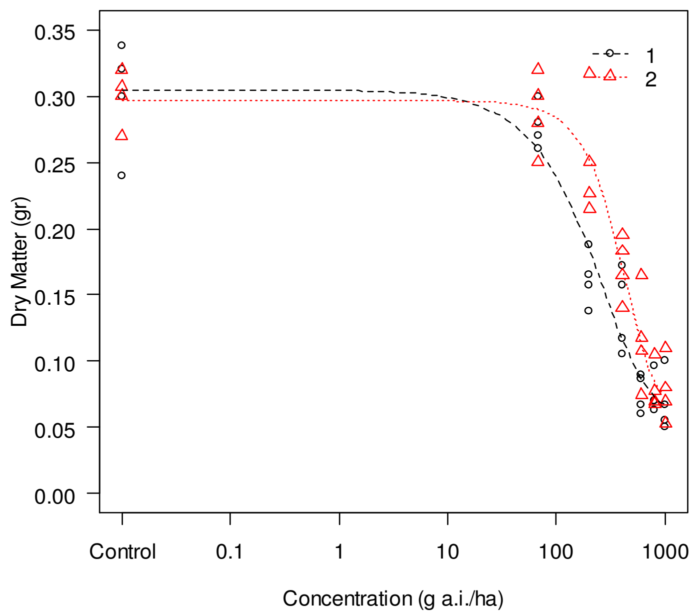

Fig 1. Dose-response curve for 2,4-D plus MCPA (circle shape) and its combination with commercial formulation of foramsulfuron (Equip) (triangle shape) on two- to four-true leaf stage of redroot pigweed.

pigweed is obtained 25 days after treatment at 607.5 g a.i. ha^{-1} of 2,4-D plus MCPA, mixed with foramsulfuron. At the four- to six-true leaf stage, individual application of 2,4-D plus MCPA led to 90 percent control of redroot pigweed, 15 and 20 days after treatment at 607.5 g a.i. ha^{-1}. In contrast, 2,4-D plus MCPA mixed with foramsulfuron caused up to 90 percent control of weed, 20 days after treatment at 405 g a.i. ha^{-1} dose (Table 1 and 2). Based on our observations, effects of 2,4-D plus MCPA at recommended dose resulted occurring of symptoms such as chlorosis and epinasty of the leaves (especially in petioles and blades) and stems. Petioles showed the highest rate of epinastic effects in comparison with other parts of plants. Also, redroot pigweed indicated epinastic symptoms when rate of 2,4-D plus MCPA in combination with foramsulfuron increased. But these symptoms in combination with foramsulfuron were less apparent than 2,4-D plus MCPA applied alone. Instead, symptoms of albinism were observed when herbicide mixture used. Both single and combined applications were effective at higher doses. However, the dose-response curve of redroot pigweed on aboveground dry matter showed that single application of 2,4-D plus MCPA was more effective for controlling redroot pigweed at 2-4 leaf stage compare to its mixture. We used higher herbicide rate of 2,4-D plus MCPA in mixture with foramsulfuron for satisfactory control of redroot pigweed, whereas lower rate of 2,4-D plus MCPA alone achieved sufficient control of redroot pigweed.(Fig. 1). Minimum dose requirement for a satisfactory efficacy of 90% reduction of redroot pigweed aboveground dry matter were 597.66 and 704.93 g a.i. ha^{-1} of 2,4-D plus MCPA application

Table 2. Visual observations of redroot pigweed control percentage (5, 10, 15, 20 and 25 days after treatments) at four- to six-true leaf stage.

Treatments	Rate	Four- to six-true leaf stage		
		5 DAT[b] (10 DAT)	15 DAT (20 DAT)	25 DAT
	g a.i. ha^{-1}	% control		
None		0	0	0
2,4-D plus MCPA	67.5	14.25 g[a] (17.5 e)[c]	19.75 e (21 d)	21.75 e
2,4-D plus MCPA with Foramsulfuron	67.5+450	10.5 g (14.75 e)	17.75 e (21.5 d)	22.25 e
2,4-D plus MCPA	202.5	46.25 e (47.5 d)	50 d (53.75 c)	55 d
2,4-D plus MCPA with Foramsulfuron	202.5+450	28.75 f (38.75 d)	45 d (52.5 c)	56.25 d
2,4-D plus MCPA	405	68.75 cd (70 c)	78.75 bc (78.75 b)	78.75 c
2,4-D plus MCPA with Foramsulfuron	405+450	62.5 d (70 c)	77 c (90 ab)	94.5 b
2,4-D plus MCPA	607.5	68.75 cd (79.75 b)	91.25 ab (93.75 a)	98.75 ab
2,4-D plus MCPA with Foramsulfuron	607.5+450	70 cd (84.75 ab)	90 ab (91.25 ab)	97.5 ab
2,4-D plus MCPA	810	76.75 bc (83.25 ab)	92.5 ab (100 a)	100 a
2,4-D plus MCPA with Foramsulfuron	810+450	80.5 b (86 ab)	92.5 ab (100 a)	100 a
2,4-D plus MCPA	1012.5	78.75 b (86.25 ab)	100 a (100 a)	100 a
2,4-D plus MCPA with Foramsulfuron	1012.5+450	89.5 a (90 a)	97 a (100 a)	100 a

[a]Means within each column followed by the same letter are not significantly different at the 0.05 probability level according to Fisher's protected LSD Test. [b]DAT: days after treatments.[c] Values in parentheses represent control 10 and 20 days after POST applications.

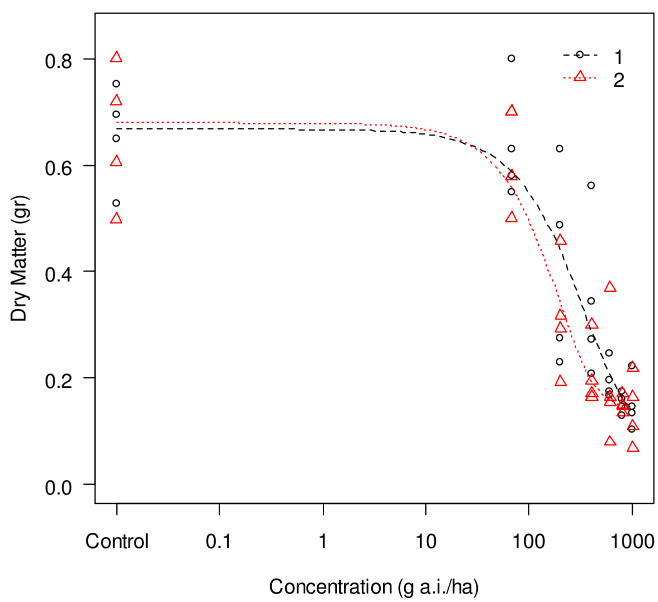

Fig 2. Dose-response curve for 2,4-D plus MCPA (circle shape) and its combination with commercial formulation of foramsulfuron (Equip) (triangle shape) on four- to six-true leaf stage of redroot pigweed.

and its mixture with foramsulfuron, respectively. These results show that rates of 2,4-D plus MCPA can be less than recommended dose (1012.5 g a.i. ha^{-1}), if controlling operations is done at this growth stage (Table 3). Application of 2,4-D plus MCPA with foramsulfuron was more effective than 2,4-D plus MCPA alone at 4-6 leaf stage. So the results of regression model, ED_{50}, ED_{80} and ED_{90} indicated that herbicides combination has more benefit to control weed than application of 2,4-D plus MCPA. Also, value of relative potency parameter showed that adding foramsulfuron as mixture to 2,4-D plus MCPA increased the efficacy of this herbicide and allowed us to use the lower rate of 2,4-D plus MCPA to sufficiently control of redroot pigweed (Fig. 2 and Table 3). Minimum dose requirement for a satisfactory control (90% reduction in weed aboveground dry matter) were 725.71 and 388.9 g a.i. ha^{-1} of 2,4-D plus MCPA and its mixture with foramsulfuron, respectively. Apparently, 2,4-D plus MCPA in combination with foramsulfuron at four- to six-true leaf stage leads to better control of redroot pigweed (Table 3).

Discussion

We concluded that less effects of 2,4-D plus MCPA with commercially formulated foramsulfuron compared to 2,4-D plus MCPA at two- to four-ture leaf stage can be due to inadequate growth of redroot pigweed. In addition, competition of herbicides on the base of inadequately grown weed can be the possible cause of low efficacy of herbicides at two- to four leaf stage. Isaacs et al. (2006) reported that 2,4-D does not seem to affect the absorption and translocation of ^{14}C-halosulfuron in common lambsquarters, regardless of the rate of applied commercially formulated halosulfuron.

Table 3. Evaluation of curve slope, ED_{50}, ED_{80}, ED_{90} and relative potency of 2,4-D plus MCPA applied alone and in mixture with foramsulfuron.

Two- to four-true leaf stage	Curve slope (b)	ED_{50}[a] (g a.i. ha^{-1})	ED_{80} (g a.i. ha^{-1})	ED_{90} (g a.i. ha^{-1})	Relative potency (R)		
					ED_{50}	ED_{80}	ED_{90}
2,4-D plus MCPA	1.10 (0.2)[b]	201.45 (34.03)	432.08 (81.5)	597.66 (137.2)	1.00	1.00	1.00
2,4-D plus MCPA+ Foramsulfuron	1.86 (0.4)	369.72 (40.2)	581.48 (69.9)	704.93 (108.02)	0.54 (0.1)	0.74 (0.2)	0.84 (0.2)
Four- to six-true leaf stage							
2,4-D plus MCPA	1.12 (0.4)	250.55 (70.5)	528.42 (161.5)	725.71 (278.9)	1.00	1.00	1.00
2,4-D plus MCPA+Foramsulfuron	1.24 (0.5)	148.24 (38.6)	291.7 (75.9)	388.9 (127.3)	1.69 (0.6)	1.81 (0.7)	1.86 (0.9)

[a]ED_{50}, ED_{80} and ED_{90} were assumed as ''minimum doses requirement for satisfactory efficacy, MDRE''. [b]Standard errors are in parentheses.

Presence of effective dose of herbicides in the site of action is very important. Because of herbicides competition (smaller leaf area and lower stomata), none of herbicides has been in effective dose in the site of action. Hence, they have needed a long time to gain effective dose in the site of action. On the other hand, when the absorption and translocation of herbicides decreased, lower rate of herbicides is flow able in the plant. Thus, plant has a chance to produce enzymes that metabolize herbicide molecules, conjugate their molecules to other molecules such as glucose or store them in the cellular organelles such as vacuole. There are many metabolic ways metabolizing ALS inhibitor herbicides. Some of these metabolic ways include alkylation, ring hydroxylation and glucose conjugation. Phenoxy herbicides are metabolized by oxydation, hydrolysis and conjugation. Therefore, efficacy of herbicides in combination has been decreased in comparison with 2,4-D plus MCPA alone at two- to four-true leaf stage.

. In contrast, 2,4-D plus MCPA alone presumably has been absorbed and translocated adequately in effective dose in the site of action, without entrance directions competitor and has controlled this weed even at lower rates. Palmer et al. (2000) reported that the excellent hemp sesbania (*Sesbania exaltata*) can be controlled with CGA-277476 alone due to a lower weed population and smaller weeds (Two- to four-leaf stage and 2 to 8 cm tall) compared to its combination with aciflurofen, chlorimuron, fomesafen or imazaquin. It seems that redroot pigweed has adequate growth, large leaves, more transition of elaborated sap and entrance directions for each other compounds at the four- to six-true leaf stage of development. Glyphosate translocated more rapidly and extensively in 15 cm plants than in 2.5 cm plants of common lambsquarters (Schuster et al., 2007). Greater translocation in more-developed common lambsquarters plants may be attributed to a larger carbohydrate sink in these plants (Hennigh et al., 2005). Furthermore, oily nature of foramsulfuron probably have had notable effect on dissolving cuticular wax of the leaf surface followed by well absorption and translocation of herbicides and therefore better control of redroot pigweed was achieved compared to 2,4-D plus MCPA application alone. The age of weeds can increased their tolerance to herbicides. Also, as weed age accumulation of herbicides per unit of plant tissue decreases in relation to herbicide rates that we use for weed control.

Thus, we used higher rates of 2,4-D plus MCPA at four- to six-true leaf stage compared to two- to four-true leaf stage. Limited injury from glyphosate in 15 cm compared to 2.5 cm common lambsquarters may be partly attributed to less glyphosate accumulation per plant unit tissue (Schuster et al., 2007). If herbicides did not prevent efficacy of each other in the mixture application, weeds need to metabolized molecules of herbicides at two site of action and this is often impossible. Therefore, aboveground dry matter of redroot pigweed has been decreased more efficiently, even at lower rates in mixture application, than 2,4-D plus MCPA alone at four- to six-growth stage. Based on the results of Bunting et al. (2005) POST tank mixtures of foramsulfuron with atrazine and dicamba improved control of Pennsylvania smartweed, common cocklebur, velvetleaf, common lambsquarters and common waterhemp (*Amaranthus rudis* Sauer.) when compared to foramsulfuron applied alone. There is also competition between two herbicides for absorption and translocation at four- to six-true leaf stage. But each of herbicides has been able to translocate to the site of action in effective dose because of more entrance directions. Hence, they have affected timely, while this effect has been done on delay at two- to four-true leaf stage. Palmer et al. (2000) explained that CGA-277476 alone controlled hemp sesbania, pitted morningglory (*Ipomoea lacunosa*), entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula*), horse purslane (*Trianthema portulacastrum*) and prickly sida (*Sida spinosa*) when applications were made to young, actively growing weeds. However, when dealing with older weed, the addition of another POST herbicide improved the control over CGA-277476 alone.

Conclusion

In conclusion, 2,4-D plus MCPA mixed with foramsulfuron had sufficient control of redroot pigweed at the both of phenological growth stages and we may reduce the rates of 2,4-D plus MCPA at four- to six-true leaf stage. But combination of herbicides at two- to four-true leaf stage, in some extent, leads to interference of herbicides with one another's absorption and translocation. Though, it is required to apply higher rates of 2,4-D plus MCPA with foramsulfuron at two- to four-true leaf stage compare to 2,4-D plus MCPA alone. Economically, it is feasible to control most of weed species, especially resistant redroot pigweed to one of herbicides and slowing down the selection pressure to delay development of resistance to herbicides in herbicides mixture compare to using single herbicide. On the other hand, curve slope for 2,4-D plus MCPA mixed with foramsulfuron at two phenological stages indicated that this combination result in rapid weed suppression compare to 2,4-D plus MCPA alone. Next research is required to examine the effects of foramsulfuron on absorption, translocation and metabolism of 2,4-D plus MCPA.

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