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CHANGES OF PADDY WEED SPECIES, DIVERSITY AND RICHNESS ASSOCIATED WITH THE HERBICIDE USE IN JAPAN

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ABSTRACT

The purpose of this study was to evaluate the effect of the herbicide on the diversity and species richness of weed in the paddy field. The field survey was conducted in October 2001 and April 2002, in farmers' paddy field, western Japan. Randomly selected 23 paddy fields were surveyed using 1m by 1m quadrate. The coverage (percentage) of 1m and the maximum height of each species (m) in each quadrate were measured. Species abundance was expressed as the volume equivalent-value (cm^3) and species diversity was calculated using Shanon-Wiener Index (H'). It was revealed that the potential species richness of paddy weed community was suppressed by the use of herbicide and no use of herbicide could enhance the weed re-growth and increase the species richness, even for the short interval. Continuous and long- time herbicide application could change the species composition in paddy fields.

Key Words : Paddy field, Herbicides, Volume equivalent weight, Diversity, Paddy weed

INTRODUCTION

Trend of change in weed species with herbicide use in Japanese paddy rice farming

Rice paddy agriculture occupies most of Japan's alluvial plains. A large proportion of cultivated field area in Japan that was about 55% in the year 2000 (MAFF, 2001) was the rice paddy field. Japanese paddy farmers depend on herbicides for weed management. They often spray herbicides between rice seasons to control re-grown perennials and germinating winter and spring weeds. Due to depopulation in the rural areas coupled with the farmers engaged in non-farm economic activities, the reduction of time spent in farming practices motivated farmers to be dependent on chemical pesticide. Decrease of wet rice fields due to abandonment and re-development into larger dry fields and communization of herbicides use have led some threatened species disappear from the paddy field and many weeds have become threatened throughout Japan (Shimoda *et al.*, 2002).

The weeds in the paddy fields of Japan have changed since the introduction of different herbicides in different periods (Shibayama, 1994, 1996, 2000, 2001). Before the introduction of herbicides, a mixed weed community including barnyard grass, annual broad-leaved species such as monochoria and some perennial species were controlled by the rotary weeder or manually. In the 1950s, after the introduction of 2, 4-D and MCPA to control broad-leaved weed, barnyard grass became the dominant weed and was which made manual or rotary weeding impossible. In the 1960s, pentachlorophenol (PCP), nitrifen and chlornitrofen (CNP) were introduced to control barnyard grass and other annual weeds at germination. Then, the spikebrush became a very serious problem among the paddy weeds.

In the 1970s, thiobencarb became popular herbicide for effective control of annual weeds and spikebrush. After a few years, however, perennial weeds such as *Cyperus serotinus*, *Sagittaria spp.* and *Scirpus juncoides* became the dominant species. Popular 'One-shot' herbicides were then introduced in the 1980s as compound herbicides which could control annuals and widely distributed perennials by single application. As the consequence, the perennial sedge *Eleocharis kuroguwai* and the perennial broad-leaved *Sagittaria trifolia*, together with some other species, became the problematic weeds. In the 1990s, some 'one-shot' herbicides were found to be effective at decreasing, or preventing increase of kuroguwai and arrowhead. Nevertheless, annual broad-leaved weeds such as monochoria, false pimpernel and some others often observed to grow abundantly in many farmers' fields. The under lying causes was herbicides resistance and inadequate water management under labor shortage after applying 'one-shot' herbicides.

In Japanese agriculture, 50 to 80% of the total amount of herbicides was applied to paddy

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rice fields (Ueji and Inao, 2001). About 5000 tons of herbicides active ingredients have been used for paddy cultivation in Japan in the 2000. There are 190 commercial paddy herbicides, but around 6 to 18 main chemical compounds (active ingredients) were applied respectively to more than 100,000 to 50,000 hectares (JAPR, 2001). The main herbicides applied to Japanese paddy fields in 2000 are listed in Table 1. In the last 10 to 20 years, combination products of two to five chemicals have become the most common. 'One-shot' herbicides including sulfonylurea compounds such as bensulfuron-methyl (BSM), pyrazosulfuron-ethyl (PSE), imazosulfuron (IS) and a few others have been very popular in recent years.

The current major weed species in paddy fields in Japan are shown in Table 2. Dominant annual species are barnyard grass, small flower umbrella sedge (*Cyperus difformis*), monochoria (*Monochoria vaginalis*), tooth cup (*Rotala indica*), false pimpernel (*Linderinia spp.*) ammania (*Ammania multiflora*) and others, while common perennial ones are knotgrass (*Paspalum distichum*), mizugayatsuri (*Cyperus serotinus*), spike rush (*Eleocharis acicularis*), bulrush (*Scirpus juncoides*), sagittaria (*Sagittaria pygmaea*) and so on.

An increase of annual brad-leaved weeds and some perennial species has been reported in many regions. In particular, in northern regions several annual broad leaves such as *Lindernia* species have been reported as a serious problem due to the increase of herbicide-resistant and intraspecific variations. Nowadays, the sulfonylurea urea herbicide resistant weeds are becoming a growing concern such as *Monochoria korsakowii, Lindernia procumbens, Lindernia dubia, Lindernia micrantha* and several other broad-leaves and blushbrush (Itoh *et al.*, 1999; Uchino *et al.*, 1999).

The present study

Information on biodiversity in different areas and under different farming practices can help policy makers to decide on the direction of agri-environmental schemes and to try and meet the commitments that the policy have made in their biodiversity conservation plan.

Moreover, change in susceptibility of weeds associated with changes in herbicide use provides only part of the picture of the impact of weed management on the weed flora of arable fields. Especially in Japan, autumn and spring weed control will obviously have a much greater impact than that in summer. Because in summer, all of the paddy field is artificially maintained, this is ideal for paddy production only. Some studies have measured the biodiversity of paddy field in growing season; however, none has done in the off-season paddy field. Therefore, in this study, evaluation of the plant diversity, species composition in autumn and in spring and the comparison of herbicide use and no use was attempted.

METHODOLOGY

The study area

The study area is in Higashi Hiroshima of Hiroshima Prefecture in Japan. Higashi Hiroshima is situated on the central part of Hiroshima Prefecture and east of Hiroshima city. The main crop in this area is paddy rice and the area is considered as a typical rice growing area of Japan. The land under paddy cultivation covers 15% (4180 ha) of the total land area and 93% of the total agricultural land (4490 ha.). Almost all of the paddy farmers use herbicide for weed control in the paddy season (May – October) along with other off-season (November – April) management. Twenty-three paddy fields having no off-season disturbance were selected for the survey. In 10 out of 23 paddy fields, no control measure was taken since 2000 and the rest 13 herbicides were used in the paddy season in the last 10 years. The surveyed paddy fields were more or less homogeneous in terms of cultivation practices, water regime, soil and weather condition.

Vegetation survey and data analysis

The vegetation survey was undertaken in autumn (October) 2001 and spring (April) 2002. In every paddy field, five quadrate of 1 x 1 m^2 was used to vegetation survey. In each quadrate, the maximum height and the surface area covered by every plant species were measured. Species abundance was expressed as the volume

Table 1. Important weed species in Japanese paddy fields

Common name		Species	Family
Annual grasses			
	Barnyardgrass	*Echinochloa oryzicola* Vasing	Poaceae
	Barnyardgrass	*Echinochloa crus-galli* (L) Beauve. Var. crus-galli	Poaceae
	Sprangletop	*Leptochola chinensis* (L..) Nees	Poaceae
Annual sedges			
	Smallflower umbrella sedge	*Cyperus difformis* L.	Cyperaceae
	Rice flatsedge	*Cyperus iria* L.	Cyperaceae
	Globe fringerush	*Fimbristylis miliacea* (L..) Vahl.	Cyperaceae
Annual broad-leaved weeds			
	Mizuaoi	*Monochoria koraskowii* Regel et Maack	Pontederiaceae
	Monochoria	*Monochoria vaginalis* (Burn. F.) Kunth	Pontederiaceae
	Indian toothcup	*Rotala indica* (Willd.) Koehne var. uliginosa (Miq.) Koehne	Lythraceae
	Ammania	*Ammania multiflora* Roxb.	Lythraceae
	Purple ammania	*Ammania coccinea* Roxb.	Lythraceae
	Common false pimpernel	*Lindernia procumbens* (Krock.) Borbas	Scorphulariaceae
	Low false pimpernel	*Lindernia dubia* (L.) Penn.	Scorphulariaceae
	Azetogarashi	*Lindernia micrantha* D. Don	Scorphulariaceae
	Eclipta	*Eclipta prostrata* (L..) L..	Compositae
	Devil beggarticks	*Bidens frondosa* L..	Compositae
	Bur beggarticks	*Bidens tripartita* L..	Compositae
	Ludwigia	*Ludwigia epilobiodes* Maxim.	Onagraceae
	Indian jointvetch	*Aeschnomene indica* L..	Leguminosae
	Marsh pepper smartweed	*Persicaria hydropiper* (L..) Spach	Polygonaceae
Perennial grasses			
	Rice cutgrass	*Leersia oryzoides* (L..) Sw.	Poaceae
	Knotgrass	*Paspalum distichum* L..	Poaceae
Perennial sedges			
	Mizugayatsuri	*Cyperus serotinus* Rottb.	Cyperaceae
	Needle spikerush	*Eleocharis acicularis* (L..) Roem. Et Schult. Var. longiseta Sven	Cyperaceae
	Kuroguwai	*Eleocharis kuroguwai* Ohwi	Cyperaceae
	Bulrush	*Scirpus juncoides* Roxb. Var. ohwianus T. Koyama	Cyperaceae
	Shizui	*Scirpus nipponicus* Makino	Cyperaceae
	Koukiyagara	*Scirpus planiculmis* Fr. Schm.	Cyperaceae
Perennial broad-leaved weeds			
	Water plaintain	*Alisma canaliculatum* A. Br. Et Nouche	Alismataceae
	Sagittaria (urikawa)	*Sagittaria pygmaea* Miq.	Alismataceae
	Arrowhead	*Sagittaria trifolia* L..	Alismataceae
	Oenanthe	*Oenanthe javanica* (Blume) D.C.	Umbellaiferae
Algae			
	Spirogyra	*Spirogyra arcla* Kutz.	Zygnemataceae
	Pithophora	*Pithophora zelleri* (Martius) Wittrock	Cladophoracea

Table 2. Changes in major weed species in Japanese paddy fields under herbicide application

Period	Main control measures and herbicides	Serious weeds
Before 1950	Rotary and hand weeding	Annual and some perennial weeds
1950s	Foliar application: 2,4-D, MCPA	*Echinochloa oryzicola*
1960s	Soil application: pentachlorophenol, chlornitrofen, nitrofen	*Echinochloa acicularis*
1970s	Foliar and soil application: thiobencarb, simetryn, molinate, oxadion, butachlor	*Sagitaria pygmaea, Scirpus juncoides, Cyperus serotinus*
1980s	'One-shot' combinations: pyrazolate, pretilachlor, bensulfuron-methyl, pyrazosulfuron-ethyl, mefenacet	*Eleocharis kuroguwai, Sagitaria trifolia*
1990s	New laborsaving formulations	Annual broad-leaved weeds
2000s	Various herbicidal combinations	Herbicide resistant weeds

Source: Shibayama, 2001

equivalent-value (cm^3) of each species by multiplication of maximum plant height (cm) and coverage (percentage) in each quadrate. The relative dominance value (percentage) of species in all the 25 paddy fields was computed by the pooling of all the volume-equivalent values for the quadrates.

Species diversity was calculated using Shanon-Wiener Index (H'):

$$H' = - \sum_{i=1} (pi \log pi)$$

Where pi is the relative dominance of species i, n is the number of species in a field. The data was analyzed using Cornell Ecology Program Series in PC-ORD Version 4 of MjM Software Design.

FINDINGS AND DISCUSSION

Forty one species were recorded in all the paddy field studied in autumn 2001 of which 26 were found in fields without herbicide use and 23 with herbicide use (Table 3). In spring, 2002, 51 species were found and the difference between the numbers of species was much larger (40) in fields having no herbicide use and 27 in herbicide use fields. *Poa annua* was dominant in both kinds of fields in autumn but in spring it was dominant exclusively in no- herbicide fields. In spring, *Alopecurus aequalis* was dominant in herbicide used fields. In both the seasons, the biomass of dominant species was much larger in the fields of no-herbicides than in the herbicide use fields. Most of the species were commonly observed in both kinds of field, however, some herbicide susceptible species were absent in herbicide used fields. The species susceptible to herbicide has been documented, as *Capsella bursa-pastoris*, (Mayor & Dessaint, 1998), *Chenopodium album* (Hyvönen and Salonen 2002), *Plantago sp.* and *Solidago sp.* (Fuhlendorf *et a.l*, 2002), *Cyperus serotinus, Vicia sepium (Kitazawa and Ohsawa, 2002).*

The dominancy of *Poa annua* (favor dry paddy field) might be triggered by the frequent use of heavy machinery leading to soil compaction (Elsen, 2000). Appearing *Alopecurus aequalis* as dominant species indicate that the fields were wet condition in spring. The other reason might be that, routine application of herbicide led *Alepocurpus sp.* to be a dominant species (Fryer, 1982). In autumn, the difference was not much bigger in species richness unlike in spring. One reason may be that most of the species can not establish effective seed bank in a year. For example, *Chenopodium album* form seed banks in summer (Ohtsuka and Ohsawa, 1994) and re-growth in the following season this explains why it was not found in herbicide used fields in both seasons.

Many studies have reported that the use of herbicide could substantially reduce the number of plant species in paddy field than no used. Past study found that there was a positive correlation between the number of weed species and residue of bensulfuron methyl detected in irrigation water of paddy field (Matsuo, 2000). All of the study fields were cultivated for a long

Table 3 Main herbicides applied to paddy rice fields in Japan in 2000

Herbicides (single chemicals or combination products)	Area applied (haX1000)
Jumbo formulation (mainly, 'one-shot' application)	
Cafenstrole + daimuron + bensulfuron-methyl(J)	123
Cafenstrole + pyrazosulfuron-ethyl(J)	33
Cafenstrole + cyclosulfamuron + daimuron (J)	28
Soil incorporation (preemergence)	
Pretilachlor (EC)	98
Pyrubuticarb + Pretilachlor (EC)	54
Bifenox + Pretilachlor (EC)	28
Soil application (preemergence)	
Pretilachlor (G)	176
Pretilachlor + benzofenap (FL)	73
Pentoxazone (FL,G)	36
Dimethametryn + pretilachlor (G)	25
Preemergence 'one-shot' application	
Imazosulfuron + daimuron +pentoxazone (FL, G)	64
Thenylchlor + bensulfuron-methyl (FL)	35
Dimethametryn + pyrazolate + pretilachlor +benfuresate (G, FL)	24
Early postemergence 'one-shot' application	
Bensulfuron-methyl + mefenacet (+daimuron)(G)	183
Cafenstrole + cyhalofop-butyl +daimuron + bensulfuron-methyl (+azimsulfuron)(FL, G)	158
Bensulfuron-methyl + thiobencarb + mefenacet (+azimsulfuron)(G)	143
Esprocarb + dimethametryn + pyrazosulfuron-ethy + pretilachlor (G)	78
(Azimsulfuron +)cyhalofop-butyl + thenylchlor + bensulfuron-methyl (FL, G)	61
Cyhalofop-butyl + pyrazosulfuron-ethy + mefenacet (G)	56
Cyhalofop-butyl +dimethametryn + pyrazosulfuron-ethy + pretilachlor (G)	49
Pyriminobac-methyl + bensulfuron-methyl + mefenacet (+azimsulfuron)(G)	49
Pyrazosulfuron-ethy + mefenacet (G)	43
Esprocarb + bensulfuron-methyl (+azimsulfuron)(G)	39
Cafenstrol + pyrazosulfuron-ethyl (G)	35
Imazosulfuron + daimuron + mefenacet (G)	33
Imazosulfuron + cafenstro + daimuron (G)	33
Imazosulfuron + esprocarb + daimuron (G)	29
Pyriminobac-methyl + thenylchlor + bensulfuron-methyl (+azimsulfuron)(G)	27
Cafenstrol + cyhalofop-butyl + pyrazosulfuron-ethy(G)	26
Cafenstrol + daimuron + bensulfuron-methyl (FL)	26
Foliar and soil application (early postemergence)	
Simetryn + molinate + MCPB (G)	96
Simetryn + thiobencarb + MCPB (G)	29
ACN (G)	27
Simetryn + benfuresate + MCPB (G)	23
Foliar application (postemergence)	105
MCPA (AS,G)	
2,4-D (AS,G,SP)	102
Cyhalofopbutyl (G, EC)	68
Bentazon (G, AS)	48
After harvesting rice or on levee (postemergence)	
Glyphosate (AS)	252
Glufosinate (AS)	86

Source: Shibayama, 2001

Table 4(a). List of species and biomass in volume equivalent value

a. Spring		
Species	No herbicide	Herbicide
Alopecurus aequalis	0.38	1.81
Aneilema keisak	-	<0.01
Artemisia princeps	0.01	-
Astragalus sinicus	<0.01	0.21
Beckmannia syzigachne	0.16	0.24
Capsella bursa-pastoris	0.06	-
Cardamine flexuosa	<0.01	0.17
Cerastium glomeratum	<0.01	<0.01
Chenopodium album var. centrorubrum	<0.01	-
Cirsium japonicum	<0.01	<0.01
Commelina communis	0.01	<0.01
Cyperus serotinus	<0.01	_
Eleocharis acicularis var. Longiseta	<0.01	_
Equisetum arvense	0.14	_
Erigeron canadensis	<0.01	<0.01
Erigeron sumatrensis	<0.01	<0.01
Gnaphalium affine	<0.01	<0.01
Gnaphalium purpureum var. spathulatum	<0.01	<0.01
Hydrocotyle sibthorpioides	_	<0.01
Ixeris dentata	<0.01	<0.01
Lapsana apogonoides	0.08	0.16
Oenanthe javanica	<0.01	0.01
Oxalis corniculata	<0.01	_
Plantago asiatica	<0.01	_
Poa annua	4.93	0.24
Prunus verecunda	0.04	0.15
Ranunculus sceleratus	<0.01	0.34
Rumex acetosa	0.03	_
Sagina japonica	<0.01	<0.01
Scirpus hotarui	<0.01	<0.01
Sedum bulbiferum	0.01	_
Solidago altissima	0.01	<0.01
Spirodela polyrhiza	<0.01	_
Stellaria alsine var. undulata	0.01	0.01
Stenactis annuus	_	<0.01
Taraxacum officinale	<0.01	_
Trifolium dubium	0.01	_
Veronica arvensis	_	<0.01
Vicia hirsuta	_	<0.01
forb 1	0.01	_
forb 2	0.01	<0.01
forb 3	_	<0.01
grass 1	0.06	_

Source: Field survey. Spring 2001

Table 4(b). List of species and biomass in volume equivalent value

b. Autumn		
Species	No herbicide	Herbicide
Aeschynomene indica	0.01	-
Alepocurus aequalis	0.36	0.07
Alepocurus japonicus	<0.01	-
Ammania multiflora	<0.01	-
Andropogon varginicus	0.54	
Artemisia princeps	-	<0.01
Astragalus sinicus	-	<0.01
Bidens triprtita	<0.01	-
Cardamine flexuosa	<0.01	<0.01
Cerastium glomeratum	-	<0.01
Chenopodium album	-	<0.01
Cirsium sp.	-	<0.01
Cyperus sp.	<0.01	<0.01
Digitaria sp.	<0.01	-
Echinochloa crus-galli	0.07	<0.01
Elatine triandra	<0.01	-
Erigeron canadensis	<0.01	-
Geranium carolinianum	-	<0.01
Hydrocotyle ramiflora	<0.01	<0.01
Juncus effusus	<0.01	<0.01
Lapsana apogonoides	<0.01	-
Lindernia procumbens	<0.01	-
Lipocarpha microcephala	<0.01	-
Mazus pumilas	<0.01	0.03
Monochoria vagnelis	<0.01	-
Oxalis corymbosa	-	<0.01
Poa annua	3.13	1.14
Rorippa islandica	-	<0.01
Rorippa islandica	-	0.06
Rumex acetosa	-	<0.01
Sagittaria trifolia	<0.01	-
Scirpus tabernaemontani	-	0.06
Sedium bulbiferum	-	0.02
Stellaria alsine	0.03	-
Stellaria media	<0.01	-
Trifolium dubium	-	0.02
Unknown 2	-	<0.01
Unknown 3	-	<0.01
Unknown1	<0.01	-
Vicia angustifolia	-	0.02

Source: Field survey, Autumn 2001

herbicides in paddy production typically changes the species composition of weed communities by reducing abundance of sensitive broad-leaved weeds and favoring tolerant grasses (Fryer and Chancellor 1970; Chancellor 1979; Mahn 1984, Shibayama, 1994). Herbicide use can result in changes in weed seed banks in arable soil (Squire *et al.*, 2000). Number of species can increase if herbicide use is reduced (Ewald and Aebischer, 2000). The weed control method influences not only the composition and relative abundance of the different species, but also its seed bank size (Mayor and Dessaint, 1998).

Otte (1992)(mentioned by Albrecht and Pilgram, 1997) reported that seed numbers increased about 753% after four years of crop cultivation having no weed control effort. Management measures to reduce the weed infestation pressure have been the main interest of many weed seed bank investigations. Most of the studies found that diversification in cultivation can lead to far-reaching changes in the soil seed bank within several years. Ninety-seven percent seed bank reduction can occur after four years of cultivation practices with weed control measure (Roberts and Feast, 1973). In this study, it was found that the growth of some species was restricted by herbicides application; therefore, herbicide application could substantially reduce the plant species diversity. The plant species tolerant to herbicides would eventually replace susceptible ones because of repeated herbicides use. The importance of weeds seed bank is primarily in seedling recruitment and subsequent

Table 5. Species diversity and species richness of weed in surveyed paddy fields

	Autumn 2001		Spring 2002	
	Species Richness(S)	Shanon diversity index (H)	Species Richness(S)	Shanon diversity index (H)
No herbicide 1	11	0.774	17	0.669
No herbicide 2	8	1.18	20	0.712
No herbicide 3	15	1.467	19	0.756
No herbicide 4	7	1.177	16	1.061
No herbicide 5	9	1.268	14	0.75
No herbicide 6	9	1.813	13	0.965
No herbicide 7	15	1.478	16	1.249
No herbicide 8	22	1.124	16	1.385
No herbicide 9	11	1.346	13	1.077
No herbicide 10	8	0.835	14	0.771
Herbicide 1	4	1.275	12	0.411
Herbicide 2	3	0.753	10	0.68
Herbicide 3	5	0.328	7	0.599
Herbicide 4	5	0.719	10	0.742
Herbicide 5	5	0.546	10	0.942
Herbicide 6	10	0.387	11	0.893
Herbicide 7	7	1.144	10	1.671
Herbicide 8	10	0.756	13	1.717
Herbicide 9	9	0.135	10	1.594
Herbicide 10	7	0.66	13	0.845
Herbicide 11	8	0.693	13	0.776
Herbicide 12	8	0.36	11	0.602
Herbicide 13	11	0.277	14	1.23

Shanon diversity index (H)= - (pi log pi)
where pi is the proportion of the total sample (total biomass)composed of species i

maintenance of high plant densities in crop fields. Effective establishment of weed stands depends on the presence of propagules and specific environmental characteristics that are suitable for seed germination and plant growth. Continued intense management of habitats would allow the seed banks to decay further, possibly to the nearly extinction of some species from the field. However, there is little hard information on long-term persistence of a species at low frequency. On the other hand, reducing the intensity of weed management has increased the species in either abundance or frequency of occurrence (Squire and Wright, 2000).

The species richness and species diversity was higher in no-herbicide used fields than the herbicide used (Table 4). Although, in spring the number of species was higher in both the fields but Shannon diversity index was not much different between the both fields and smaller than that in the autumn. The reason might be that with the increasing number of species the biomass production reduced. On the internal community level, Keddy *et al.*, (2002) compared the competitive performance and growth of phytometer. According to his experimental study, plant size and leaf shape were two characteristics that predicted the relative competitive performance the most.

Most of the common species are the typical weed community of wet paddy field of this region and *Alopecurus aequalies*, *Ranaunculus scelertus* and *Beckmania syzigache*, will appear if the field is submerged at about 10-30 cm of water (Shimoda, 1996). Moreover, our result is indicating to the change in plant species richness in spring paddy field of this region. Some species such as, *Glyceria acutiflora*, *Mazus pumilus*, *Hemistepta lyrata*, *Conyza sumatrensis*, *Ixeris polycephala* and some other reported by Shimoda (1996) were not at all observed in this study. They might have disappeared or decreased over the long period of continuous cultivation with intense management (Marshal *et al.*, 2001).

In consequence of our study, it was revealed that the potential species richness of weed community is suppressed by herbicide use in paddy fields (Legere and Dereksen, 2000).

CONCLUSION

This study indicated the change of weed species in paddy fields in Japan. It also indicated that the species richness and diversity of paddy weeds are affected by the continuous herbicides use. Some species could regenerate if no herbicide had been used, even for two consecutive crop seasons. Our findings suggest that continuous and long time herbicide application is menace to the paddy weed species. Further research on the herbicide effect to the change of weed species should be conducted on long-term basis and policy maker should emphasize on the reduction of paddy herbicide use.

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