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Article

DIFFERENTIAL TOLERANCE OF PUMPKIN SPECIES TO BENTAZON, METRIBUZIN, TRIFLURALIN, AND OXYFLUORFEN

Tolerância Diferencial de Espécies de Abóbora a Bentazon, Metribuzin, Trifluralin e Oxifluorfen

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ABSTRACT - Response of pumpkin species including *Cucurbita pepo* convar. *Pepo*, *Cucurbita moschata* Duch, *Cucurbita pepo*, *Cucurbita maxima*, and *Lagenaria vulgaris* to bentazon, trifluralin, metribuzin, and oxyfluorfen was evaluated in Outdoor pot experiments in 2014 and 2015. Different postemergence doses (bentazon and oxyfluorfen) and preplant incorporated (metribuzin and trifluralin) herbicides were evaluted on pumpkin species at various growth stages. Results showed that the sensitivity of pumpkins species to applied herbicide varied greatly among tested species. On overall, dry weights of *Cucurbita* spp. were reduced by 12.50%, 48.60%, 23%, and 73.13% when pumpkin was treated with trifluralin, metribuzin, bentazon and oxyfluorfen, respectively. Pumpkin crops were not tolerant of metribuzin and oxyfluorfen and plants showed injures. Results indicated that trifluralin and bentazon have the potential for possible application in pumpkin particularly when broadleaf weeds are dominant.

Keywords: broadleaf weeds, crop, dominant weeds, sensitivity.

*RESUMO - A reação de espécies de abóbora, incluindo **Cucurbita pepo** convar. **Pepo**, **Cucurbita moschata**, **Cucurbita pepo**, **Cucurbita maxima** e **Lagenaria vulgaris**, a bentazon, trifluralin, metribuzin e oxyfluorfen foi avaliada em experimentos com vasos ao ar livre em 2014 e 2015. Diferentes doses em pós-emergência (bentazon e oxifluorfen) e herbicidas incorporados pré-plantio (metribuzin e trifluralin) foram avaliados em espécies de abóbora em vários estádios de crescimento. Os resultados mostraram que a sensibilidade das espécies de abóbora ao herbicida aplicado variou muito entre as espécies testadas. Em geral, o peso seco de **Cucurbita** spp. foi reduzido em 12,50%, 48,60%, 23% e 73,13% quando a abóbora foi tratada com trifluralin, metribuzin, bentazon e oxifluorfen, respectivamente. As culturas de abóbora não foram tolerantes a metribuzin e oxifluorfen, e as plantas apresentaram muitas injúrias. Os resultados indicaram que trifluralin e bentazon têm potencial para aplicação em abóbora, particularmente quando plantas daninhas de folha larga forem dominantes.*

Palavras-chave: plantas daninhas de folha larga, cultura, plantas daninhas dominantes, sensibilidade.

INTRODUCTION

Based on the Food and Agriculture Organization of the United Nations (FAO, 2014), pumpkin production has increased in Iran. Iran's ranking in the top ten pumpkin producing countries had moved from 6th during 2005-2009 to 5th slot in

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2012 (FAO, 2014). Pumpkin crops can play a very important role in enriching the crop rotation in Iranian farmlands which are dominated by cereals such as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*).

Globally, weeds are the main problem for pumpkin growers (Starke et al., 2006; Trader et al., 2007; Walters et al., 2008; Kammler et al., 2010). Redroot pigweed (*Amaranthus retroflexus*), common lambs quarters (*Chenopodium album*), jimsonweed (*Datura stramonium*), field bindweed (*Convolvulus arvensis*) common purslane (*Portulaca oleracea*), foxtails (*Setaria* spp.), johnson grass (*Sorghum halepense*), nightshades (*Solanum* spp.), and common cocklebur (*Xanthium strumarium*) are the most troublesome weeds in Cucurbitaceae crops grown across Iran. The relatively open canopy of Cucurbitaceae makes them very sensitive to weed competition (Mallot and Ashley, 1988; Monks and Schultheis, 1998).

Iranian pumpkin growers typically rely on hand weeding for season-long weed control, which is not economic in most cases. In the Iranian pesticide market, like in other countries there is only a few registered herbicides available to control weeds in pumpkin fields. Among the above mentioned dominant weeds of Iranian pumpkin fields, grasses are readily controlled with ACCase-inhibitor herbicides such as haloxyfop-R-methyl and sethoxydim (Vencill, 2002), which are registered and frequently available for utilization. Nonetheless, Iranian farmers' main problem is chemical control of broadleaf weeds, mainly due to lack of availability of suitable selective herbicides such as halosulfuron (Webster et al., 2003; Theodore et al., 2003; Starke et al., 2006; Trader, 2007).

Bentazon, trifluralin, metribuzin, and oxyfluorfen control a wide range of weeds and the use of these herbicides would be beneûcial in pumpkin crop systems. Little published information is available on pumpkin tolerance to these herbicides. Thus, the safety of these herbicides on pumpkin needs to be established. In addition, these herbicides were chosen to be evaluated in the present paper as they are available for farmers in the Iranian pesticide market.

Therefore, the aim of this study was to test the tolerance of some of the dominant cultivated pumpkin species across Iran to bentazon, trifluralin, metribuzin, and oxyfluorfen.

MATERIALS AND METHODS

General procedures

Outdoor pot experiments were carried out to evaluate the tolerance of five different pumpkin species to bentazon, trifluralin, metribuzin, and oxyfluorfen. Pots were placed on benches located at Campus of Agriculture and Natural Resources, Razi University, Kermanshah (34°212 N, 47°92 E; elevation 1318.6 m), Iran, during 2014 and 2015. Pots remained outdoors for the duration of the study. According to Kermanshah Meteorological Organization (2015), during the experiments, the mean temperature and relative humidity were 26.6 °C (2014), 30 °C (2015) and 12.8% (2014) and 10% (2015), respectively. Tested pumpkins species included were *Cucurbita pepo* convar. *Pepo*, *Cucurbita moschata*, *Cucurbita pepo*, *Cucurbita maxima*, and *Lagenaria vulgaris.* Various pumpkin species were chosen to represent the different types of pumpkins grown across Iran.

On June 10, 2014 and June 25, 2015 which nearly coincide with the initiation of pumpkin planting date by farmers in the region, four seeds of the above mentioned pumpkin species were planted 3.0 cm deep in each of the 4.5 L plastic pots. The soil used for filling pots was loam, comprised of 43% sand, 32% silt, and 25% clay with 0.74% of total organic matter and a pH of 6.9. Washed river sand was added to the base of each pot to improve drainage. Potting soil contained the entire essential macro and micro-nutrients and was watered so that plants were never under any moisture stress. Pumpkin plants were reduced at the one-leaf stage to two plants per pot and irrigation was complementarily performed during the experiment. The whole study consisted of experiment 1 and experiment 2 as shown below.

Experiment 1

In this section, using POST (bentazon and oxyfluorfen) and PPI (metribuzin and trifluralin) herbicides, four separate trials were conducted. Each individual herbicide had a separate trial.

In all trials of this section, each treatment consisted of four replicates with one pot representing a replicate. Treatments in each individual trial were arranged as completely randomized designs and a non-treated pot was included for comparison.

Procedure for applying for postemergence (POST) herbicides

Bentazon and oxyfluorfen were applied POST in deionized water with an experimental backpack sprayer delivering 190 L ha^{-1} at 250 kPa. Four seeds of the above mentioned pumpkin species were planted 3 cm deep in each pot. Pumpkin plants were treated at 3-4-(V3), 4-7-(V7), and 7-10 (V10) leaf stage with bentazon (1 kg a.e. ha^{-1}) while oxyfluorfen (0.5 kg a.i. ha^{-1}) used only at the plant growing stage of V7, as a preliminary experiment indicated that all pumpkin species died after application at higher and lower growing stages (data not shown).

Procedure for applying preplant incorporated (PPI) herbicides

On the basis of the surface area of the pots and the weight soil they contained, the appropriate dose for each herbicide was calculated. Trifluralin and metribuzin were incorporated into the potting soil. Desired doses of each herbicide (trifluralin at 1, 1.5 and 2 kg a.i. ha^{-1} and metribuzin at 0.75 kg a.i. ha^{-1}) were prepared by adding a relevant amount for each dose to 1 L of deionized water, mixing with the potting soil in a mixer with a backpack sprayer, then mixing for 10 min. The herbicide-treated potting soil was used to fill the pots. It is noticeable that 1 mg kg^{-1} concentration is equal to 0.046 kg ha^{-1} broadcast to the soil surface. These herbicide concentrations were chosen according to the results of a preliminary experiment (data not shown).

Experiment 2

In this experiment, the phytotoxicity of bentazon (1 kg a.i. ha^{-1}), trifluralin (1.5 kg a.i. ha^{-1}), metribuzin (0.75 kg a.i. ha^{-1}), and oxyfluorfen (0.5 kg a.i. ha^{-1}) to all pumpkin species was studied. These herbicide doses were chosen based on the results of Experiment 1. All procedures were similar to the Experiment 1, except that the growing stage at which the postemergence herbicides were applied was V7. In this experiment, each treatment consisted of four replicates with one pot representing a replicate. The experiment was conducted as completely randomized designs with a factorial arrangement of treatments. A non-treated pot of each pumpkin species was included for comparison.

Data collection and analysis

For both experiments (experiments 1 and 2), pumpkin plants were visually rated for discoloration, growth reduction, and overall injury on a scale of 0 (no discoloration, growth reduction, or injury) to 100% (complete discoloration, growth reduction, or injury) at 7, 14, and 21 days after treatment (DAT). Shoots were excised at the soil surface at 42 (for POST herbicides) and 49 (forPPI herbicides) DAT, dried at 90 ^{o}C for 24 h, and weighed to determine dry weight.

Injury ratings and shoot weights from all trials were converted to percent control before analysis. Data transformations did not improve the distribution of data. Therefore, only the non-transformed raw data were analyzed. All data were subjected to analysis of variance (ANOVA) using SAS statistical software (Version 9.1). The data were analyzed as a mixed model using the Proc Mixed procedure of SAS. Fisher's Protected LSD (Pe”0.05) was used for means separation. The effect of year and its interactions with treatments were not signiûcant after analysis; the data presented were pooled over year.

RESULTS AND DISCUSSIONS

The injury symptoms of discoloration (chlorosis) from foliar applications of bentazon at 14 DAT were greatest for *C. maxima* followed by *C. moschata*, *C. pepo*, *L. vulgaris*, and *C. pepo* convar. *Pepo* with 23.08, 21.50, 20.00, 19.58, and 14.08%, respectively. This trend for visual growth stunting, overall injury, dry weight reduction was as *L. vulgaris*, *C. moschata*, *C. pepo*, *C. maxima*, *C. pepo* convar. *Pepo*; *C. moschata*, *C. pepo*, *C. maxima*, *L. vulgaris*, *C. pepo* convar. *Pepo*; *C. pepo*, *C. maxima*, *Lagenaria vulgaris*, *C. moschata*, *C. pepo* convar. *Pepo*. Although bentazon injured all pumpkin cultivars at 14 DAT, only slight differences in overall injury occurred between cultivars (Table 1).

When averaged across all pumpkin species examined, the greatest injury (for all kinds of injury symptoms) was observed when bentazon was applied at V10 following V3 and V7. This order for dry weight reduction was as V10, V7, and V4. Despite the fact that the pumpkin recovered from bentazon injury, there was a slight decrease in pumpkin dry weight when a herbicide was applied at the V7 stage. Therefore, the best bentazon application timing would be at V7.

This is the first report regarding the application of bentazon in different pumpkin species. This herbicide in Iran is registered for application as POST in soybean, beans, corn, and rice. It controls a broad spectrum of annual broadleaf weeds, including common lambsquarters and common cocklebur (Vencill, 2002). Bentazon does not consistently control perennial broadleaf weeds, although top growth suppression can be obtained on some perennial weeds such as ûeld bindweed (*Convolvulus arvensis*) (Vencill, 2002), which is a common weed across Iranian pumpkin fields. In addition, the safety of this herbicide on pumpkin needs to be established.

Differential response of inbred corn (*Zea mays*) to bentazon is reported to be associated with a difference in bentazon metabolism (Wu and Wang, 2003). Varying sensitivity of pumpkin species to bentazon probably has a physiological basis (Bradshaw et al., 1992). Therefore, selectivity of bentazon for pumpkin plants is dependent on herbicide dose, crop growth stage and the environmental conditions under which crops are grown. Hence, before applying bentazon in pumpkin fields, all these factors, particularly environmental ones, should be considered.

At higher doses of trifluralin, the damage created on pumpkin plants increased. The optimum herbicide dosage for crop safety was 1.5 kg a.i. ha^{-1}. Although applying lower rates of herbicide has resulted in the lowest crop damage, but weeds were not effectively suppressed (Table 2). The best amount of trifluralin for crop safety was 1.5 kg a.i. ha^{-1}.

As is evident from Table 2, all injury symptoms including discoloration, visual growth stunting, overall injury, and dry weight reduction from applications of trifluralin into the soil before pumpkin

Table 1 - Plant discoloration, visual growth reduction and overall injury at 14 DAT and dry weight reduction at 42 DAT for five pumpkin species treated with bentazon (1 kg a.e. ha^{-1}) at different growth stages

Pumpkin species	Growth stage	Discoloration	Visual growth reduction	Overall injury	Dry weight reduction
		(%)			
C. pepo convar. *Pepo*	3-4 leaf	12.50 e	23.50 fg	23.25 e	9.00 bc
	4-7 leaf	12.50 e	21.00 hi	12.00 h	6.75 c
	7-10 leaf	17.25 d	19.75 i	25.50 de	9.50 b
C. moschata	3-4 leaf	20.00 c	25.00 d-f	27.50 cd	6.75 c
	4-7 leaf	17.75 cd	27.75 bc	24.00 e	9.25 bc
	7-10 leaf	26.75 a	27.00 cd	31.75 a	14.25 a
C. pepo	3-4 leaf	18.25 c	27.50 bc	25.50 de	15.50 a
	4-7 leaf	16.00 cd	22.75 gh	21.00 f	15.25 a
	7-10 leaf	25.75 ab	34.00 a	30.00 ab	16.00 a
C. maxima	3-4 leaf	26.25 cd	25.00 d-f	25.00 e	14.00 a
	4-7 leaf	17.50 cd	25.25 d-f	17.25 g	13.50 a
	7-10 leaf	25.50 ab	24.50 e-g	28.75 bc	15.00 a
L. vulgaris	3-4 leaf	17.00 d	29.25 b	19.25 fg	10.00 a
	4-7 leaf	17.75 cd	25.50 d-f	18.50 g	15.25 a
	7-10 leaf	24.00 b	26.25 c-e	25.50 de	14.25 a

Means in each column with the same letter are not significantly different according to Fisher's Protected LSD (P≤0.05).

Table 2 - Percentage of plant discoloration, visual growth reduction, and overall injury at 14 DAT and dry weight reduction at 49 DAT for five pumpkin species treated with various doses of trifluralin

Pumpkin species	Herbicide dosage (kg a.i. ha^{-1})	Discoloration	Visual growth reduction	Overall injury	Dry weight reduction
		(%)			
C. pepo convar. Pepo	1.0	16.75 de	22.25 f	19.00 gh	5.50 gh
	1.5	21.50 c	25.75 d-f	20.00 fg	9.50 d-g
	2.0	22.75 bc	23.75 ef	25.75 de	8.75 e-g
C. moschata	1.0	14.50 de	32.00 bc	16.75 hi	8.50 fg
	1.5	18.75 cd	31.00 bc	18.50 gh	12.50 c-f
	2.0	23.75 bc	28.00 c-d	30.25 bc	13.75 b-d
C. pepo	1.0	23.75 bc	35.00 ab	27.50 cd	10.50 c-f
	1.5	23.25 bc	37.25 a	30.25 bc	12.25 c-f
	2.0	28.75 a	32.75 a-c	33.00 ab	17.00 b
C. maxima	1.0	22.50 bc	28.5 cd	18.50 gh	14.75 bc
	1.5	23.00 bc	34.25 ab	28.50 cd	13.00 b-e
	2.0	30.00 a	30.75 bc	34.00 a	23.75 a
L. vulgaris	1.0	13.50 e	28.25 c-e	15.25 i	11.00 c-f
	1.5	28.75 a	33.25 ab	23.25 e	4.25 h
	2.0	26.75 ab	32.00 bc	22.75 ef	22.50 a

Means in each column with the same letter are not significantly different according to Fisher's Protected LSD (P≤0.05).

planting were observed. Nevertheless, overall injury and dry weight reduction resulting from utilizing trifluralin was not very low when compared with the control (non-treated pots).

Generally, *C. pepo* convar. *Pepo* was more tolerant to trifluralin application than other pumpkin species as its dry weight reduction was the lowest when compared with the control. The most susceptible pumpkin species was *C. maxima* followed by *C. pepo*, *L. vulgaris*, *C. moschata*, *C. pepo* convar. *Pepo* (Table 2). Based on visual symptoms, the tolerance of species to trifluralin did not follow a trend similar to dry weight reduction. The highest discoloration, visual growth reduction, overall injury were related to *C. pepo*. And dry weight reduction to *C. maxima* together, while the order of the most tolerant species acceding to these symptoms was as *C. moschata*, *C. pepo*, *L. vulgaris*, *C. pepo* convar. *Pepo*. Despite apparent injury signs created on the pumpkin plants treated with trifluralin herbicide,the plants recovered from damage vey well in the end. Trifluralin is registered to be applied as PPI in a large variety of crops, including oil-seed crops, cucurbits, and tomatoes. It primarily controls annual grasses. It controls certain small-seeded broadleaf weeds (Vencill, 2002). Similar to trifluralins, other researchers working on ethalûuralin (from the Diniroaniline chemical family) have shown that it can control broadleaf weeds in pumpkin for a short time and has the potential to injure pumpkin plants (Galloway and Weston, 1996; Grey et al., 2000).

Soil application of metribuzin greatly reduced the growth of pumpkin species examined. Both initial injury symptoms and dry weight reduction were high. Because the preliminary tests showed pumpkin species seriously injured from the application of metribuzin. Therefore, final trials were conducted with only 0.75 kg a.i./hametribuzin. However, all pumpkin species examined were seriously injured from applications of metribuzin, but sensitivity greatly varied among the species tested (Table 3).

The most susceptible species according to preliminary symptoms (i.e., discoloration visual growth stunting, and overall injury) was *C. moschata* while *L. vulgaris* and *C. pepo* convar. *Pepo* showed the highest tolerance to metribuzin soil incorporation. Finally, *C. pepo* convar. *Pepo* was the best tolerant pumpkin as its dry weight reduction by metribuzin was the lowest (Table 3).

Metribuzin is an inhibitor of photosystem II (PSII) that can be applied PPI in soybean potatoes, corn and as POST-directed in some cereals. It controls many annual broadleaf weeds, such as pigweed spp., along with some annual grasses (Vencill, 2002). Metribuzin is widely applied in

Table 3 - Percentage of plant discoloration, visual growth reduction, and overall injury at 14 DAT and dry weight reduction at 49 DAT for five pumpkin species treated with metribuzin (0.75 kg a.i. ha^{-1})

Pumpkin species	Discoloration	Visual growth reduction	Overall injury	Dry weight reduction
	(%)			
C. pepo convar. *Pepo*	35.83 b	42.25 b	39.66 b	68.75 a
C. moschata	46.75 a	48.92 a	56.58 a	57.08 b
C. pepo	46.25 a	46.92 a	59.50 a	50.83 c
C. maxima	41.91 b	50.25 a	55.91 a	49.79 c
L. vulgaris	41.16 b	43.00 b	41.58 b	45.41 c

Means in each column with the same letter are not significantly different according to Fisher's Protected LSD (P≤0.05).

Iranian potato fields. Although in this study metribuzin was very effective in controlling weeds but its damage to all tested pumpkin species was not acceptable.

Similar to metribuzin, foliar application of oxyfluorfen has a great impact on visual symptoms and dry weight of all pumpkins tested. The highest level of discoloration, visual growth reduction, overall injury, and dry weight reduction belonged to *C. pepo*, *L. vulgaris*, *C. pepo* convar. *Pepo*, and *L. vulgaris*, respectively (Table 4), while the order of species based on the lowest level of the above mentioned injury syptoms (tolerance to oxyflurfen) was as *C. pepo* convar. *Pepo*, *C. maxima*, *Lagenaria vulgaris*, and *C. moschata*. Generally, oxyfluorfen was very toxic to pumpkin plants, so only the results of utilizing L ha^{-1} are reported here. According to the results of this study, oxyfluorfen was not safe to none of the pumpkins tested, so it is not suggested to be applied in pumpkin fields. Oxyfluorfen, a diphenylether (Ramalingam et al., 2013), is applied commonly in onion fields by Iranian vegetable growers. Hence it was tested for possible application in pumpkin fields as well. In opposition to our results, it has been reported that oxyfluorfen is able to control broadleaf weeds in some broadleaf vegetables such as cabbage (*Brassica olearcea* var. capitata) and chile pepper (*Capsicum annum*) (Amador-Ramirez et al., 2007; Hatterman-Valenti and Auwarter, 2007; James and Bielinski, 2005). It controls many annual broad and grass weeds, along with top growth of nuts edges and perennial grasses (Vencill, 2002; Gilreath and Santos, 2005).

Table 4 - Percentage of plant discoloration, visual growth reduction, and overall injury at 14 DAT and dry weight reduction at 42 DAT for five pumpkin species treated with oxyfluorfen (0.5 kg a.i. ha^{-1}) at different growth stages)

Pumpkin species	Growth stage	Discoloration	Visual growth reduction	Overall injury	Dry weight reduction
		(%)			
C. pepo convar. *Pepo*	3-4 leaf	62.00 a-c	80.50 a-c	65.75 ab	70.00 de
	4-7 leaf	37.75 e	57.75 fg	64.00 ab	65.50 ef
	7-10 leaf	41.50 de	76.75 a-d	55.00 b-e	82.75 ab
C. moschata	3-4 leaf	64.25 a-c	56.50 g	51.25 de	70.75 de
	4-7 leaf	55.25 b-d	74.75 a-e	52.00 c-e	81.50 a-c
	7-10 leaf	63.00 a-c	70.50 b-g	61.00 a-d	41.00 g
C. pepo	3-4 leaf	65 a-c	82.75 ab	66.25 ab	59.00 f
	4-7 leaf	70.00 ab	63.50 d-g	65.00 ab	88.50 a
	7-10 leaf	58.00 bc	72.00 b-g	57.75 a-e	74.25 b-e
C. maxima	3-4 leaf	66.75 ab	72.50 c-f	56.25 a-e	79.75 a-d
	4-7 leaf	54.75 c-d	66.00 c-g	52.50 c-e	81.25 a-c
	7-10 leaf	62.25 ac	59.75 e-g	67.25 a	64.25 ef
L. vulgaris	3-4 leaf	48.50 c-e	80.25 a-c	63.00 a-c	78.25 a-d
	4-7 leaf	57.50 bc	82.00 ab	49.50 e	71.75 c-e
	7-10 leaf	76.50 a	89.50 a	47.50 e	88.50 a

Means in each column with the same letter are not significantly different according to Fisher's Protected LSD (P≤0.05).

Based on results of the second Experiment (the data presented are pooled over pumpkin species), trifluralin showed the highest selectivity for all pumpkin species treated (Figure 1). Pumpkin dry weight reduction due to soil incorporation of trifluralin was 12.5%. The most reduction in pumpkin dry weight occurred by oxyfluorfen, followed by metribuzin and bentazon. Theses results confirm that of the first Experiment. As it is clear from Figure 1, pumpkin plants were sensitive to moderate tolerance to bentazon and relatively tolerant to trifluralin.

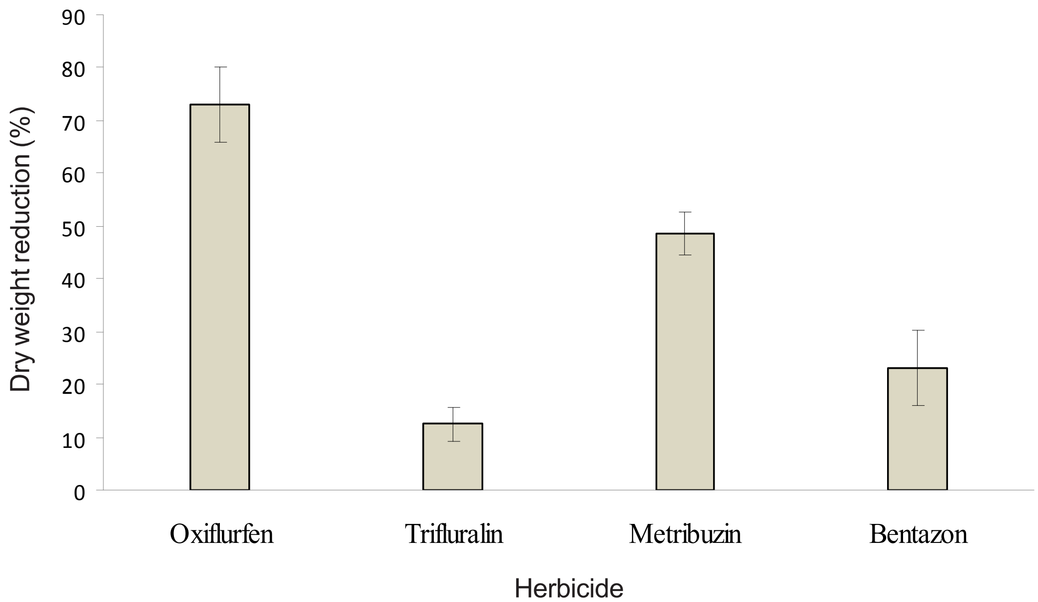

Figure 1 - Percentage of dry weight reduction of pumpkin plant (averaged across five pumpkin species) in response to the application of different herbicides. Vertical bars represent standard error.

Dry weight reduction of injury from applying oxyfluorfen and metribuzin ranged from 48 to 70%; 45 and this reduction are never acceptable. In agreement with our results, other researchers have reported varying responses from different vegetable crops to herbicides applied (Robinson et al., 1994; O'Sullivan and Sikkema, 2001)

The aim of this study for involving oxyfluorfen and metribuzin was to evaluate the potential of these herbicides for use in various pumpkin fields as they are widely used by farmers and very effective against weeds. According to our results, in crop rotations involving pumpkins, application of metribuzin should be avoided due to its soil persistence and possible pumpkin damage. Depending on weed flora of pumpkin field, either bentazon or trifluralin can be applied. As mentioned earlier, trifluralin weed control spectrum is almost grasses. Therefore, it would be beneficial when specific grasses were present in pumpkin fields which are not easily controlled by ACCase-inhibitor herbicides. Despite the benefits of trifluralin for the control of several grass weeds in pumpkins, there are limitations for its utilization in higher organic matter soils.

The most promising herbicide would be bentazon as the main problem of pumpkin producer is broadleaf weeds such as redroot, common lambsquarters and common cocklebur, especially if early-season crop injury can be tolerated (Laura et al. 1992). Probably different environmental factors occurring in real field conditions may alter pumpkin plants sensitivity to bentazon as it is a contact herbicide. For instance, Hutchinson et al. (2004) have reported that higher temperature has led to increasing the sensitivity of potato plants to rimsulfuron. Current label specifications in the Iranian pesticide market do not recommend the application of bentazon and trifluralin in pumpkin fields. An ideal herbicide should result in less injury to the crop but some damages to crops, even by highly selective herbicide, usually occur and crop recovery from herbicide phytotoxicity and final yield is of greatest significance (Hatzios and Penner, 1985).

Pumpkin species have exhibited pronounced differences in tolerance to bentazon, trifluralin, metribuzin, and oxyfluorfen herbicides. Overall, even though metribuzin, and oxyfluorfen have controlled weeds well, the level of injury is not acceptable to growers. Pumpkins injury by trifluralin and bentazon was lower compared with other herbicides tested, but some minor pumpkin injury was still observed with trifluralin. Despite early-season phytotoxicity by trifluralin and bentazon, pumpkin plants were able to recover and produce yield lower than those in the check treatments.

These herbicides are registered in major agronomic crops and offer broad spectrum preemergence and postemergence weed control that would be beneûcial in pumpkin plants. Variable sensitivity of pumpkin species to trifluralin and bentazon application should certainly be considered by growers when selecting these herbicides. Therefore, additional studies are needed to determine the selectivity of trifluralin and bentazon under many potential environmental and edaphic conditions, especially because many pumpkin crops are grown over varied climates.

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