

Effect of continuous direct seeding on weed species diversity in Seberang Perai rice granary, Malaysia

(Kesan tabur terus yang berterusan terhadap kepelbagaian spesies rumput di jelapang padi Seberang Perai, Malaysia)

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Key words: direct-seeded rice, weed survey, importance value, Sorenson index, Simpson's index

Abstract

Survei rumput telah dijalankan selama sembilan musim berturut-turut di Seberang Perai, Malaysia antara Januari 1990 dan Oktober 1994. Spesies rumput yang dominan antara musim dibandingkan dengan menggunakan nilai kepentingan. Sejumlah 48 spesies rumput daripada 36 genus yang tergolong dalam 22 famili telah dicatat. Daripada jumlah tersebut, 23 spesies daun lebar, 12 rumput, 9 rusiga dan 4 rumput air. Kurang daripada 30 spesies yang penting dan hanya dua hingga empat spesies yang dominan setiap musim. *Echinochloa crus-galli* var. *formosensis* dan *Leptochloa chinensis* yang terbanyak dan oleh itu merupakan yang paling dominan dan bersaing pada semua musim yang dikaji. Susunan spesies-spesies yang dominan ialah *Monochoria vaginalis*, *Bacopa rotundifolia* dan *E. crus-galli* pada luar musim 1990, *M. vaginalis* dan *E. crus-galli* pada musim utama 1990/91, *Leptochloa chinensis*, *M. vaginalis* dan *E. crus-galli* pada luar musim 1991, *L. chinensis*, *E. crus-galli* dan *Fimbristylis miliacea* pada musim utama 1991/92, *B. rotundifolia*, *M. vaginalis*, *E. crus-galli* dan *L. chinensis* pada luar musim 1992, *L. chinensis* dan *E. crus-galli* pada musim utama 1992/93, *L. chinensis*, *E. crus-galli* dan *B. rotundifolia* pada luar musim 1993, *L. chinensis*, *E. crus-galli*, *S. guyanensis* dan *Najas graminea* pada musim utama 1993/94, dan *B. rotundifolia*, *L. chinensis* dan *S. grossus* pada luar musim 1994. Kepelbagaian spesies rumput berasaskan indeks kesamaan Sorenson menunjukkan sekurang-kurangnya 38% spesies yang disenaraikan wujud pada semua musim.

Abstract

Weed surveys were conducted in nine consecutive seasons at Seberang Perai, Malaysia between January 1990 and October 1994. The dominant weed species between seasons were compared using importance value. A total of 48 weed species belonging to 22 families under 36 genera were recorded. Of these, 23 species were broad-leaved weeds, 12 grasses, 9 sedges and 4 submerged weeds were recorded. Two to four of the species were dominant with less than 30 marginal species each season. *Echinochloa crus-galli* var. *formosensis* and *Leptochloa chinensis* were ubiquitous, dominant and competitive weeds in all

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seasons. The rating of dominant species was *Monochoria vaginalis*, *Bacopa rotundifolia* and *E. crus-galli* during the off-season 1990; *M. vaginalis* and *E. crus-galli* during the main season 1990/91; *Leptochloa chinensis*, *M. vaginalis* and *E. crus-galli* during the off season 1991; *L. chinensis*, *E. crus-galli* and *Fimbristylis miliacea* during the main season 1991/92; *B. rotundifolia*, *M. vaginalis*, *E. crus-galli* and *L. chinensis* during the off-season 1992; *L. chinensis* and *E. crus-galli* during the main season 1992/93; *L. chinensis*, *E. crus-galli* and *B. rotundifolia* during the off season 1993; *L. chinensis*, *E. crus-galli*, *S. guyanensis* and *Najas graminea* during the main season 1993/94; *B. rotundifolia*, *L. chinensis* and *S. grossus* during the off season 1994. Weed species diversity based on Sorenson's index of similarity indicated that at least 38% of the listed species occurred in all seasons.

Introduction

In Malaysia, rice double cropping covers an area of about 209 300 ha which is principally found in the eight granary areas in Peninsular Malaysia. One of the areas is Seberang Perai (13 000 ha) in Penang (Figure 1). In this area, direct seeding has been practised since the 1980s.

Consequently, due to the change in cultural practices, weeds become a major constraint to rice production, and therefore weed management is a necessary prerequisite to overcome the problem. Effective weed control requires knowledge of taxonomy, distribution, ecology and biology of weeds (De Datta 1988). This is in view of the dynamic changes taking place in weed communities since the adoption of direct seeding rice culture in the 1980s.

Surveys on rice weed community in this area have been made by Baki and Md. Khir (1983) as well as Azmi and Anwar (1988). The most common species identified at that times were *Monochoria vaginalis*, *Fimbristylis miliacea*, *Echinochloa crus-galli*, *Scirpus grossus* and *Limnocharis flava*. It is with such notion that the present set of surveys on weed communities over nine consecutive seasons of direct seeding of rice was made. The objective of this study was to assess the composition, distribution and structure of rice weed communities in this area in nine consecutive seasons from January 1990 to October 1994. Such information on the temporal changes of the

weed species composition is important to formulate the appropriate weed control strategies to produce optimum yields.

Materials and methods

Weed surveys of Seberang Perai granary were conducted in the off and main seasons of 1990–1994 at five locations in Seberang Perai (Figure 1). The main season normally starts from October and ends in February while the off season lasts from April to September. For such purpose, samplings were made randomly in each location using the list count quadrat (1 m x 1 m) method (Kim and Moody 1983). Eight quadrats were randomly taken in each site. Surveys were conducted 2 months after sowing on residual weeds which escaped weed control practices. A total of 40 quadrat samples were taken in each studied season. Weed species observed in each quadrat were identified, listed and counted. The taxonomical aspects in this study followed the nomenclature of Soerjani et al. (1987).

The coverage for each weed species within the quadrat was also estimated with the rating scales based on the methods of Tjitrosemito and Alex (1989). The rating scales used are as follows:

- 1 = 0–5% weed coverage
- 2 = 6–25% weed coverage
- 3 = 26–50% weed coverage
- 4 = 51–75% weed coverage
- 5 = 76–95% weed coverage

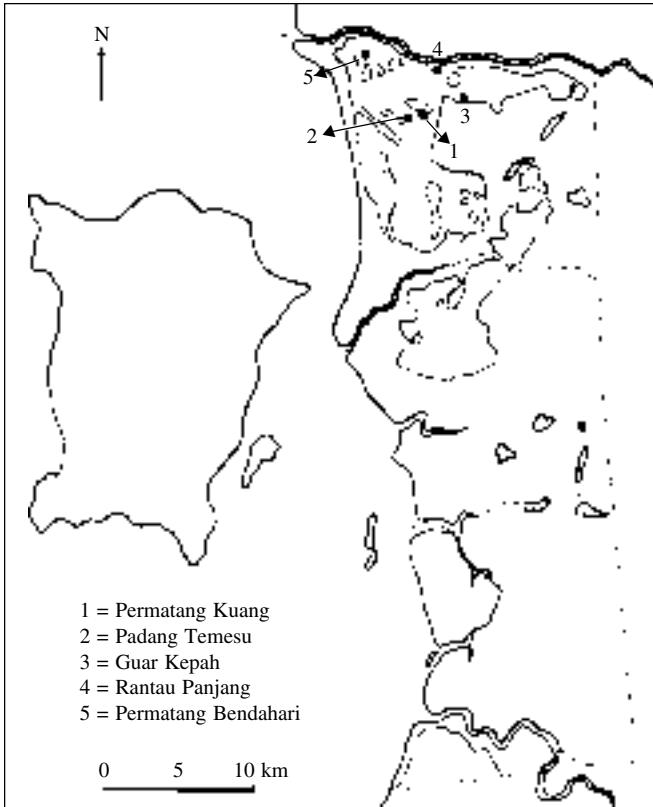


Figure 1. Surveyed locations in Seberang Perai rice growing areas (shaded)

The predominance of a particular species within a community is denoted by its importance value (IV) index and this can be calculated using methods of Kim and Moody (1983). Derivations of the IV indices were as follows:

Density = no. of individuals ÷ area sampled

Relative density = (density for a species ÷ total density for all species) x 100

Dominance = total of basal area or area coverage values ÷ area sampled

Relative dominance = (dominance for a species ÷ total dominance for all species) x 100

Frequency = no. of plots in which species occur ÷ total no. of plots sampled

Relative frequency = (frequency value for a species ÷ total frequency value for all species) x 100

Importance value = relative density + relative dominance + relative frequency

Comparisons of speciation among weed communities in the different growing seasons were based on Sorenson's index of similarity (S) (Goldsmith et al. 1986).

Computation of the S value is as follows:

$$S = [2J \div (A + B)] \times 100$$

where S = comparison of association between seasons A and B

J = no. of species common to both seasons A and B

A = no. of species presence in season A

B = no. of species presence in season B

The bigger the S value indicates the close similarity the species composition in both seasons A and B. Conversely, a smaller S value reflects the divergence in species similarity for the two seasons.

Simpson's index (Kim and Moody 1983) which is a measurement of the concentration of dominance, can be used to determine the degree of diversity in a community. This can be determined by using the following equation,

$$\text{Simpson's index (C)} = \sum (y/N)^2$$

where y = importance value

N = sum of the importance values
for all species in the sample

Importance value is used to compare the dominance structure of weed communities in each planting season. Therefore, the dominance curves are constructed by plotting the IV of an individual weed community against the weed ranking in the decreasing order of importance.

Results and discussion

A total of 48 weed species belonging to 22 families under 36 genera were observed in the nine consecutive seasons (January 1990 to October 1994) in Seberang Perai rice areas (Table 1). Of these species, 23 were broad-leaved weeds, 12 grasses, 9 sedges and 4 aquatic/submerged weeds. These represent 56.5% from 85 weed species reported in the rice areas in Peninsular Malaysia (Azmi et al. 1993). The number of species recorded in nine consecutive seasons ranged from 26 to 35 (Table 2). The differences in the total number of species in between the seasons were likely due to the occurrence of rare species (<5%). This mainly attributed to the temporal changes in direct-seeding areas.

The most important weed species in each season surveyed and their rankings in decreasing order of dominance were almost similar (Table 3). The overall weed composition of the nine consecutive surveyed seasons were almost similar. The

large value of Sorenson's index of similarity as shown in Table 4 indicated that similar weed species present in each season. The off season 1990 and the main season 1990/91 recorded the largest index value of 93 while the main seasons of 1991/92 and 1992/93 showed the smallest value of 38. This may be due to the fluctuation of the direct-seeding areas as stated earlier.

Evidently, the values of Simpson's index ranged from 0.06 to 0.09, indicating that weed community in each season was not so diverse and was only dominated by 2-4 specific weed species (Table 2).

The differences in the structure of weed communities in each season surveyed are shown in the dominance curves in Figure 2. In the off season 1990 and the main season 1990/91, only two species, namely *Monochoria vaginalis* and *Leptochloa chinensis*; *Limnocharis flava* and *Echinochloa crus-galli*, were relatively pronounced. On the other hand, species *E. crus-galli* and *L. chinensis* were dominant in the main seasons of 1991/92 and 1992/93. In the off season 1992, due to the abundant supply of water from the rain and irrigation, *Bacopa rotundifolia*, *M. vaginalis* and *E. crus-galli* were prominence. Another grassy weed to watch in future when farmers targeting their control on those grasses is *E. oryzicola*. It was found to infest direct-seeded fields since the off season 1991.

There was a gradual increase in grassy weeds except in the off season 1992 (Figure 3). In the off season 1992, because of the availability of water supply throughout the crop season, there was a sudden increase in aquatic weeds. It should be interesting to note that although there was an increase in grassy weeds, the grassy weed components were dominated by *E. crus-galli* and *L. chinensis*. In this particular case, *L. chinensis* was found to be more dominant than *E. crus-galli* in the main season 1992/93, off season 1993, main season 1993/94 and off season 1994. This was probably due to heavy usage of herbicides such as molinate and quinclorac which were only effective

Table 1. Weed species in rice-growing areas in Peninsular Malaysia and Seberang Perai

Family	Species found in rice-growing areas in Peninsular Malaysia (adapted from Azmi et al. 1993)	Local name	Species in Seberang Perai rice areas
Aquatic weeds (submerged)			
Characeae	<i>Chara zeylanica</i> Kl. ex Willd.	alga	
Gentaceae	<i>Nymphoides indica</i> (L.) O.K.	teratai	
Hydrocharitaceae	<i>Blyxa malayana</i> Ridl.	malaya	X
	<i>Ceratophyllum demersum</i>	lumut	X
	<i>Hydrilla verticillata</i> (L.f.) Royle	lelumut	X
Lentibularaceae	<i>Utricularia aurea</i> Lour.	lumut ekor kucing	X
Najadaceae	<i>Najas graminea</i> (non Del.) Ridl.	lumut	X
Nymphaeaceae	<i>Nymphaea nouchali</i> Burm.f.	kelipok/telipuk	
Broad-leaved weeds			
Alismataceae	<i>Sagittaria guyanensis</i> H.B.K.	keladi air	X
Amaranthaceae	<i>Alternanthera sessilis</i> (L.) D.C.	keremak	X
Araceae	<i>Pistia stratiotes</i> L.	kiambang	X
Asteraceae	<i>Eclipta prostrata</i> (L.) L.		X
Azollaceae	<i>Azolla pinnata</i> R. Br.	kiambang kecil	X
Butomaceae	<i>Limnocharis flava</i> (L.) Buch.	paku rawan	X
Capparaceae	<i>Cleome rutidosperma</i> DC.		
Commelinaceae	<i>Commelina nudiflora</i> L.	rumut aur	
Convolvulaceae	<i>Ipomea aquatica</i> Forsk.	kangkong	
Elatinaceae	<i>Elatine</i> sp.		
Eriocaulaceae	<i>Eriocaulon cinereum</i> R. Br.		
Euphorbiaceae	<i>Phyllanthus niruri</i> L.	dukung anak	
Lamiaceae	<i>Hyptis brevipes</i> Poit	butang baju	X
Lemnaceae	<i>Lemna minor</i> L.	kiambang halus	X
	<i>Lemna perpusilla</i>	kiambang	
	<i>Spirodela polyrhiza</i> (L.) Schleid	kiambang	X
Lythraceae	<i>Rotala indica</i> (Willd.) Koehne	telinga tikus	X
	<i>Rotala rosea</i> (Poir.) C.D. Cook		
Marsileaceae	<i>Marsilea crenata</i> Presl	tapak itik	X
Onagraceae	<i>Ludwigia adscendens</i> (L.) Hara	tinggir bangau	X
	<i>Ludwigia hyssopifolia</i> (G. Don) Exell	jinaleh	X
	<i>Ludwigia octovalvis</i> (Jacq.) Raven		
Parkeriaceae	<i>Ceratopteris pteridoides</i> (Hook) Hieron	paku pakis	X
Pontederiaceae	<i>Monochoria vaginalis</i> (Burm.f.) Presl	keladi agas	X
	<i>Monochoria hastata</i> (L.) Solms		
Portulacaceae	<i>Portulaca oleracea</i> L.		
Rubiaceae	<i>Hedyotis corymbosa</i> (L.) Lamk.		X
Salvinaceae	<i>Salvinia cucullata</i> Roxb. ex Bory	kiambang	
	<i>Salvinia molesta</i> D.S. Mitchell	kiambang bulu	X
Scrophulariaceae	<i>Bacopa rotundifolia</i> (Michx.) Wettst.		X
	<i>Bacopa monnieri</i> (L.) Pennel.	kedemi	
	<i>Dopatrium junceum</i> (Roxb.) Buch.-Ham ex Benth		
	<i>Limnophila aromatica</i> (Lamk.) Merr.	beremi	X
	<i>Lindernia anagallis</i> (Burm.f.) Pennell		X
	<i>Lindernia ciliata</i> (Colsm.) Pennel		
	<i>Microcarpaea minima</i> (Koen.) Merr.		

X indicates presence

(cont.)

Table 1. (cont.)

Family	Species found in rice-growing areas in Peninsular Malaysia (adapted from Azmi et al. 1993)	Local name	Species in Seberang Perai rice areas
Sphenocleaceae	<i>Sphenoclea zeylanica</i> Gaertn.	cempedak air	X
Sterculiaceae	<i>Melochia corchorifolia</i> L.		
Grasses			
Poaceae (Graminea)	<i>Brachiara mutica</i> (Forsk.) Stapf	terbung	
	<i>Cynodon dactylon</i> (L.) Pers.	minyak	
	<i>Digitaria adscendens</i> (H.B.K.) Henr.		X
	<i>Echinochloa crus-galli</i> (L.) Beauv. { <i>E. crus-galli</i> var. <i>crus-galli</i> } { <i>E. crus-galli</i> var. <i>formosensis</i> }	sambau	X
	<i>Echinochloa colona</i> (L.) Link	padi burung	X
	<i>Echinochloa oryzicola</i> Vasing	sambau	X
	<i>Echinochloa picta</i> (Koen.) Michael	sambau merah	X
	<i>Echinochloa stagnina</i> (Retz.) Beauv.	sambau merah	
	<i>Eragrostis uniolodes</i> (Retz.) Nees ex Steud		
	<i>Hymenachne acutigluma</i> (Steud.) Gililand	jolok	X
	<i>Isachne globosa</i> (Thunb.) O.K.	rumpuk minyak	X
	<i>Ischaemum rugosom</i> Salisb.	colok cina	X
	<i>Ischaemum timorensis</i> Kunth	sarang buaya	
	<i>Leersia hexandra</i> Sw.	lidah rimau	X
	<i>Leptochloa chinensis</i> (L.) Nees	ekor tebu	X
	<i>Oryza rufipogon</i> Griff	padi hantu	X
	<i>Paspalum commersonii</i> Lamk.	jaringan	
	<i>Paspalum distichum</i> (non L.) Ridley	masin	X
	<i>Paspalum longifolium</i> Roxb.		
	<i>Paspalum vaginatum</i> Swartz.		X
	<i>Panicum repens</i> L.	kerunung padi	X
	<i>Sacciolepis myosuroides</i> (R.Br.) A. Camus	rumpuk kemani	
Sedges			
Cyperaceae	<i>Cyperus babakan</i> Steud.	menerung	X
	<i>Cyperus compactus</i> Retz	para-para	
	<i>Cyperus difformis</i> L.		X
	<i>Cyperus diffusus</i> L.		
	<i>Cyperus digitatus</i> Roxb.		
	<i>Cyperus distans</i> L.f.		
	<i>Cyperus haspans</i> L.	sumbu	X
	<i>Cyperus iria</i> L.		X
	<i>Cyperus pulcherrimus</i> Willd. ex Kunth		
	<i>Cyperus polystachyos</i> Rottb.		
	<i>Eleocharis acutangula</i> (Roxb.) Schult.		
	<i>Eleocharis geniculata</i> (L.) R. & S.		
	<i>Eleocharis ochrostachys</i> Steud		
	<i>Fimbristylis acuminata</i> Vahl	janggut keli	
	<i>Fimbristylis miliacea</i> (L.) Vahl	tahi kerbau	X
	<i>Fimbristylis schoenoides</i> (Retz.) Vahl		
	<i>Fuirena umbellata</i> Rottb.	kelulut	X

X indicates presence

(cont.)

Table 1. (cont.)

Family	Species found in rice-growing areas in Peninsular Malaysia (adapted from Azmi et al. 1993)	Local name	Species in Seberang Perai rice areas
Cyperaceae	<i>Scirpus grossus</i> L.f.	menerong	X
	<i>Scirpus juncooides</i> Roxb.	bulat	X
	<i>Scirpus lateriflorus</i> Gmel.		X
	<i>Scirpus mucronatus</i> L.	kercut	

X indicates presence

Table 2. Weed species diversity in nine consecutive seasons in Seberang Perai rice areas

Season	No. of weed species	Simpson's index
Off season 1990	29	0.064
Main season 1990/91	26	0.072
Off season 1991	27	0.065
Main season 1991/92	27	0.079
Off season 1992	29	0.064
Main season 1992/93	34	0.082
Off season 1993	35	0.061
Main season 1993/94	32	0.062
Off season 1994	30	0.092

against *E. crus-galli*. Normally, control methods are based on the most competitive weed of the previous season. This phenomenon will result in weed succession, thereby changing the dominance of the weed species in a particular season. Therefore, the ranking of dominance weed species was related to the pressure and intensity applied by farmers to control the weeds. Another interesting phenomenon was the emergence of *B. rotundifolia* as a dominant weed species in a few seasons indicating its resistance in areas where phenoxy herbicides were widely used. Apparently, *M. vaginalis* and *F. miliacea* would remain as the dominant weeds in direct-seeded rice areas because of tremendous size of seed bank of these weeds since the practice of transplanting method.

The trend in weed composition with the continuation of direct seeding practice will result in the dominance of prevalent grassy weeds. Ampong-Nyarko and De Datta (1989) reported that the weed flora in

a rice field is greatly influenced by the method of rice culture. Continuous rice cultivation with unchanged cultural system encourages the build-up of weeds adapted to that system. The same trend of weed shift was reported for the Kemubu area where rapid rise of *E. crus-galli* as the most dominant weed species was found related to the adoption of direct-seeded rice cultivation (Azmi and Mashhor 1995). Therefore, for efficient weed control management, it is recommended that control measure should be first targeted toward grassy weeds, especially the most noxious and competitive species like *E. crus-galli* and *L. chinensis*.

Water management might also influence the weed species that could grow well in association with a direct-seeded rice. The emergence of *L. chinensis* as the most dominant weed in the main season 1992/93, off season 1993 and main season 1993/94 indicated that lack of water during crop establishment encourages the emergence of this weed. Moody and Drost (1981) reported that *L. chinensis* established faster under dry condition but did not emerge in transplanted rice where plots were permanently flooded. Weed control methods adopted by farmers may effect weed species growing in association with rice. Ho (1991) reported that the continuous usage of phenoxy herbicides since the 1960s and 1970s has favoured the proliferation of grasses at the expense of broad-leaved weeds. Furthermore, molinate was used to control *E. crus-galli* but unfortunately has escalated the infestation of *L. chinensis* and *E. oryzicola* (Azmi and Baki 1995).

Table 3. Relative density, relative dominance, relative frequency and importance value (>5.0%) of predominant weeds collected from Seberang Perai rice areas over nine consecutive seasons

Species	Relative density (%)	Relative dominance (%)	Relative frequency (%)	Importance value (%)
Off season 1990				
<i>Monochoria vaginalis</i> (Burm.) Presl	14.34	13.10	8.90	36.35
<i>Echinochloa crus-galli</i> (L.) Beauv.	11.06	14.34	10.57	36.28
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	13.53	9.25	9.46	32.24
<i>Cyperus iria</i> L.	7.66	6.55	6.12	20.33
<i>Leptochloa chinensis</i> (L.) Nees	6.47	8.09	5.56	20.13
<i>Fimbristylis miliacea</i> (L.) Vahl	4.98	3.85	5.01	13.84
<i>Sagittaria guyanensis</i> H.B.K.	3.45	5.01	5.01	13.47
<i>Paspalum vaginatum</i> Swartz.	2.47	4.24	5.01	11.72
<i>Sphenoclea zeylanica</i> Gaertn.	3.70	3.47	4.45	11.62
<i>Rotala indica</i> (Willd.) Koehne	3.87	2.70	2.78	9.35
<i>Lemna minor</i> L.	5.02	0.77	2.78	8.58
<i>Echinochloa colona</i> (L.) Link	1.02	3.08	3.90	8.00
<i>Scirpus grossus</i> L.f.	1.57	2.70	3.34	7.61
<i>Ludwigia hyssopifolia</i> (G. Don) Exell	1.11	2.70	3.34	7.14
<i>Panicum repens</i> L.	1.28	2.31	2.78	6.37
<i>Cyperus difformis</i> L.	2.21	2.31	1.67	6.20
<i>Hymenachne acutigluma</i> (Steud.) Gililand	1.66	2.32	1.67	5.65
<i>Spirodela polyrhiza</i> (L.) Schleid.	3.40	0.58	1.67	5.65
<i>Scirpus juncooides</i> Roxb.	0.94	1.93	2.78	5.65
<i>Limnocharis flava</i> (L.) Buch.	0.39	2.31	2.78	5.49
Main season 1990/91				
<i>Monochoria vaginalis</i> (Burm.f.) Presl	21.88	15.31	11.65	48.84
<i>Echinochloa crus-galli</i> (L.) Beauv.	10.22	12.30	12.61	35.13
<i>Leptochloa chinensis</i> (L.) Nees	5.32	11.30	5.83	22.44
<i>Fimbristylis miliacea</i> (L.) Vahl	7.25	7.03	6.78	21.07
<i>Sagittaria guyanensis</i> H.B.K.	6.34	6.53	7.76	20.63
<i>Limnocharis flava</i> (L.) Buch.	2.13	8.78	4.37	15.28
<i>Lindernia anagallis</i> (Burm.f.) Pennell	5.51	4.77	4.85	15.13
<i>Paspalum vaginatum</i> Swartz.	2.43	4.77	6.79	13.99
<i>Echinochloa colona</i> (L.) Link	3.15	4.02	3.89	11.06
<i>Cyperus iria</i> L.	3.38	3.77	3.89	11.04
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	4.48	3.26	2.91	10.66
<i>Sphenoclea zeylanica</i> Gaertn.	2.24	3.51	4.37	10.13
<i>Cyperus difformis</i> L.	2.01	3.26	3.39	8.67
<i>Lemna minor</i> L.	4.94	0.25	2.91	8.10
<i>Spirodela polyrhiza</i> (L.) Schleid	3.19	0.50	2.43	6.13
<i>Marsilea crenata</i> Presl	3.15	0.25	2.43	5.84
<i>Scirpus juncooides</i> Roxb.	2.39	1.76	1.46	5.61
<i>Salvinia molesta</i> D.S. Mitchell	1.86	1.51	1.94	5.30
<i>Scirpus grossus</i> L.f.	2.01	1.76	1.46	5.23
Off season 1991				
<i>Monochoria vaginalis</i> (Burm.f.) Presl	12.03	9.61	11.31	32.95
<i>Leptochloa chinensis</i> (L.) Nees	12.19	11.08	8.80	32.08
<i>Limnocharis flava</i> (L.) Buch.	5.56	18.47	5.67	29.70

(cont.)

Table 3. (cont.)

Species	Relative density (%)	Relative dominance (%)	Relative frequency (%)	Importance value (%)
Off season 1991				
<i>Echinochloa crus-galli</i> (L.) Beauv	9.09	8.13	11.96	29.18
{ <i>E. crus-galli</i> var. <i>formosensis</i>	8.13	7.14	10.69	25.96}
{ <i>E. crus-galli</i> var. <i>crus-galli</i>	0.96	0.99	1.27	3.20}
<i>Fimbristylis miliacea</i> (L.) Vahl	7.38	6.41	5.85	19.64
<i>Bacopa rotundifolia</i> (Michx.) Westst.	7.27	5.17	5.02	17.47
<i>Marsilea crenata</i> Presl	6.47	4.68	5.02	16.17
<i>Echinochloa colona</i> (L.) Link	6.04	5.66	4.40	16.11
<i>Sagittaria guyanensis</i> H.B.K.	3.42	5.17	6.91	15.51
<i>Sphenoclea zeylanica</i> Gaertn.	2.78	3.69	3.78	10.25
<i>Echinochloa oryzicola</i> Vasing	4.17	3.20	2.51	9.88
<i>Lindernia anagallis</i> (Burm.f.) Pennell	3.80	1.48	3.78	9.06
<i>Ischaemum rugosum</i> Salisb.	3.32	3.94	1.27	8.52
<i>Cyperus iria</i> L.	1.82	1.97	3.78	7.57
<i>Panicum repens</i> L.	1.50	1.23	3.16	5.88
<i>Scirpus grossus</i> L. f.	2.09	1.72	1.89	5.70
<i>Cyperus difformis</i> L.	1.77	1.72	1.89	5.38
<i>Paspalum distichum</i> L.	1.55	0.99	2.51	5.05
Main season 1991/92				
<i>Echinochloa crus-galli</i> (L.) Beauv.	11.32	20.83	11.76	43.92
{ <i>E. crus-galli</i> var. <i>formosensis</i>	11.28	20.62	11.10	43.01}
{ <i>E. crus-galli</i> var. <i>crus-galli</i>	0.04	0.21	0.66	0.91}
<i>Leptochloa chinensis</i> (L.) Nees	17.72	12.58	10.45	40.74
<i>Fimbristylis miliacea</i> (L.) Vahl	10.64	9.28	7.20	27.12
<i>Monochoria vaginalis</i> (Burm. f.) Presl	7.81	8.66	7.20	23.67
<i>Cyperus iria</i> L.	4.68	6.81	9.15	20.63
<i>Echinochloa oryzicola</i> Vasing	5.53	6.60	7.83	19.97
<i>Lindernia anagallis</i> (Burm.f.) Pennell	8.79	6.19	4.56	19.54
<i>Sagittaria guyanensis</i> H.B.K.	5.88	5.36	6.54	17.78
<i>Limnocharis flava</i> (L.) Buch.	3.39	5.57	7.20	16.15
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	4.85	3.71	3.93	12.49
<i>Lemna minor</i> L.	5.36	0.83	2.61	8.80
<i>Scirpus grossus</i> L.f.	1.50	2.68	2.61	6.79
<i>Salvinia molesta</i> D.S. Mitchell	1.80	1.86	1.95	5.61
<i>Spirodela polyrhiza</i> (L.) Schleid	3.00	0.62	1.95	5.57
<i>Cyperus haspans</i> L.	1.80	1.65	1.95	5.41
<i>Limnophila aromatica</i> (Lamk.) Merr.	1.59	1.65	1.95	5.19
Off season 1992				
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	14.42	11.31	6.98	32.71
<i>Monochoria vaginalis</i> (Burm.f.) Presl	14.53	7.99	8.84	31.35
<i>Echinochloa crus-galli</i> var. <i>formosensis</i>	7.69	11.65	11.16	30.50
<i>Leptochloa chinensis</i> (L.) Nees	5.95	9.32	9.30	24.57
<i>Cyperus iria</i> L.	3.99	9.98	5.58	19.55
<i>Lindernia anagallis</i> (Burm.f.) Pennell	6.55	6.99	5.12	18.66
<i>Fimbristylis miliacea</i> (L.) Vahl	7.76	3.66	4.65	16.08
<i>Najas graminea</i> (non Del.) Ridl.	6.23	5.66	3.72	15.61
<i>Sagittaria guyanensis</i> H.B.K.	3.45	3.66	6.05	13.16
<i>Lemna minor</i> L.	5.34	1.83	5.12	12.29

(cont.)

Table 3. (cont.)

Species	Relative density (%)	Relative dominance (%)	Relative frequency (%)	Importance value (%)
Off season 1992				
<i>Scirpus grossus</i> L. f.	3.28	3.66	3.26	10.19
<i>Paspalum vaginatum</i> Sw.	1.75	2.66	4.65	9.06
<i>Utricularia aurea</i> Lour.	3.92	3.00	1.86	8.77
<i>Echinochloa oryzicola</i> Vasing	1.96	3.00	3.72	8.68
<i>Limnocharis flava</i> (L.) Buch.	1.21	3.33	3.72	8.26
<i>Ludwigia hyssopifolia</i> (G. Don) Exell	1.64	2.33	2.33	6.29
<i>Azolla pinnata</i> R. Br.	2.49	0.67	1.86	5.02
Main season 1992/93				
<i>Leptochloa chinensis</i> (L.) Nees	22.78	18.53	12.25	53.56
<i>Echinochloa crus-galli</i> var. <i>formosensis</i>	13.31	14.21	13.04	40.59
<i>Monochoria vaginalis</i> (Burm.f.) Presl	8.22	8.38	7.51	24.11
<i>Cyperus iria</i> L.	4.85	8.38	8.70	21.95
<i>Fimbristylis miliacea</i> (L.) Vahl	7.45	7.11	6.72	21.28
<i>Echinochloa oryzicola</i> Vasing	6.07	6.85	5.53	18.45
<i>Lindernia anagallis</i> (Burm.f.) Pennell	9.13	3.55	5.53	18.22
<i>Limnocharis flava</i> (L.) Buch.	2.39	4.57	5.53	12.50
<i>Sagittaria guyanensis</i> H.B.K.	2.73	3.81	4.74	11.28
<i>Lemna minor</i> L.	4.04	2.54	3.95	10.54
<i>Spirodela polyrhiza</i> (L.) Schleid.	2.70	1.52	2.37	6.59
<i>Ludwigia hyssopifolia</i> (G. Don) Exell	1.01	2.54	2.77	6.32
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	1.75	2.28	1.58	5.62
<i>Ischaemum rugosum</i> Salisb.	1.99	2.03	1.58	5.60
Off season 1993				
<i>Leptochloa chinensis</i> (L.) Nees	10.91	13.20	12.04	36.15
<i>Echinochloa crus-galli</i> var. <i>formosensis</i>	9.86	10.80	10.47	31.13
<i>Bacopa rotundifolia</i> (Michx.) Wettst	14.30	7.40	6.28	27.99
<i>Fimbristylis miliacea</i> (L.) Vahl	6.34	9.40	6.28	22.02
<i>Monochoria vaginalis</i> (Burm.f.) Presl	7.19	7.00	6.28	20.47
<i>Limnophila aromatica</i> (Lamk.) Merr.	5.16	6.20	4.19	15.55
<i>Cyperus iria</i> L.	4.38	5.80	5.24	15.41
<i>Sagittaria guyanensis</i> H.B.K.	3.27	4.60	6.81	14.67
<i>Echinochloa oryzicola</i> Vasing	5.03	4.60	3.67	13.29
<i>Echinochloa colona</i> (L.) Link	3.59	5.40	3.67	12.66
<i>Najas graminea</i> (non Del.) Ridl.	3.59	1.80	4.71	10.10
<i>Utricularia aurea</i> Lour.	2.81	2.40	3.14	8.35
<i>Ludwigia hyssopifolia</i> (G. Don) Exell	1.31	2.80	2.62	6.72
<i>Limnocharis flava</i> (L.) Buch.	1.44	2.00	3.14	6.58
<i>Lindernia anagallis</i> (Burm.f.) Pennell	2.29	1.00	2.62	5.90
<i>Panicum repens</i> L.	1.24	2.00	2.09	5.34
<i>Rotala indica</i> (Willd.) Koehne	2.94	0.60	1.57	5.11
<i>Scirpus grossus</i> L. f.	1.31	1.60	2.09	5.00
Main season 1993/94				
<i>Leptochloa chinensis</i> (L.) Nees	7.85	13.00	11.00	31.85
<i>Echinochloa crus-galli</i> var. <i>formosensis</i>	10.36	10.94	10.00	31.29
<i>Sagittaria guyanensis</i> H.B.K.	11.35	8.28	7.00	26.63
<i>Najas graminea</i> (non Del.) Ridl.	11.40	7.09	6.00	24.49

(cont.)

Table 3. (cont.)

Species	Relative density (%)	Relative dominance (%)	Relative frequency (%)	Importance value (%)
Main season 1993/94				
<i>Lemma minor</i> L.	12.22	1.66	7.00	20.87
<i>Monochoria vaginalis</i> (Burm.f.) Presl	7.20	6.33	6.00	20.47
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	5.00	6.33	6.00	17.33
<i>Echinochloa oryzicola</i> Vasing	5.80	6.21	3.03	15.03
<i>Cyperus iria</i> L.	4.98	5.02	5.00	15.00
<i>Limnocharis flava</i> (L.) Buch.	5.79	3.07	3.00	11.86
<i>Fimbristylis miliacea</i> (L.) Vahl	1.39	5.44	5.00	11.83
<i>Echinochloa colona</i> (L.) Link	1.36	4.14	3.50	8.99
<i>Limnophila aromatica</i> (Lamk.) Merr.	1.43	3.67	3.50	8.59
<i>Ludwigia hyssopifolia</i> (G. Don) Exell	1.11	2.78	3.50	7.39
<i>Scirpus grossus</i> L. f.	2.42	1.83	3.00	7.25
<i>Utricularia aurea</i> Lour.	1.05	2.36	2.00	5.41
Off season 1994				
<i>Bacopa rotundifolia</i> (Michx.) Wettst.	19.22	19.10	15.19	53.41
<i>Leptochloa chinensis</i> (L.) Nees	12.54	17.09	14.56	44.18
<i>Scirpus grossus</i> L. f.	9.52	13.92	8.23	31.67
<i>Echinochloa crus-galli</i> (L.) Beauv.	6.57	10.56	10.76	27.78
{ <i>E. crus-galli</i> var. <i>formosensis</i>	4.76	7.26	6.33	18.35}
{ <i>E. crus-galli</i> var. <i>crus-galli</i>	1.81	3.30	4.43	9.54}
<i>Azolla pinnata</i> R. Br.	16.77	4.49	1.27	22.52
<i>Monochoria vaginalis</i> (Burm.f.) Presl	6.17	6.57	8.86	21.60
<i>Limnocharis flava</i> (L.) Buch.	3.35	3.27	8.23	14.85
<i>Marsilea crenata</i> Presl.	6.71	3.53	1.27	11.50
<i>Utricularia aurea</i> Lour.	2.48	4.02	2.53	9.03
<i>Sagittaria guyanensis</i> H.B.K.	1.95	1.98	4.43	8.36
<i>Lemma minor</i> L.	3.35	0.86	3.80	8.01
<i>Ischaemum rugosom</i> Salisb.	1.07	4.48	1.90	7.45

Table 4. Sorenson's index of similarity of weed species in Seberang Perai rice areas

Season	OS 1990	MS 1990/91	OS 1991	MS 1991/92	OS 1992	MS 1992/93	OS 1993	MS 1993/94	OS 1994
OS 1990	–	93	82	82	79	43	75	75	75
MS 1990/91	93	–	79	79	76	43	72	76	68
OS 1991	82	79	–	74	79	41	74	75	77
MS 1991/92	82	79	74	–	68	38	66	62	64
OS 1992	79	76	79	68	–	41	78	79	81
MS 1992/93	43	43	41	38	41	–	81	82	75
OS 1993	75	72	74	66	78	81	–	89	74
MS 1993/94	75	76	75	62	79	82	89	–	77
OS 1994	75	68	77	64	81	74	74	77	–

OS = off season

MS = main season

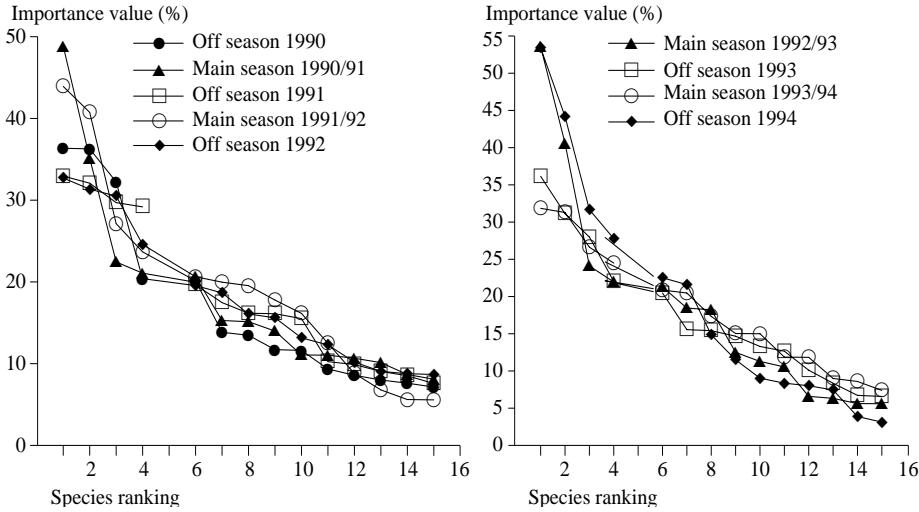


Figure 2. Dominance curves for the surveys of weed communities in Seberang Perai rice areas, Malaysia (the highest point represents the species with the most dominance and only the top 15 species are plotted)

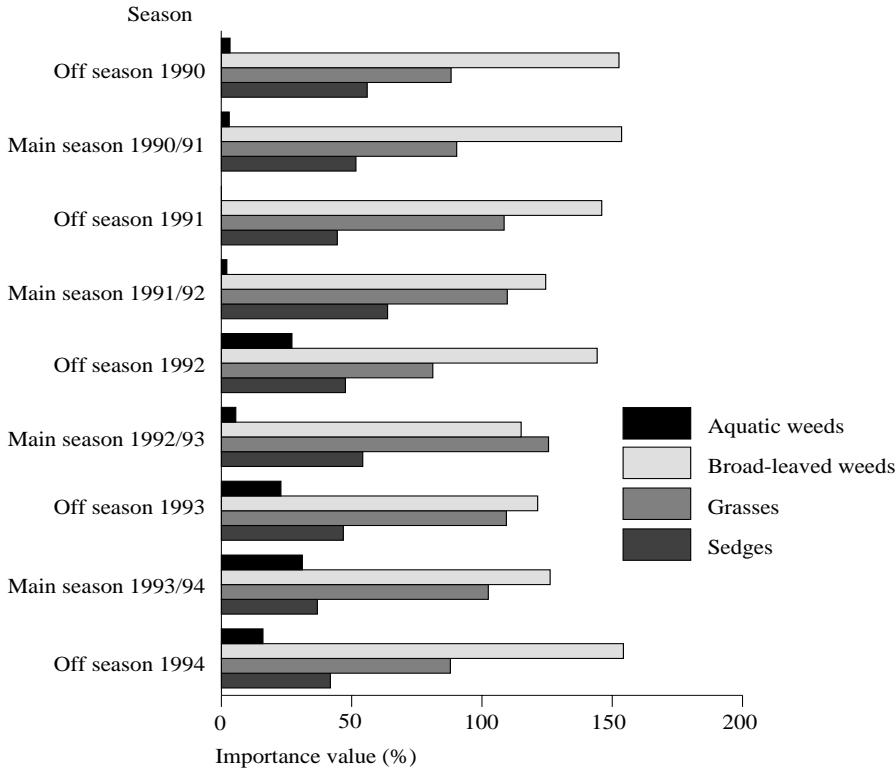


Figure 3. The temporal changes of weed communities in Seberang Perai rice areas based on the summed importance value

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