

## Control of sulfonylurea-resistant *Diplachne fusca* (DF) and reduction of rice yield by occurrence densities of DF in reclaimed paddy fields

OH DO KWON<sup>2</sup>, SE JI JANG<sup>1</sup> AND YONG IN KUK<sup>\*,1</sup>

<sup>1</sup>Department of Oriental Medicine Resources  
Sunchon National University, Suncheon-540 742, Republic of Korea  
<sup>\*</sup>(e-mail : yikuk@sunchon.ac.kr)

(Received : October 05, 2016/Accepted : November 30, 2016)

### ABSTRACT

The objectives of this research were to determine alternative herbicides for the control of *Diplachne fusca* in a greenhouse and quantify levels of yield reduction as affected by occurrence densities of *Diplachne fusca* in a reclaimed paddy field. An accession of *D. fusca* was 52-62 and 28-48% controlled even when treated with two times the recommended use rate of pyrazosulfuron+pyriminobac and methazosulfuron at two- or three-leaf stage of *D. fusca*, respectively. Other accessions were completely controlled by the above herbicides. The sulfonylurea-resistant *D. fusca* accession was controlled 100% with benzobicyclone+thiobencarb benzobicyclone+fentrazamide, fentrazamide+oxadiagyl, thoibencarb, and benzobicyclone when applied at 0 day after seeding and pyrimisulfan+mefenacet, bensulfuron+mesotrione+pyrifitalid+pretilachlor, imazosulfuron+ pyraclonil+bromobutide, halosulfuron+indanofan+benfuresate, azimsulfuron+metamifop+carfentrazon and bensulfuron+mefenacet+oxadiagyl when applied at 3-leaf stage, and cyhalofop-butyl and fenoxaprofop-P-ethyl when applied at 5-leaf stage. Rice yield was reduced 48 and 88% by densities of 10 and 30 plants per m<sup>2</sup> in rice paddy fields, respectively. The rice yield loss was directly due to reduction of the number of panicle and spikelet.

**Key words :** *Diplachne fusca*, resistance, rice, sulfonylurea-herbicide, yield

### INTRODUCTION

The reclaimed land occurs in weed species such as *Diplachne fusca*, *Scirpus planiculmis*, reed (*Phragmites communis*) and *Suaeda glauca* (Bunge) Bunge, generally unlike in normal paddy fields (Wongwattana *et al.*, 1995) because they are highly salt tolerant and can survive at a very high salinity (EC<sub>c</sub>) conditions of 40,000 µS/cm (Qureshi *et al.*, 1982). Among the above-listed weeds, *D. fusca* had not occurred at reclaimed paddy fields in Korea for the last 20 years (Hong *et al.*, 1995). However, recently, occurrence of *D. fusca* in reclaimed paddy fields in Korea has been increasing and becoming a troublesome weed.

*D. fusca* is an annual grass weed, occurs in soil depths within 0.8 cm, and has a faster growth rate than rice in salinity from 0.1 to 0.2‰; it also shows severe competition with rice because of a large number of tillers (about 35 populations per hill), and becomes a

seed rapidly shattering at 20 days after flowering (Hong *et al.*, 1995). In addition, *D. fusca* occurs more easily in direct seeding than transplanting rice cultivation because the weed has better growth under dry conditions. In this regard, the change of rice cultivation method into direct seeding may be one of reasons that the *D. fusca* is becoming a troublesome weed.

Sulfonylurea herbicide-based mixtures have been widely used in the paddy fields of Korea to control a broad spectrum of broadleaf and grass weeds (KCPA, 2014). Repeated use of the same sulfonylurea-based mixtures has resulted in the development of resistance in several rice weed species (Kuk *et al.*, 2002, 2003a, b). At present, 11 species of sulfonylurea-resistant weeds such as *Monochoria vaginalis*, *Cyperus difformis* L. and *Rotala indica* (Willd) Koehne have been found in paddy fields in Korea since *Monochoria korsakowii* was first observed in 1998 (Park *et al.*, 2011).

<sup>2</sup>Jeollanamdo Agricultural Research and Extension Services, Naju-520 715, Republic of Korea.

The sulfonylurea-resistant weeds were mostly observed in normal paddy rice fields, but recently *M. korsakowill* and *Scirpus planiculmis* were observed in reclaimed paddy fields (Park *et al.*, 1999, 2009). In addition, *D. fusca* of three accessions collected from reclaimed paddy fields was survived by a sulfonylurea-based mixture, pyrazosulfuron + pyriminobac (21+30 g a. i./ha), which is registered for use in rice in Korea. Therefore, we hypothesized that the accession would be resistant to some sulfonylurea herbicides. If the *D. fusca* is left uncontrolled, it may cause serious yield loss in reclaimed paddy fields. For example, the occurrence of resistant biotype of *Monochoria vaginalis* in direct-seeded rice culture in Korea caused 70% rice yield loss (Kuk *et al.*, 2003b). Thus, the objectives of this research were to determine alternative herbicides for the control of *D. fusca* in a greenhouse and quantify levels of yield reduction as affected by occurrence densities of *D. fusca* in a reclaimed paddy field.

## MATERIALS AND METHODS

### Plant Materials

Seeds of 10 suspected sulfonylurea-resistant *D. fusca* biotypes were collected from locations throughout Youngamgun, Korea in 2010. The fields where samples were collected had been treated with sulfonylurea herbicide-based mixtures, for more than five consecutive years. The seeds were sown in pots (1/2,000a) filled with clay loam paddy soil and placed in a greenhouse maintained at 30/25°C with a 14/10 h day/night period. Pots were flooded 3 cm deep to simulate-saturated situations. Two-leaf stages were treated with a sulfonylurea herbicide mixture, pyrazosulfuron+pyriminobac GR (21+30 g a. i./ha). Seeds were harvested from the surviving plants after the above herbicide treatment and used for further study.

### Resistance to Sulfonylurea Herbicides

One gram of seeds was sown in pots (1/2,000a) filled with clay loam paddy soil. At the two-leaf stage or three-leaf stage, seedlings were treated with pyrazosulfuron+pyriminobac (21+30, 42+60 g a. i./ha) or methazosulfuron (100, 200 g a. i./ha). The two herbicides were

applied into the flooded pots in granular form. Pyrazosulfuron+pyriminobac and methazosulfuron were provided by Sungbo Chemical and Kyung Nong Corporation, Korea, respectively. The number of survivors and aboveground dry weight were recorded 30 days after treatment (DAT). Visual ratings for herbicide efficacy were recorded 10, 20, and 30 days after treatment using a scale of 0 to 9, where 0 equals no control and 9 equals complete control. Controlling efficacy was calculated based on aboveground dry weight compared with untreated control.

### Response to Sulfonylurea Herbicides and Other Herbicides

In order to determine controlling efficacy on *D. fusca*, we treated 27 herbicides with different application time. Application time, rates and formulations of herbicides used in this study are listed in Table 1. The number of survivors and aboveground dry weight were recorded 42 DAT for herbicides of immediate treatment after puddling, 30 DAT for herbicides of 3-leaf stage and 20 DAT for herbicides of foliar application (5-leaf stage). Other procedures were the same as those described in the above section.

### Rice Yield by Occurrence Densities of *Diplachne fusca* in a Reclaimed Paddy Field

A field experiment was conducted in a paddy field infested with *D. fusca* in Muangun, Korea. Rice cv. Hwanggunnuri was planted using machine transplanting, on 30 May, 2011. Plot size was 4 x 5 m. The experimental design was a randomized complete block with three replications. Urea fertilizer was used at 110 kg N/ha. Fifty per cent of this applied pre-plant incorporated, 25% at six-leaf stage and 25% at panicle formation stage. Phosphorus and potassium were also applied pre-plant incorporated at 60 and 70 kg/ha, respectively. Other cultural management practices were carried out in accordance with the standard rice cultivation method of the Rural Development Administration of Korea (RDA, 1998). Densities of *D. fusca* were arranged by 0, 10 and 30 populations per m<sup>2</sup>. Rice yield samples were harvested from three 1 m<sup>2</sup> quadrats per plot. Yield parameters—number of panicles, spikelets per panicle, ripened grain (%) and 1,000-grain weight were determined

**Table 1.** Herbicides used in this study

Application time (days after seedling DAS)	Herbicides	Formulation <sup>b</sup>	Dosage (g a.i./ha)	
0 DAS <sup>a</sup>	Benzobicyclone thiobencarb	2.5+30% SE	100+1,200	
	Benzobicyclone fentrazamide	3+2.5% SC	120+100	
	Fentrazamide oxadiargyl	2+1.3% EC	80+52	
	Thiobencarb	7% GR	2,100	
	Benzobicyclon	3.5% SC	140	
	Pentoxazon	5% SC	200	
	Oxadiargyl	1.7% EC	68	
	Benzobicyclone pretilachlor	3+9% SE	120+360	
	Butachlor	33% EW	1,320	
	Pretilachlor	37% EW	555	
	Bromobutid thiobencarb	4+20% SE	200+1,000	
	Pyrazolate	36% SC	1,800	
	3-leaf stage	Pyrimisulfan mefenacet	1+15% SC	50+750
		Bensulfuron mesotrione pyriftalid pretilachlor	0.17+0.3+1.5+0.4% GR	51+90+450+120
Imazosulfuron pyraclonil bromobutide		1.5+3.6+18% GG	75+180+900	
Halosulfuron indanofan benfuresate		0.18+0.4+1.3% GR	54+120+390	
Azimsulfuron metamifop carfentrazone		0.05+0.3+0.25% GR	15+90+75	
Bensulfuron mefenacet oxadiargyl		1+2+0.6% SC	50+100+30	
Bensulfuron fentrazamide		1+6% SC	50+300	
Penoxsulam tefurytrione		0.5+4.2% SC	25+210	
Azimsulfuron carfenstrol		0.05+1% GR	15+300	
Flucetosulfuron benzobicyclone carfentrazone		0.07+0.6+0.25% GR	21+180+75	
Imazosulfuron benzobicyclon pyriminobac		1.5+4+0.6% SC	75+200+30	
Methazosulfuron		0.33% GR	99	
5-leaf stage		Cyhalofop-butyl	5% EC	250, 500
		Fenoxaprop-P-ethyl	7% EC	70, 140
	Penoxsulam	3% SC	30, 60	

<sup>a</sup>SC : Suspension concentrate. EW : Oil emulsion in water, EC : Emulsifiable concentrate, SE : Suspo-emulsion and GR : granule.

from these samples. In addition, clum and spike lengths were also determined. Yield index was caculated based on yield of milled rice.

### Statistical Analysis

All experiments were conducted two or three times with three replicates for each treatment. Data were analyzed using analysis of variance (ANOVA) procedure in the Statistical Analysis Systems (SAS, 2000) software. Means were separated using Duncan's multiple range test (P=0.05).

## RESULTS AND DISCUSSION

### Resistance to Sulfonylurea Herbicides

*D. fusca* was not observed in reclaimed rice fields until 2010. However, recently *D. fusca* was dominant in the reclaimed rice fields used for monoculture rice production, which had been routinely treated with sulfonylurea herbicide-based mixtures for more than six consecutive years. It was suspected that the

*D. fusca* had developed resistance to these herbicides. Three accessions among 10 accessions of *D. fusca* were survived by a sulfonylurea herbicide mixture, pyrazosulfuron+pyriminobac GR (21+30 g a. i./ha) (data not shown). This observation indicates that the three accessions of *D. fusca* were evolved in these fields. Thus, we harvested seeds from the survived accession of *D. fusca* and seeded in soils of pots. We applied in pots at recommended or two times the recommended rates of a sulfonylurea-herbicide mixture, pyrazosulfuron+pyriminobac and a sulfonylurea-herbicide, methazosulfuron at two- or three-leaf stage of *D. fusca* (Table 2). The accession of *D. fusca* was only 52-62% controlled even when treated with two times the recommended use rate of pyrazosulfuron+pyriminobac at two- or three-leaf stage of *D. fusca*. In addition, the accession of *D. fusca* was 28-48% controlled even when treated with two times the recommended use rate of methazosulfuron at two- or three-leaf stage of *D. fusca*. Although early application (2-leaf stage) of both the herbicides showed better control in *D. fusca*

**Table 2.** Effects of sulfonylurea-herbicides on the resistant accession of *D. fusca* treated two or three-leaf stages

Herbicide	Application time (Leaf stage)	Dosage (g a.i./ha)	Visual rate <sup>a</sup>			Individual number (pot <sup>-1</sup> ) <sup>c</sup>	Shoot dry wt. (g/pot) <sup>d</sup>	Controlling efficacy (%) <sup>e</sup>
			10 DAA <sup>b</sup>	20 DAA	30 DAA			
Pyrazosulfuron/pyriminobac	2	21+30	7.0	6.0	4.0	79	15.7a	53.6
		42+60	7.5	6.0	4.0	56	13.0a	62.0
	3	21+30	4.0	5.0	4.5	66	26.1ab	22.8
		42+60	4.0	10	0.0	132	16.3a	51.8
Methazosulfuron	2	100	7.5	5.0	3.0	45	22.7a	32.8
		200	7.5	5.0	3.0	54	17.6a	47.8
	3	100	3.0	3.0	2.0	86	33.1b	2.1
		200	0.0	0.0	0.0	115	24.4ab	27.9
Check	-	-	-	-	-	113	33.8b	-

<sup>a</sup>Visual rate, a rating of 0 represents no weed control and 9 indicates complete control.

<sup>b</sup>DAA-Days after application.

<sup>c,d</sup>Individual number and shoot dry weight were determined at 30 days after application.

<sup>e</sup>Controlling efficacy was calculated based on shoot dry weight.

<sup>f</sup>Means within a column followed by the same letters are not significantly different at P=0.05 level according to Duncan's multiple range test.

accession than relatively late application (3-leaf stage), the *D. fusca* accession showed very limited control. Thus, the accession may be resistant to sulfonylurea-herbicides. Further studies will be needed to determine resistance levels between resistant and susceptible biotypes of *D. fusca*. To date, a lot of sulfonylurea-resistant weeds such as *Monochoria vaginalis* and *Rotal indica* (Willd) Koehne were observed in paddy fields in Korea (Kuk *et al.*, 2002; Park *et al.*, 2011).

### Response to Sulfonylurea Herbicides and Other Herbicides

In order to find herbicides for control of the sulfonylurea-resistant *D. fusca* accession, we applied 12 soil-applied herbicides (Table 3). The sulfonylurea-resistant *D. fusca* accession was controlled 90-100% with benzobicyclon+thiobencarb, benzobicyclon+fentrazamide, fentrazamide+oxadiagyl, thoibencarb, benzobicyclon, pentoxazon, and oxadiagyl when applied at recommended rates. It is, therefore, possible to use the above herbicides for control of the sulfonylurea-resistant *D. fusca* accession. However, benzobicyclon+pretilachlor, butachlor, pretilachlor, bromobutid+thiobencarb and pyrazolate that provided only 62-84% control of the sulfonylurea-resistant *D. fusca* accession. Although the above herbicides showed lower controlling efficacy on

the sulfonylurea-resistant *D. fusca* accession, they do not seem to be resistant to the herbicides.

When applied at three-leaf stage of *D. fusca*, the sulfonylurea-resistant *D. fusca* accession was controlled completely by recommended rates of pyrimisulfan+mefenacet, bensulfuron+mesotrione+pyrifthalid+pretilachlor, imazosulfuron+pyraclonil+bromobutide, halosulfuron+indanofan+benfuresate, azimsulfuron+metamifop+carfentrazone, and bensulfuron+mefenacet+oxadiagyl (Table 3). Bensulfuron+fentrazamide, penoxsulfuron+tefurytrione, and azimsulfuron+carfenestrol gave fair control (78-89%) of the sulfonylurea-resistant *D. fusca* accession. Among sulfonylurea herbicide-based mixtures, flucetosulfuron+enzobicyclon+ carfentrazone and imazosulfuron+benzobicyclon+ pyriminobac showed poor control (50-65%) of the sulfonylurea-resistant *D. fusca* accession. In addition, the sulfonylurea-resistant *D. fusca* accession was controlled only 20% by a sulfonylurea-herbicide, methazosulfuron. These results suggest that sulfonylurea-resistant *D. fusca* accession could not be controlled effectively with sulfonylurea herbicide-based mixtures. Thus, use of herbicides with different modes of action, such as cyhalofop-butyl, is necessary to manage sulfonylurea-resistant *D. fusca* accession. Similar to our research, sulfonylurea herbicide-

**Table 3.** Effects of various herbicides on the resistant accession of *D. fusca* treated at 0 day after seeding or 3-leaf stage

Application time (days after seeding, DAS)	Herbicide	Visual rate <sup>a</sup>			Individual No. (pot <sup>-1</sup> ) <sup>c</sup>	Shoot dry wt. (g/pot) <sup>d</sup>	Controlling efficacy (%) <sup>e</sup>
		10 DAA <sup>b</sup>	20 DAA	30 DAA			
0 DAS	Benzobicyclone thiobencarb	9.0	9.0	9.0	0	0.0a	100
	Benzobicyclone fentrazamide	9.0	9.0	9.0	0	0.0a	100
	Fentrazamide oxadiargyl	9.0	9.0	9.0	0	0.0a	100
	Thiobencarb	9.0	9.0	9.0	0	0.0a	100
	Benzobicyclon	9.0	9.0	9.0	0	0.0a	100
	Pentoxazon	9.0	9.0	8.8	2	1.2a	96.4
	Oxadiargyl	9.0	8.9	8.0	4	3.1a	90.8
	Benzobicyclone pretilachlor	8.8	8.5	8.0	3	5.5bc	83.7
	Butachlor	8.5	8.3	6.5	4	8.5cd	74.9
	Pretilachlor	9.0	8.7	6.5	7	10.2de	70.0
	Bromobutid thiobencarb	8.5	8.2	5.0	10	10.3de	69.6
	Pyrazolate	8.5	8.2	6.0	29	12.7de	62.4
	Check	-	-	-	113	33.8f	-
	3-Leaf stage	Pyrimisulfan mefenacet	8.7	9.0	9.0	0	0.0a
Bensulfuron mesotrione pyriftalid pretilachlor		8.5	9.0	9.0	0	0.0a	100
Imazosulfuron pyraclonil bromobutide		8.7	9.0	9.0	0	0.0a	100
Halosulfuron indanofan benfuresate		8.7	9.0	9.0	0	0.0a	100
Azimsulfuron metamifop carfentrazon		8.7	9.0	9.0	0	0.0a	100
Bensulfuron mefenacet oxadiargyl		8.7	9.0	9.0	0	0.0a	100
Bensulfuron fentrazamide		8.0	8.5	8.0	1	3.6ab	89.3
Penoxsulam tefurytrione		8.0	7.0	7.0	3	6.0b	82.1
Azimsulfuron carfenstrol		8.0	7.5	7.0	1	7.4c	78.1
Flucetosulfuron benzobicyclone carfentrazon		6.5	6.5	6.0	16	11.8cd	65.2
Imazosulfuron benzobicyclon pyriminobac		6.5	6.0	5.0	56	16.8d	50.2
Methazosulfuron		0.0	0.0	0.0	103	27.4e	18.9
Check		-	-	-	113	33.8f	-

<sup>a</sup>Visual rate, a rating of 0 represents no weed control and 9 indicates complete control.

<sup>b</sup>DAA-Days after application.

<sup>c,d</sup>Individual number and shoot dry weight were determined at 42 days after application.

<sup>e</sup>Controlling efficacy was calculated based on shoot dry weight.

<sup>f</sup>Means within a column followed by the same letters are not significantly different at 5% level according to Duncan's multiple range test.

resistant biotypes of *Monochoria vaginalis* and *Rotala indica* were cross-resistant to other sulfonylurea herbicides, but not to all the other sulfonylurea herbicides (Kuk *et al.*, 2002, 2003).

The sulfonylurea-resistant *D. fusca* accession was completely controlled by the recommended rates of foliar herbicides, cyhalofop-butyl and fenoxaprop-P-ethyl (Table 4). However, the sulfonylurea-resistant *D. fusca* accession was not controlled by the two times the recommended use rate of a sulfonylurea herbicide, penoxsulam.

### Rice Yield by Occurrence Densities of *Diplachne fusca* in a Reclaimed Paddy Field

If the sulfonylurea herbicide-resistant *D. fusca* is left uncontrolled in reclaimed paddy fields, it causes severe rice yield loss. Thus, we arranged densities (10 or 30 plants per m<sup>2</sup>) of *D. fusca* in a paddy field and then investigated yield components at harvesting time (Table 5).

Yield components such as clum and spike lengths, panicle and spikelet number were reduced more by increasing occurrence densities of *D. fusca*. For example, rice yield was reduced 48 and 88% by densities of 10 and 30 plants per m<sup>2</sup>, respectively. However, other yield components such as ripened grain and 1000-grain weight were the same in the occurrence density. Therefore, it was concluded that rice yield loss was directly due to reduction of the number of panicle and spikelet. The occurrence of resistant *Monochoria vaginalis* in Korea can cause up to 70% rice yield loss (Kuk *et al.*, 2003b). Thus, continuous monitoring of sulfonylurea-resistant *D. fusca*, including its distribution and spread, is imperative to resistance management.

### ACKNOWLEDGEMENT

This paper was supported by Suncheon National University Research Fund in 2016.

**Table 4.** Effects of foliar applied herbicides on the resistant accession of *D. fusca* treated at 5-leaf stage

Herbicide	Dosage (g a.i./ha)	Visual rate <sup>a</sup>		Individual No. (pot <sup>-1</sup> ) <sup>c</sup>	Shoot dry wt. (g/pot) <sup>d</sup>	Controlling efficacy (%) <sup>e</sup>
		10 DAA	20 DAA			
Cyhalofop-butyl	250	9.0	9.0	0	0.0a	100
	500	9.0	9.0	0	0.0a	100
Fenoxaprofop-P-ethyl	70	9.0	9.0	0	0.0a	100
	140	9.0	9.0	0	0.0a	100
Penoxsulam	30	0.0	0.0	32	20.8b	13.6
	60	0.0	0.0	28	23.7b	1.8
Check	-	-	-	41.0	24.1b	-

<sup>a</sup>Visual rate, a rating of 0 represents no weed control and 9 indicates complete control.

<sup>b</sup>DAA-Days after application.

<sup>c,d</sup>Individual number and shoot dry weight were determined at 20 days after application.

<sup>e</sup>Controlling efficacy was calculated based on shoot dry weight.

<sup>f</sup>Means within a column followed by the same letters are not significantly different at 5% level according to Duncan's multiple range test.

**Table 5.** Yield and its components of rice plants as affected by densities of *D. fusca* at reclaimed paddy fields

No./m <sup>2</sup>	<i>D. fusca</i>			Clum (cm)	Spike (cm)	Panicle No./m <sup>2</sup>	Spikelet No./ plant	Ripened ratio (%)	1,000 grain (g)	Yield (MT/ha)	Yield loss (%)
	Height (cm)	Tillers (No./plant <sup>2</sup> )	Dry wt. (g/plant <sup>2</sup> )								
0	-	-	-	72	21	12.9	106	78.4	20.8	4.74	-
10	122.0	24.3	84.0	65	19	9.1	87	76.7	20.8	2.45	48
30	131.7	40.3	102.7	59	18	3.9	74	78.5	19.9	0.56	88
L. S. D (P=0.05)				3.2	0.9	1.6	17.6	NS	0.8	0.99	
C. V. (%)				2.1	2.1	8.1	8.7	2.8	1.6	16.9	

NS : Not Significant.

## REFERENCES

- Hong, K. S., Hwang, I. T., Kim, S. E., Choi, J. S., Lee, B. H. and Cho, K. Y. (1995). Germination characteristics of *Diplachne fusca* seeds. *Kor. J. Weed Sci.* **15** : 183-87.
- KCPA (Korea Crop Protection Association) (2014). *Guide Book of Using the Agrochemicals*. Sam Jeong Press Co., Seoul. 1438 p.
- Kuk, Y. I., Jung, H. I., Kwon, O. D., Lee, D. J., Burgos, N. R. and Guh, J. O. (2003a). Sulfonylurea herbicide-resistant *Monochoria vaginalis* in Korean rice culture. *Pest Manage. Sci.* **59** : 949-61.
- Kuk, Y. I., Kim, K. H., Kwon, O. D., Lee, D. J., Burgos, N. R., Jung, S. and Guh, J. O. (2003b). Cross-resistance pattern and alternative herbicides for *Cyperus difformis* resistant to sulfonylurea herbicides in Korea. *Pest Manage. Sci.* **60** : 85-94.
- Kuk, Y. I., Kwon, O. D. and Im, I. B. (2002). Sulfonylurea herbicide-resistant *Scirpus juncooides* Roxb. in Korean rice culture. *Korean J. Weed Sci.* **22** : 296-305.
- Park, T. S., Kang, C. K., Park, J. E., Ku, B. I., Park, H. K., Ghimire, S. R., Kim, Y. D. and Ko, J. K. (2009). Identification and management of sulfonylurea-resistant biotype of *Scirpus planiculmis* in reclaimed paddy fields, *Korea. Kor. J. Weed Sci.* **29** : 159-66.
- Park, T. S., Kim, C. S., Park, J. E., Oh, Y. K. and Kim, K. U. (1999). Sulfonylurea-resistant biotype of *Monochoria korsakowii* in reclaimed paddy fields in Seosan, Korea. *Korean J. Weed Sci.* **19** : 340-44 (In Korean).
- Park, T. S., Lee, I. Y., Seong, K. Y., Cho, H. S., Park, H. K., Ko, J. K. and Kang, U. G. (2011). Status and prospect of herbicide resistant weeds in rice field of Korea. *Korean J. Weed Sci.* **31** : 119-133 (In Korean).
- Rural Development Administration of Korea (1998). *Guidance methods for food crop cultivation*. pp. 55-86.
- SAS (Statistical Analysis System) (2000). *SAS/STAT Users Guide, Version 7*. Cary, NC : Statistical Analysis System Institute, Electronic Version.
- Ureshi, R. H., Salim, M., Abdulah, M. and Pitman, M. G. (1982). *Diplachne fusca* : An Australian salt-tolerant grass used in Pakistani agriculture. *J. Aust. Inst. Agric. Sci.* **48** : 195-99.
- Wongwattana, C., Surawattananon, S. and Nanakorn, M. (1995). Survey of weeds in salt-affected area in north-east Thailand. Proc. 15<sup>th</sup> Asian Pacific Weed Science Conference. Asian Pacific Weed Science Society, Tsukuba. pp. 792-97.