

## Residual Effect of Thiobencarb and Oxadiargyl on Spinach and Lettuce in Rotation with Rice

M. Mahmoudi<sup>1</sup>, R. Rahnemaie<sup>1\*</sup>, S. Soufizadeh<sup>2</sup>, M. J. Malakouti<sup>1</sup>, and A. Es-haghi<sup>3</sup>

### ABSTRACT

Field experiments were conducted to evaluate the effect of thiobencarb and oxadiargyl herbicides on rice (*Oryza sativa* L.) and their possible residual effects on spinach (*Spinacea oleracea* L.) and lettuce (*Lactuca sativa* L.) at Dashtnaz and Gharakhil Agricultural Research Stations, Iran. Treatments included thiobencarb at 3.16 and 6.33 kg a.i. ha<sup>-1</sup>, oxadiargyl at 0.15 and 0.30 kg a.i. ha<sup>-1</sup> and a non-treated control. After harvesting rice, trial plots were kept undisturbed until late September when spinach was seeded in half of each plot. In November lettuce was transplanted in another half of the plots. Soil residual oxadiargyl at 0.30 kg a.i. ha<sup>-1</sup> stunted rice up to 31%, but this injury was transient and did not reduce yield. The adverse effect of oxadiargyl on rice was lower at Gharakhil possibly due to the greater binding by soil organic matter (OM). At Dashtnaz, spinach fresh yield was significantly affected by soil residues of oxadiargyl. Whereas lettuce fresh yield was significantly reduced in both thiobencarb and oxadiargyl treated plots. At Gharakhil, fresh yield of lettuce was not affected significantly. The experimental results revealed that soil characteristics, in particular OM content, are the main factors controlling the effect of thiobencarb and oxadiargyl residues. Furthermore, it could be concluded that oxadiargyl affected rice and spinach fresh yield greater than thiobencarb. Since no statistically significant differences were found in rice, spinach, and lettuce yield between the two applied doses of thiobencarb, from economical and environmental point of view, the lower thiobencarb dose is recommended to be used in paddy fields of northern Iran.

**Keywords:** Herbicides, Herbicide injury, Residual effects, Soil contamination.

### INTRODUCTION

Thiobencarb [5-tert-butyl-3-(2,4-dichloro-5-propargyloxyphenyl)-1,3,4-oxadiazol-2-(3H)-one] and oxadiargyl [5-tert-butyl-3-(2,4-dichloro-5-propargyloxyphenyl)-1,3,4-oxadiazol-2-(3H)-one] herbicides are widely used to control weeds in paddy fields of northern part of Iran. Thiobencarb and oxadiargyl belong to carbamothioates and oxadiazols, respectively. Thiobencarb is a systemic pre-emergence herbicide that is used to control broadleaved weeds, annual grasses, and sedge. It is absorbed by roots and shoots

of grass seedlings and then translocated upward through apoplast to locations where it inhibits lipid synthesis (HRAC, 2005). In contrast, oxadiargyl is used as pre- and post-emergence to control broadleaved and grass weeds. Oxadiargyl blocks porphyrin biosynthesis by inhibiting protoporphyrinogen oxidase (Hwang *et al.*, 2004).

Spinach, lettuce, wheat (*Triticum aestivum* L.), rapeseed (*Brassica napus* L.) and soybean (*Glycine max* L.) are the common crops in rotation with rice in Mazandaran, northern Iran (Filizadeh *et al.*, 2007; Peykani *et al.*, 2009). Under these cropping patterns, the effect of herbicides used in rice should be considered

<sup>1</sup> Department of Soil Sciences, Tarbiat Modares University, Tehran, Islamic Republic of Iran.

\* Corresponding author, e-mail: rasoul.rahnemaie@modares.ac.ir

<sup>2</sup> Department of Agroecology, Environmental Sciences Research Institute, Shahid Beheshti University, Tehran, Islamic Republic of Iran.

<sup>3</sup> Razi Vaccine and Serum Research Institute, Karaj, Islamic Republic of Iran.



on the rotational crops. This potential for herbicide injury depends mainly on the herbicide persistence in soil and the sensitivity of the rotational crop, which in turn influences the choice of herbicide. Sometimes, rotational crops recover without a yield reduction (Johnson and Talbert, 1996).

The ability of plants to absorb herbicide residues has been studied using radioactive markers (Suss and Grampp, 1973; Fuhr and Mittelstaedt, 1980). Traces of clopyralid, dicamba, and 3,6-dichlorosalicylic acid have been found in straw and/or grain of rye (*Secale cereale* L.) (Sakaliene et al., 2009). Theoretically, Papiernik et al. (2007) predicted that uptake of isoxaflutole by the plant and its phytotoxic diketonitrile metabolite (DKN), [2-cyano-3-cyclopropyl-1-(2-methylsulfonyl-4-trifluoromethylphenyl) propan-1, 3-dione], account for about 50% of the applied mass.

The visual damage and yield reduction due to the carryover of many herbicides have been reported on different plants. In Arkansas, cotton (*Gossypium hirsutum* L.) injury was noted in fields treated with imazaquin in the previous year (Barnes et al., 1989). Carryover of imazaquin also showed injury symptoms on the corn (*Zea mays* L.) (Renner et al., 1988; Mills and Witt, 1989; Curran et al., 1991), which caused yield reductions in some cases (Curran et al., 1992). Imazaquin and imazethapyr residues reduced spinach yield planted 3 to 4 months after cowpeas (*Vigna unguiculata* (L.) Walp.) (Johnson and Talbert, 1993).

In a study by Miller (2003), no adverse effect was observed on spinach, planted 12 months after sulfentrazone application. However, Brandenberger et al. (2007) reported that sulfentrazone applied at 224g a.i. ha<sup>-1</sup> in watermelon (*Citrullus lanatus* Thunb.) severely reduced spinach emergence, when it was planted 14 to 17 weeks after application. Sulfentrazone soil residues also stunted growth of spinach and reduced its yield. Residues of sulfentrazone applied to watermelon at 450 g ha<sup>-1</sup> also stunted growth of broccoli (*Brassica oleracea* (L.) var. botrytis) and cabbage (*Brassica oleracea* (L.) var. capitata) (Brandenberger et al., 2007).

Ramamoorthy (1991) applied 1 kg ha<sup>-1</sup> thiobencarb in rice field and found no negative impact on cowpea and greengram bean (*Phaseolus radiatus* L.). Nepalia and Jain (2000) studied the carryover of oxadiazon and observed no reduction either in dry matter or yield of greengram bean. Pannacci (2006) reported that the risk of lettuce injury from imazamox was very high when this herbicide was applied to the previous crop.

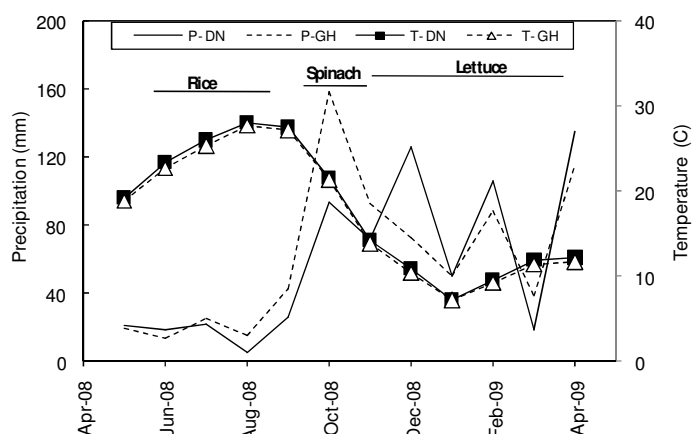
In a greenhouse experiment, thiobencarb residues did not significantly affect root and stem of lettuce, while root and stem length were affected by oxadiargyl (Valioalahpor et al., 2008).

Lettuce and spinach are two common rotational crops with rice in Mazandaran province. However, little is known about possible effects of thiobencarb and oxadiargyl herbicides applied in rice fields on the rice and subsequent crops. Thus, this research was conducted to evaluate the effects of the herbicides on rice and to determine their possible carryover on the two rotational crops.

## MATERIALS AND METHODS

Field experiments were conducted at Dashtnaz and Gharakhil research stations in Mazandaran province during 2008 and 2009. Dashtnaz is located at 36° 42' 7.8" N latitude and 53° 12' 29.1" E longitude and Gharakhil is at 36° 29' 25" N and 52° 46' 17" E. The climate at both sites is subtropical, typified by relatively high humidity and with mean annual precipitation of 668 mm for Dashtnaz and 735 mm for Gharakhil. Monthly precipitation and air temperature at the two sites are shown in Figure 1. Soil characteristics are presented in Table 1. At Gharakhil, soil had a slightly higher pH, and much higher OM and calcium carbonate equivalent (CCE) than Dashtnaz. There was no record of thiobencarb or oxadiargyl use at either site for at least the three years prior to onset of these trials.

Experimental plots were arranged in a randomized complete block design with five treatments and four replications. Plots



**Figure 1.** Monthly precipitation (P) and temperature (T) at Dashtnaz (DN) and Gharakhil (GH) in 2008-2009. The horizontal lines represent the growth period of rice, spinach and lettuce.

consisted of fifteen 4-meter rows spaced 0.30 m apart. The distance between plants within the rows was 0.25 m. A 1-m buffer was used between plots and a 2-m buffer between blocks. Layout levees were covered by plastic sheets, and rows of plots were separated by alternating irrigation and drainage ditches to prevent herbicide movement between the plots. Rice (Tarom cultivar) was transplanted on June 1, 2008 at Dashtnaz and on May 27, 2008, at Gharakhil. Treatments included a non-treated weedy control, pre-emergence applications of thiobencarb (Arysta LifeScience, Akashicho, Chuo-Ku Tokyo 104-6591, Japan) at 3.16 and 6.33 kg a.i.ha<sup>-1</sup>, and oxadiargyl (Bayer CropScience, Monheim am Rhein, Germany) at 0.15 and 0.30 kg a.i. ha<sup>-1</sup>. The lower doses were based on the manufacturer's recommendation and the higher doses were closer to the amount used by the farmers. Thiobencarb and oxadiargyl were respectively applied 6 and 5

days after transplanting. The herbicides were applied with a backpack sprayer (400 L ha<sup>-1</sup> at 170 kPa with flat fans nozzles) when water depth in the rice plots was about 5 cm. Fertilizers were used based on soil testing of sampled plots. Top dressing and pests and diseases control were done according to the local farmers' common practice. Rice was manually harvested on August 25, 2008, at Gharakhil and the next day at Dashtnaz. Plots were kept undisturbed until September 24 (Dashtnaz) and September 25, 2008 (Gharakhil) when spinach (cultivar, Barg Pahn Holandy) was planted (250 g 100 m<sup>-2</sup>) in half of each plot (10 m<sup>2</sup>). Land preparation was done by hand and spinach was seeded in 10 rows with 0.2 cm interval between the rows. On November 26 (Dashtnaz) and November 15, 2008 (Gharakhil), lettuce (cultivar, Kahoo Pich Babol) was transplanted at 0.2 m spacing into 4 m long rows that were 0.5 m apart. Four rows were considered in each plot. For

**Table 1.** Soil characteristics in Dashtnaz and Gharakhil research sites.

Site	Series	Classification	pH	OM	TNV	Silt	Clay	CEC	Texture
				%	%	%	%	cmol <sub>c</sub> kg <sup>-1</sup>	
Dashtnaz	Varendan	Typic Calcixerolls	7.3	3.42	20.25	37.9	39.4	22.6	Silty Clay Loam
Gharakhil	Ganj Afrooz	Typic Calciaquolls	7.7	5.55	60.5	41.4	39.4	21.7	Clay Loam



both spinach and lettuce, slug (*Agriolimax agrestis* L.) activity and weeds were effectively controlled by means of chemical and hand, respectively. In case of lettuce, nitrogen (25 kg ha<sup>-1</sup>) was top dressed.

### Data Collection and Statistical Analysis

#### Rice

Herbicide injury was visually assessed at 30 days after application. A scale of 0 (no injury) to 100% (dead) was used to evaluate the injury. Rice was harvested from the whole plots after excluding the border effects, and grain yield (adjusted to 12% moisture) and 1000-seed weight were determined. Analysis of variance was conducted using the GLM procedure in SAS (SAS Institute, 2001) and the mean values were compared by the Tukey test at  $P=0.05$  level of significance. Rice yield and yield components data were subjected to a  $\log(x+1)$  transformation where required. Logarithmic and inverse data transformations were done simultaneously for spinach. Data for each location was analyzed separately since weather conditions, soil characteristics, planting dates, and weed species were somewhat different at each site.

#### Spinach

Spinach was harvested at Dashtnaz November 12, 2008. Spinach plants were counted in the two central rows of each plot and then pulled from the soil for recording plant height and number of leaves. Petiole

length and leaf area were calculated using the Image Tools Software3 (Ver. 3) from digital images of the leaves. To determine fresh and dry yields, spinach plants were weighed immediately after harvesting and then oven-dried at 70 °C for 60h. Because spinach emergence at Gharakhil was considerably reduced by excessive rainfall and flooding (Figure 1), those data are not included in this article.

#### Lettuce

Lettuce was harvested on April 14 and 15, 2009, at Dashtnaz and Gharakhil, respectively. Plants within randomly placed 1-m<sup>2</sup> quadrates were selected and the number of leaves, plant height, and fresh weight were recorded as with spinach. Lettuce was then oven-dried at 70 °C for 72 hours and weighted.

## RESULTS AND DISCUSSION

#### Rice

Rice grain yields were not significantly different among herbicide treatments at Dashtnaz (Table 2). The difference in grain yields of herbicide treated plots could mainly be due to the difference in density of rice seeds (no m<sup>-2</sup>) in these treatments (Table 2). The observed effect implies that the density of seeds(no m<sup>-2</sup>) is more important than the 1000-seed weight in total rice yield (Murayama, 1979). Visual rating indicated the negative effect of oxadiargyl at 0.3 kg

**Table 2.** Effect of experimental treatments on rice injury, grain yield, 1000-seed weight, and seed number m<sup>-2</sup> at Dashtnaz and Gharakhil.

Treatments	Rate (kg a.i. ha <sup>-1</sup> )	Dashtnaz				Gharakhil			
		Rice injury (%)	Grain yield (kg ha <sup>-1</sup> )	1000- seed weight (g)	Seed density (no m <sup>-2</sup> )	Rice injury (%)	Grain yield (kg ha <sup>-1</sup> )	1000- seed weight (g)	Seed density (no m <sup>-2</sup> )
Control	0	0 b	4,666 a*	23.53 a	19,811 a	0 a	2,717 a	23.04 a	11,771 a
Thiobencarb	3.16	0.5 b	4,792 a	23.93 a	20,042 a	1 a	3,251 a	22.19 a	14,651 a
Thiobencarb	6.33	1 b	5,085 a	23.29 a	21,821 a	1 a	3,023 a	22.40 a	13,496 a
Oxadiargyl	0.15	5 b	4,872 a	23.46 a	20,779 a	1 a	2,943 a	22.05 a	12,674 a
Oxadiargyl	0.3	31 a	4,646 a	23.40 a	19,887 a	1 a	3,201 a	22.32 a	14,426 a

\*The same letter means no significant different at  $P\leq 0.05$ .

a.i. ha<sup>-1</sup> on rice growth (Table 2) with 31% injury, which was significantly higher than the other treatments. Severe leaf chlorosis and general stunting were obvious on rice treated with oxadiargyl at 0.3 kg a.i. ha<sup>-1</sup>. However, the injury was transient and no significant difference was observed in the grain yield of this treatment compared to the control.

At Gharakhil, grain yields of the herbicide treated plots were insignificantly higher than the control, which could mainly be attributed to their higher density of rice seeds (no m<sup>-2</sup>) (Table 2). The highest density of rice seeds (no m<sup>-2</sup>) belonged to the thiobencarb treatment at low dose. At Gharakhil, visual rice injury from oxadiargyl was not as severe as at Dashtnaz. The difference in rice response to oxadiargyl was probably due to the differences in the soil properties. Higher soil OM at Gharakhil had probably caused higher adsorption of oxadiargyl (Wehtje *et al.*, 1993; Ying and Williams, 2000b). At a lower soil solution equilibrium concentration (due to the higher adsorption), rice injury by oxadiargyl and its controlling effect on weeds are reduced. Field observations and rice yield at Gharakhil confirm this hypothesis.

Thiobencarb application did not significantly result in visible injury on rice plants at both sites (Table 2). Hill *et al.* (1990) did not also observe any visible injury on rice due to the application of thiobencarb at 4.5 kg a.i. ha<sup>-1</sup>. Similar to oxadiargyl, thiobencarb could strongly be adsorbed by soil organic matter (Braverman *et al.*, 1990), however, its persistence in soil had no considerable negative effect on the growth and yield of rice.

Some increase in yield may be related to the control of weeds by the herbicides. In the control plots, no physical/chemical treatment was applied against various weeds, where especially sedge (*Cyperus* spp.), at Dashtnaz, and barnyardgrass (*Echinochloa* spp.), at Gharakhil, grew. By comparing the efficacy of the two herbicides, one may conclude that the effect of these chemicals on rice yield and weed control depends mainly on the soil properties. Higher yield was achieved in thiobencarb treated plots at both sites, indicating higher efficacy of thiobencarb than oxadiargyl in rice fields. However, decision making on which chemical to use also depends on other environmental impacts and cost effectiveness of the herbicide.

### Spinach

Fresh yield of spinach was significantly affected by the herbicide residues in the soil (Table 3). Among herbicide treated plots, greatest fresh spinach yields were with the high rates of thiobencarb and oxadiargyl. Carryover of low doses of thiobencarb and oxadiargyl reduced spinach fresh yield by 15% and 36%, respectively, in comparison with the control. Herbicides insignificantly reduced dry matter yield, the number of leaves per plant, and plant height (Table 3). Brandenberger *et al.* (2007) reported that emergence, growth, and yield of spinach was reduced due to the soil residues of sulfentrazone (Brandenberger *et al.*, 2007). Moreover, it has been shown that spinach is very sensitive to imazamox soil residues (Pannacci *et al.*, 2006). Decrease in spinach

**Table 3.** Effect of experimental treatments on yield and some agronomic characteristics of spinach at Dashtnaz.

Treatments	Rate (kg a.i. ha <sup>-1</sup> )	Fresh yield (kg ha <sup>-1</sup> )	Fresh yield reduction (%)	Dry matter yield (kg ha <sup>-1</sup> )	No of leaves plant <sup>-1</sup>	Plant height (cm)	Petiole length (cm)	Leaf area index
Control	0	16,375 a	0	1,378 a	12.08 a	26.3 a	12.2 a	0.31 a
Thiobencarb	3.16	14,000 ab	14.5	1,190 a	11.78 a	25.7 a	14.1 a	0.35 a
Thiobencarb	6.33	14,688 ab	10.3	1,037 a	11.53 a	24.2 a	12.3 a	0.37 a
Oxadiargyl	0.15	10,500 b	35.9	1,062 a	11.38 a	23.8 a	12.5 a	0.26 a
Oxadiargyl	0.3	12,688 ab	22.5	1,051 a	11.08 a	25.8 a	14.3 a	0.32 a



yield is consistent with reductions in the number of leaves per plant and plant height. These results are supported by significant and positive correlations that exist between the number of leaves per plant and plant height and fresh yield (Table 4). As shown in Table 4, there is a negative correlation between fresh yield and petiole length. Leaf area index (LAI) responded differently to the herbicide residues in soil (Table 3). A significant and positive correlation exists between fresh yield and LAI. Greater LAI, however, did not result in more dry matter yield in the herbicide treated plots. This would be explained through shorter height of spinach under these treatments that may mean more shading of leaves on one another and, thus, less efficient canopy photosynthesis compared to the control.

Thiobencarb half-lives are approximately 100-200 and 12-77 days in flooded and non-flooded soils, respectively (Nakamura *et al.*, 1977; Kawamoto and Urano, 1990; Doran *et al.*, 2006). The change from reductive to oxidative state facilitates degradation of thiobencarb due to increase in microbial activities (Doran *et al.*, 2006). This condition was fulfilled in the studied fields. Therefore, no significant effect was observed in spinach yield, which was seeded four months after thiobencarb application (Table 3).

No data were found in the literature for oxadiargyl half-life and its adsorption

affinity. However, the half-life of oxadiazon, which belongs to the same chemical family as oxadiargyl, is between 48 and 108 days (Sudo *et al.*, 2002). Oxadiazon is strongly adsorbed on clays and organic matter (Wehtje *et al.*, 1993; Ying and Williams, 2000a). Hence, slow release of oxadiargyl from soil particles into bulk solution, may have a negative and significant effect on spinach growth and yield.

### Lettuce

Soil residues of thiobencarb and oxadiargyl reduced significantly lettuce fresh yield at Dashtnaz (Table 5). The lowest fresh yield was obtained from the high dose of oxadiargyl. At Gharakhil, a non-significant trend in fresh yield was observed.

Dry matter yield of lettuce at Dashtnaz was not affected significantly by the herbicides (Table 5). At Gharakhil, soil residues of thiobencarb had no noticeable effect on lettuce fresh and dry matter yields compared with the control, but carryover of oxadiargyl at low dose caused 25% reduction in lettuce dry matter yield. A positive and significant correlation was found between the fresh yield with dry matter and with plant height (Table 6).

Half-lives suggested by researchers for oxadiazon, which belong to the same

**Table 4.** Correlation coefficients of fresh yield, dry matter yield, plant height, petiole length, and leaf area index in spinach at Dashtnaz.

	Fresh yield	Dry matter yield	No of leaves plant <sup>-1</sup>	Plant height	Petiole length	leaf area index
Fresh yield	1	0.91**	0.53*	0.52*	-0.42 <sup>ns</sup>	0.56*
Dry matter yield	0.91**	1	0.37 <sup>ns</sup>	0.42 <sup>ns</sup>	-0.25 <sup>ns</sup>	0.40 <sup>ns</sup>
No of leaves plant <sup>-1</sup>	0.53*	0.37 <sup>ns</sup>	1	0.29 <sup>ns</sup>	-0.11 <sup>ns</sup>	0.17 <sup>ns</sup>
Plant height	0.52*	0.42 <sup>ns</sup>	0.29 <sup>ns</sup>	1	0.11 <sup>ns</sup>	0.38 <sup>ns</sup>
Petiole length	-0.42 <sup>ns</sup>	-0.25 <sup>ns</sup>	-0.11 <sup>ns</sup>	0.11 <sup>ns</sup>	1	0.18 <sup>ns</sup>
Leaf area index	0.56*	0.40 <sup>ns</sup>	0.17 <sup>ns</sup>	0.38 <sup>ns</sup>	0.18 <sup>ns</sup>	1

NS: Not significant.

\* and \*\*, Designate significance at the 0.05 and 0.01 probability levels, respectively.

**Table 5.** Effect of experimental treatments on yield and some agronomic characteristics of lettuce at Dashtnaz and Gharakhil.

Treatments	Dashtnaz					Gharakhil			
	Rate (kg a.i.ha <sup>-1</sup> )	Fresh yield (kg ha <sup>-1</sup> )	Dry matter yield (Kg ha <sup>-1</sup> )	Dry matter yield reduction%	No of leaves plant <sup>-1</sup>	Plant height (cm)	Fresh yield (Kg ha <sup>-1</sup> )	Dry matter yield (Kg ha <sup>-1</sup> )	No of leaves plant <sup>-1</sup>
Control	0	47,875 a	4,000 a	0	20.8 a	34.6 a	37,033 a	4,100 a	18.9 a
Thiobencarb	3.16	31,250 b	2,917 a	27	20.7 a	34.8 a	35,350 a	4,100 a	16.8 a
Thiobencarb	6.33	31,625 ab	4,167 a	-4	17.3 a	34.7 a	30,973 a	4,100 a	19.6 a
Oxadiargyl	0.15	33,334 ab	3,292 a	18	20.5 a	35.4 a	33,667 a	3,075 a	18.2 a
Oxadiargyl	0.3	30,125 b	3,375 a	16	17.3 a	35.2 a	29,290 a	3,860 a	18.4 a

**Table 6.** Correlation coefficients of fresh yield, dry matter yield, number of leaves plant<sup>-1</sup>, and plant height in lettuce at Dashtnaz and Gharakhil.

	Dashtnaz					Gharakhil			
	Fresh yield	Dry matter yield	No of leaves plant <sup>-1</sup>	Plant height		Fresh yield	Dry matter yield	No of leaves plant <sup>-1</sup>	Plant height
Fresh yield	1	0.71 <sup>*</sup>	-14 <sup>ns</sup>	0.53 <sup>ns</sup>		1	0.87 <sup>**</sup>	0.37 <sup>ns</sup>	0.75 <sup>**</sup>
Dry matter yield	0.71 <sup>*</sup>	1	-0.32 <sup>ns</sup>	0.19 <sup>ns</sup>		0.87 <sup>**</sup>	1	0.25 <sup>ns</sup>	0.67 <sup>*</sup>
No of leaves plant <sup>-1</sup>	-14 <sup>ns</sup>	-0.32 <sup>ns</sup>	1	-0.03 <sup>ns</sup>		0.37 <sup>ns</sup>	0.25 <sup>ns</sup>	1	0.14 <sup>ns</sup>
Plant height	0.53 <sup>ns</sup>	0.19 <sup>ns</sup>	-0.03 <sup>ns</sup>	1		0.75 <sup>**</sup>	0.67 <sup>*</sup>	0.14 <sup>ns</sup>	1



chemical family as oxadiargyl (Sudo *et al.*, 2002), are long enough to maintain a concentration in soil solution and affect soil fauna population or diversity or be absorbed directly by lettuce and make disorders in physiological processes that, consequently, reduce lettuce yield. Additionally, it is noted that some market value properties of the plants were undoubtedly influenced by the herbicide residues, for instance rice 1000-seed weight and spinach petiole length. Ability or inability of rice, spinach, and lettuce for herbicide absorption is not clearly known. As observed, the high dose of oxadiargyl led to chlorosis and growth reduction in rice. This may imply the absorption of oxadiargyl by rice and, consequently, its negative effect on the physiology of the plant. On the other hand, oxadiargyl is a broad-leaf herbicide and acts by blocking the porphyrinogen oxidase biosynthesis (Hwang *et al.*, 2004). Hence, it may be expectable that this herbicide adversely affects growth of broad-leaf vegetables such as spinach and lettuce.

During the experimental period, the mean annual precipitation at Dashtnaz and Gharakhil were 563 and 622 mm, which were about 15% below the long term averages. On the other hand, the air temperature was, respectively, 2.3% and 5% above the annual mean (Figure 1). Under wet soil condition, higher temperature favors microbial degradation of the herbicides. However, higher temperature and lower precipitation than the long-term average means that, during the present experiment, herbicides carryover from rice to the aftercrops was probably more than an average season.

## CONCLUSIONS

Based on the statistical analysis and discussion of the experimental data, the followings can be concluded:

Oxadiargyl affects rice and spinach fresh yield more than thiobencarb.

Assuming the same environmental risk for both herbicides, application of thiobencarb is to be preferred over using oxadiargyl.

No statistically significant differences were found in rice, spinach, and lettuce yield between the two applied doses of thiobencarb. Therefore, from economical and environmental point of view, the lower thiobencarb dose i.e. 3.16 kg a.i. ha<sup>-1</sup>, is recommended to be used in Iranian paddy fields.

The observed visual symptoms on rice plants and yield reduction in the rotational crops imply the possible presence of these chemicals in the plant tissues.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge Mazandaran Agricultural and Natural Resources Research Center, and Dashtnaz and Gharakhil Agricultural Research Stations for their technical supports and assistance in field experiments.

## REFERENCES

1. Barnes, C. J., Goetz, A. J. and Lavy, T. L. 1989. Effects of Imazaquin Residues on Cotton (*Gossypium-hirsutum*). *Weed Sci.*, **37**(6): 820-824.
2. Brandenberger, L. P., Shrefler, J. W. Webber, C. L., Talbert, R. E., Payton, M. E., Wells, L. K. and McClelland, M. 2007. Injury Potential from Carryover of Watermelon Herbicide Residues. *Weed Technol.*, **21**(2): 473-476.
3. Braverman, M., Locascio, S. Dusky, J. and Hornsby, A. 1990. Mobility and Bioactivity of Thiobencarb. *Weed Sci.*, **38**(6): 607-614.
4. Curran, W. S., Knake, E. L. and Liebl, R. A. 1991. Corn (*Zea mays*) Injury Following Use of Clomazone, Chlorimuron, Imazaquin, and Imazethapyr. *Weed Technol.*, **5**: 539-544.
5. Curran, W. S., Liebl, R. A. and Simmons, F. W. 1992. Effects of Tillage and Application Method on Clomazone, Imazaquin, and Imazethapyr Persistence. *Weed Sci.*, **40**: 482-489.



6. Doran, G., Eberbach, P. and Helliwell, S. 2006. The Sorption and Degradation of the Rice Pesticides Fipronil and Thiobencarb on Two Australian Rice Soils. *Aust. J. Soil Res.*, **44**(6): 599-610.
7. Filizadeh, Y., Rezazadeh, A. and Younessi, Z. 2007. Effects of Crop Rotation and Tillage Depth on Weed Competition and Yield of Rice in the Paddy Fields of Northern Iran. *J. Agr. Sci. Tech.*, **9**(2): 99-105.
8. Fuhr, F. and Mittelstaedt, W. 1980. Plant Experiments on the Bioavailability of Unextracted [Carbonyl-14c]Methabenzthiazuron Residues from Soil. *J. Agric. Food Chem.*, **28**: 122-125.
9. Hill, J. E., Roberts, S. R., Bayer, D. E. and Williams, J. F. 1990. Crop Response and Weed-Control from New Herbicide Combinations in Water-Seeded Rice (*Oryza-sativa*). *Weed Technol.*, **4**(4): 838-842.
10. HRAC. 2005. *Classification of Herbicides According to Mode of Action*. Retrieved Accessed June 23, 2010, From <http://www.hracglobal.com/Publications/ClassificationofHerbicideModeofAction/tabid/222/Default.aspx>.
11. Hwang, I. T., Hong, K. S., Choi, J. S., Kim, H. R., Jeon, D. J. and Cho, K. Y. 2004. Protoporphyrinogen IX-Oxidizing Activities Involved in the Mode of Action of a New Compound N-[4-Chloro-2-Fluoro-5-{3-(2-Fluorophenyl)-5-Methyl-4,5-Dihydroisoxazol-5-Yl-Methoxy}-Phenyl]-3,4,5,6-Tetrahydrophthalimide. *Pestic. Biochem. Physiol.*, **80**(2): 123-130.
12. Johnson, D. H. and Talbert, R. E. 1993. Imazaquin, Chlorimuron, and Fomesafen May Injure Rotational Vegetables and Sunflower (*Helianthus-annuus*). *Weed Technol.*, **7**(3): 573-577.
13. Johnson, D. H. and Talbert, R. E. 1996. Cotton (*Gossypium hirsutum*) Response to Imazaquin and Imazethapyr Soil Residues. *Weed Sci.*, **44**(1): 156-161.
14. Kawamoto, K. and Urano, K. 1990. Parameters for Predicting Fate of Organochlorine Pesticides in the Environment. 3. Biodegradation Rate Constants. *Chemosphere.*, **21**(10-11): 1141-1152.
15. Miller, T. W. 2003. Effect of Several Herbicides on Green Pea (*Pisum sativum*) and Subsequent Crops. *Weed Technol.*, **17**(4): 731-737.
16. Mills, J. A. and Witt, W. W. 1989. Efficacy, Phytotoxicity, and Persistence of Imazaquin, Imazethapyr, and Clomazone in No-Till Double-Crop Soybeans (*Glycine max*). *Weed Sci.*, **37**: 353-359.
17. Murayama, N. 1979. *The Importance of Nitrogen for Rice Production*. In: "Nitrogen and Rice". Los Banos, IRRI, Los Banos, Philippines, PP. 5-23.
18. Nakamura, Y., Ishikawa, K. and Kuwatsuka, S. 1977. Studies on Metabolism of Benthocarb .4. Degradation of Benthocarb in Soils as Affected by Soil-Conditions. *J. Pestic. Sci.*, **2**(1): 7-16.
19. Nepalia, V. and Jain, G. L. 2000. Effect of Weed Control and Sulphur on Yield of Indian Mustard (*Brassica juncea*) and Their Residual Effect on Summer Greengram (*Phaseolus Radiatus*). *Indian J. Agron.*, **45**(3): 483-488.
20. Pannacci, E., Onofri, A. and Covarelli, G. 2006. Biological Activity, Availability and Duration of Phytotoxicity for Imazamox in Four Different Soils of Central Italy. *Weed Res.*, **46**(3): 243-250.
21. Papiernik, S. K., Yates, S. R., Barikani, S. H. S. and Azari, A. 2007. Processes Affecting the Dissipation of the Herbicide Isoxaflutole and Its Diketonitrile Metabolite in Agricultural Soils under Field Conditions. *J. Agric. Food Chem.*, **55**(21): 8630-8639.
22. Peykani, G. R., Kelashemi, M. K., Barikani, S. H. S. and Azari, A. 2009. Determining the Best Variety of Rice for Cultivation Using Kataoka's and Telser's Risky-Linear Programming Methods - Case Study of Gilan Province 2000-2006. *J. Agr. Sci. Tech.*, **11**(1): 1-8.
23. Ramamoorthy, K. 1991. Effect of Herbicides on Weeds and Yield of Upland Rice (*Oryza Sativa*) and Residual Effect on Cowpea (*Vigna unguiculata*) and Greengram (*Phaseolus radiatus*). *Indian J. Agron.*, **36**(3): 304-307.
24. Renner, K. A., Meggitt, W. F. and Leavitt, R. A. 1988. Influence of Rate, Method of Application, and Tillage on Imazaquin Persistence in Soil. *Weed Sci.*, **36**: 90-95.
25. Sakaliene, O., Papiernik, S. K., Koskinen, W. C., Kavoliunaite, I. and Brazenaitei, J. 2009. Using Lysimeters to Evaluate the Relative Mobility and Plant Uptake of Four Herbicides in a Rye Production System. *J. Agric. Food Chem.*, **57**(5): 1975-1981.
26. Sudo, M., Kunitatsu, T. and Okubo, T. 2002. Concentration and Loading of Pesticide



- Residues in Lake Biwa Basin (Japan). *Water Res.*, **36**(1) 315-329.
27. Suss, A. and Grampp, B. 1973. The Uptake of Absorbed Monolinuron in the Soil by Mustard Plants. *Weed Res.*, **13**: 254.
28. Valioalahpor, R., Rashed Mohassel, M. H., Baghestani M. A., L. A. and Hassanzadeh Khayate, M. 2008. Residual Effects of Herbicides Applied in Paddy Fields on Growth of Some Aftercrops in Mazandaran Province. *Agri. Sci. and Tech. J.: Crop Protection.*, **22**(2): 59-70.
29. Wehtje, G. R., Gilliam, C. H. and Hajek, B. F. 1993. Adsorption, Desorption, and Leaching of Oxadiazon in Container Media and Soil. *Hortscience.*, **28**(2): 126-128.
30. Ying, G. G. and Williams, B. 2000. Dissipation of Herbicides in Soil and Grapes in a South Australian Vineyard. *Agric. Ecosyst. Environ.*, **78**(3): 283-289.
31. Ying, G. G. and Williams, B. 2000. Laboratory Study on the Interaction between Herbicides and Sediments in Water Systems. *Environ. Pollut.*, **107**(3): 399-405.

### اثر باقیمانده علف کش های تیوبنکارب و اگزادیارژیل روی اسفناج و کاهو در تناوب با برنج

م. محمودی، ر. راهنمایی، س. صوفی زاده، م. ج. ملکوتی و ع. اسحاقی

#### چکیده

به منظور ارزیابی اثر علف کش های تیوبنکارب و اگزادیارژیل روی برنج (*Oryza sativa* L.) و اثر باقیمانده آنها روی اسفناج (*Spinacea oleracea* L.) و کاهو (*Lactuca sativa* L.)، آزمایش های مزرعه ای در ایستگاه های تحقیقات کشاورزی دشت ناز و قراخیل-شمال ایران انجام شد. علاوه بر شاهد، تیمارها شامل تیوبنکارب با غلظت های ۳/۱۶ و ۶/۳۳ و اگزادیارژیل با غلظت های ۰/۱۵ و ۰/۳ کیلوگرم ماده موثر در هکتار بود. بعد از برداشت برنج، کرت های آزمایشی دست نخورده نگاه داشته شد تا اوایل مهر که در نیمی از سطح آنها اسفناج کشت گردید. در آذرماه در نیم دیگر از کرت ها کاهو نشاء گردید. اگزادیارژیل بیشتر از تیوبنکارب باعث اختلال در رشد و ایجاد کلروز در برنج گردید. اثرات منفی اگزادیارژیل در ایستگاه قراخیل کمتر بود که علت آن احتمالاً جذب سطحی بیشتر این علف کش توسط مواد آلی خاک بود. عملکرد تر اسفناج بطور معنی داری تحت تاثیر بقایای خاکی اگزادیارژیل در خاک دشت ناز قرار گرفت. در حالیکه اثر هر دو علف کش در کاهش عملکرد تر کاهو در ایستگاه دشت ناز معنی دار بود. در قراخیل عملکرد تر کاهو کاهش معنی داری نشان نداد. نتایج آزمایش ها نشان دادند که خصوصیات خاکی بویژه مقدار ماده آلی، از عوامل اصلی کنترل کننده بقایای تیوبنکارب و اگزادیارژیل هستند. علاوه می توان نتیجه گرفت که اگزادیارژیل رشد رویشی و عملکرد برنج و عملکرد تر اسفناج را بیشتر از تیوبنکارب تحت تاثیر قرار می دهد. از آنجا که هیچگونه تفاوت معنی داری در عملکرد برنج، اسفناج و کاهو در دو غلظت بکار-رفته تیوبنکارب مشاهده نشد، با توجه به مسائل اقتصادی و ملاحظات زیست محیطی، غلظت پایین تیوبنکارب برای استفاده در اراضی شالیزاری شمال ایران توصیه می شود.