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Species composition and biodiversity indexes of weeds in paddy rice on two sides of dike system during three crops in an Giang Province, Vietnam

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Abstract

Aim: This study was conducted to provide data on weed species composition and biodiversity indexes at different rice crops inside and outside of the dike system in An Giang province, Vietnam.

Methodology: Weeds were collected from paddy rice of inner and outer side of dike system from six districts of An Giang province, Vietnam. From each sampling sites, two quadrats with 100 m² (10 m × 10 m) per quadrat were selected to collect weed after 75-80 days of rice planting. Weeds were collected and identified for their scientific name, and the number of each species was defined, followed by calculation of the occurrence frequency and density of samples. Biodiversity indices viz. Shannon-Weaver (H'), Simpson (1-λ), Margalef (d), and similarity index were also studied among three crops and two sides of dike system.

Results: The weed composition in the paddy rice in An Giang was diversity with 137 species. Among them, the most species belonged to families Poaceae, Cyperaceae, and Compositae. The species composition of Crop 3 was the highest one. Species occurrence frequency and weed density of groups C, D, E reached the highest value in Crop 1, followed by Crop 2 and 3. The biodiversity indices of weed species composition in the studied sites were high, reaching the highest value in Crop 3.

Interpretation: The results of this study enhance the knowledge of weed species composition and biodiversity indexes to effectively manage and control weeds in rice cultivation.

Key words: Biodiversity index, Dike system, Paddy rice, Weeds

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Introduction

The Mekong Delta located in the south part of Vietnam, where climate conditions and condense river systems facilitate for the development of plants, rice crops especially. In the Mekong Delta, the plant composition is diverse in rice paddy fields, as shown by 188 identified species (Duong *et al.*, 2003). These species influence the productivity and quality of rice, for example, they compete with rice for light, nutrition, and water. Moreover, they support the growth of pests and plant diseases and provide shelters for rice-destroying rats. However, many of these species are beneficial for local people as they can be used as vegetables, traditional medicine, and natural fertilizer.

An Giang province is situated across Tien and Hau rivers, which belong to the Mekong river system. This province has enriched surface water and a high sediment level, which facilitates the growth of rice. Interestingly, most of An Giang areas are covered with flood water 1-4 m deep from the end of July to early December every year (Duong *et al.*, 2017). Therefore, prior to 1995, rice was annually produced by two rice crops which produce 5.25 tons ha (Huynh *et al.*, 2013). To increase cropping areas and rice productivity, as well as to control flood impacts, a dike system was built at multiple areas to additionally produce triple rice cropping (Nguyen *et al.*, 2016). As a result, it has been formed three-rice-crop regions (fully dike system) different with two-rice crops areas (semi-dyke system). Although the dike system provides some benefits for the growth of rice, it caused several drawbacks such as preventing sediment flow to rice fields, and water exchange between rice fields and rivers (Pham *et al.*, 2015), affecting the local ecosystem and biological diversity. There are significant differences between the species composition from Outer dike and Inner dike (Dinh *et al.*, 2020). However, since the dike system has been build, the plant composition of rice fields areas has not examined. Therefore, this study aimed to provide data on the weed species composition and biodiversity indices at different rice crops inside and outside of the dike system in An Giang province, Vietnam.

Materials and Methods

This study was conducted during three crops: Crop 1 is from 4/2019 to 7/2019, Crop 2 is from 8/2019 to 11/2019, and Crop 3 is from 12/2019 to 3/2020. Samples were collected within 75-80 days after the rice was planted. This time was selected because of the mature weeds, which aid in the classification, collection and analysis of data samples.

The study area included six districts Cho Moi, Chau Phu, Tinh Bien, Tri Ton, Thoai Son, and Chau Doc in An Giang province. At each district, two rice fields examined: Outer dike (two crops per year) and Inner dike (three crops per year) (Fig. 1).

To survey local farmers and agricultural managers in An Giang, the method of Participatory Rural Appraisal (Nguyen and

Vromant, 2009) was used. This method helps to generate data of rice-growing sites, crops, and plant composition within rice fields.

To investigate sampling sites and to design quadrats of sampling, methods of Nguyen (2007) were applied. At each sampling sites, there was two standard sampling plots (quadrat) located 150 - 200 m apart, with 100 m² (10 m x 10 m) per quadrat. The quadrates were placed through three field habitats, including inside, banks of rice field and along the small canals that carry water into the rice field. There were 5 sub-squares of sample collection, each had 1 m² at 4 corners and central of the quadrat. Plants were collected and identified for their scientific name before calculating the occurrence frequency and density of samples.

The scientific names of plant samples were identified by using taxonomic comparison, in combination with using references from published data of plant classification (Duong *et al.*, 2003; Pham, 1999; Pham, 2000; Pham, 2003; Suk *et al.*, 2000; Tran *et al.*, 2018; Vo, 2002; Vo, 2004). The plant list then was adjusted according to Checklist of Plant species of Vietnam (Nguyen and Dorofeev, 2003; Nguyen and Dorofeev, 2005) and information from the website of The Plant List (2013).

The occurrence frequency of plant species was calculated by the formula: $F(\%) = p/p \times 100$ (p : number of quadrats in which the species occurs, P : total number of quadrats examined) (Sharma, 2003). Based on F values, plants were arranged into 5 groups: Group A with very low occurrence frequency ($F=1-20\%$); Group B with low occurrence frequency ($F=21-40\%$); Group C with moderate occurrence frequency ($F=41-60\%$); Group D with high occurrence frequency ($F=61-80\%$) and group E with very high occurrence frequency ($F=81-100\%$).

The density (individuals m⁻²) was calculated: $D = (\text{individual m}^{-2}) = \text{Total number of individuals of a species in all the quadrats} / \text{Number of quadrats examined}$ (Sharma, 2003).

Biodiversity indices such as Shannon-Weaver's diverse index: (Shannon and Weaver, 1949), Simpson's dominant index: I (Simpson, 1949), Margalef's abundant index: $d = (Margalef, 1958)$ ($p_i = n_i/N$, n_i : the number of individuals of i^{th} species; S : the number of species; N : total number of individuals of all species in all quadrats examined) were estimated by PRIMER v.6 (Clarke and Gorley, 2006). The S17 Bray Curtis Similarity Index was used to determine the similarity of weed species composition among three crops and two sides of dike system (Bray and Curtis, 1957).

The fluctuation of plant composition toward crops and dike features was examined by PERMANOVA test. The correlation between several factors, including crop x site of sampling in the crop x dike, sampling site x dike; and plant composition was examined by PERMANOVA test. The PRIMER

Fig. 1 : Illustration of sampling sites of rice crop in An Giang province.

v6 software was used in combination with PERMANOVA for data analysis. All tests were performed with p-value of 5%.

Results and Discussion

In this study, 478 weed samples were collected from 12 rice-growing sites (in 6 districts in An Giang province). They were stored at the Plant Laboratory at Can Tho University, Can Tho city, Vietnam. Based on the classification result, 137 species belonged to 103 genera of 42 families in 2 phyla, Polypodiophyta and Magnoliophyta, were identified. Of which, Magnoliophyta was dominant with 135 species belonging to 101 genera of 40 families, Polypodiophyta had only 2 species belonging to 2 genera of 2 families. Three families with the highest number of species were Poaceae with 24 species, Cyperaceae with 14 species, and Compositae with 10 species. Compositae species *Sphaeranthus africanus*, *Eclipta prostrata*, *Vernonia cinerea* were distributed mainly along the coast and on the banks of rice field such. Species of families Poaceae and Cyperaceae were distributed both onshore, onshore and in flooded fields, typically

Echinochloa crus-galli, *Leptochloa chinensis*, *Oryza rufipogon* (Poaceae) and *Cyperus digitatus*, *Cyperus iria*, *Eleocharis dulcis*, *Fimbristylis quinquangularis* (Cyperaceae). Four genera with the highest number of species were *Cyperus* with 8 species, *Paspalum* with 5 species, *Ludwigia* and *Euphorbia* with 4 species. Compared to the results of Duong *et al.* (2003) with 75 species, 43 genera and 30 plant families were found in wet rice fields in Vietnam. This study showed more diverse taxon composition, since this was conducted in rice fields, near the field and on the edge of the field, therefore, the species composition had both aquatic and terrestrial weeds. However, this result was also similar to previous result (Duong *et al.*, 2003) which dominated in the number of species of the Poaceae and Cyperaceae.

The most diverse weed species were found in Crop 3 with 111 species accounting for 81.02% of the total number of species, followed by Crop 1 with 101 species (accounting for 73.72% of the total number of species), and the lowest was Crop 2 with 62 species (accounting for 45.26% of the total number of species). The Crop 2 is the flooding season, therefore, the survey was only

Table 1 : Frequency of occurrence and density of weed species collected in rice growing areas in An Giang province

Scientific name	Occurrence frequency (%)					Density (individual m ⁻²)					Biodiversity indices		
	C1	C2	C3	In	Out	C1	C2	C3	In	Out	d	H'	1- $\bar{e}$ '
<i>Marsilea quadrifolia</i> L.	8.30	0.00	8.30	0.00	16.70	0.042	0.000	0.017	0.000	0.058	0.9854	0.5637	0.7476
<i>Ceratopteris thalictroides</i> (L.) Brongn.	25.00	16.70	25.00	16.70	33.30	0.042	0.050	0.050	0.033	0.067	1.8728	0.8679	0.8769
<i>Ruellia tuberosa</i> L.	25.00	16.70	16.70	33.30	0.00	0.042	0.017	0.025	0.050	0.000	2.1239	0.7970	0.8376
<i>Achyranthes aspera</i> L.	0.00	16.70	8.30	11.10	0.00	0.000	0.033	0.017	0.022	0.000	1.6097	0.6778	0.8485
<i>Alternanthera paronychioides</i> St.-Hil.	83.30	66.70	33.30	61.10	58.30	0.217	0.200	0.108	0.172	0.167	1.9879	0.9610	0.8811
<i>Alternanthera sessilis</i> (L.) A. DC.	16.70	0.00	16.70	0.00	33.30	0.025	0.000	0.017	0.000	0.042	1.8463	0.7273	0.8476
<i>Amaranthus lividus</i> L.	16.70	0.00	8.30	0.00	25.00	0.025	0.000	0.008	0.000	0.033	1.6097	0.6589	0.8333
<i>Amaranthus spinosus</i> L.	8.30	0.00	8.30	0.00	16.70	0.008	0.000	0.017	0.000	0.025	1.8205	0.6614	0.8611
<i>Amaranthus tricolor</i> L.	8.30	0.00	0.00	0.00	8.30	0.008	0.000	0.000	0.000	0.008	1.8205	0.4771	1.0000
<i>Gomphrena celosioides</i> Mart.	8.30	0.00	8.30	11.10	0.00	0.017	0.000	0.008	0.017	0.000	1.3654	0.5693	0.8056
<i>Centella asiatica</i> (L.) Urb. in Mart.	8.30	0.00	0.00	0.00	8.30	0.017	0.000	0.000	0.000	0.017	1.1162	0.4771	0.8000
<i>Ageratum conyzoides</i> L.	50.00	0.00	8.30	22.20	25.00	0.050	0.000	0.008	0.022	0.025	2.2992	0.8202	0.8667
<i>Eclipta prostrata</i> L.	58.30	16.70	33.30	38.90	41.70	0.058	0.083	0.067	0.083	0.042	2.4424	0.9479	0.8814
<i>Emilia sonchifolia</i> (L.) DC. in Wight	0.00	16.70	8.30	11.10	0.00	0.000	0.017	0.008	0.011	0.000	2.2324	0.6778	0.9333
<i>Eupatorium odoratum</i> L.	8.30	0.00	8.30	11.10	0.00	0.008	0.000	0.008	0.011	0.000	2.2324	0.6778	0.9333
<i>Praxelis clematidea</i> (Griseb.) R.M.King & H.Rob.	25.00	16.70	8.30	16.70	16.70	0.058	0.033	0.017	0.033	0.042	2.0020	0.8582	0.8769
<i>Sphaeranthus africanus</i> L.	0.00	0.00	16.70	0.00	16.70	0.000	0.000	0.025	0.000	0.025	1.3654	0.5693	0.8056
<i>Struchium sparganophorum</i> (L.) Kuntze	0.00	16.70	16.70	11.10	8.30	0.000	0.033	0.025	0.022	0.008	2.2156	0.7997	0.8857
<i>Synedrella nodiflora</i> (L.) Gaertn.	25.00	0.00	0.00	11.10	8.30	0.033	0.000	0.000	0.017	0.008	2.0121	0.7090	0.8485
<i>Tridax procumbens</i> L.	0.00	16.70	16.70	16.70	0.00	0.000	0.017	0.025	0.022	0.000	1.6097	0.6399	0.8182
<i>Vernonia cinerea</i> (L.) Less.	16.70	0.00	16.70	11.10	16.70	0.025	0.000	0.017	0.011	0.025	2.2156	0.8247	0.9048
<i>Hydrocera triflora</i> (L.) Wight & Arn.	8.30	0.00	8.30	0.00	16.70	0.008	0.000	0.017	0.000	0.025	1.3654	0.5693	0.8056
<i>Coldenia procumbens</i> L.	8.30	0.00	8.30	0.00	16.70	0.017	0.000	0.008	0.000	0.025	1.8205	0.6614	0.8611
<i>Heliotropium indicum</i> L.	25.00	16.70	25.00	16.70	33.30	0.050	0.017	0.042	0.028	0.058	2.2324	0.8820	0.8810
<i>Cleome chelidonii</i> L. f.	41.70	0.00	16.70	16.70	33.30	0.050	0.000	0.033	0.028	0.042	2.0581	0.8727	0.8874
<i>Cleome viscosa</i> L.	0.00	16.70	0.00	5.60	0.00	0.000	0.033	0.000	0.011	0.000	1.1162	0.4771	0.8000
<i>Ceratophyllum demersum</i> L.	0.00	16.70	8.30	5.60	8.30	0.000	0.033	0.008	0.011	0.008	1.8205	0.6614	0.8611
<i>Ipomoea aquatica</i> Forsk.	41.70	16.70	33.30	27.80	41.70	0.058	0.017	0.058	0.039	0.067	2.6270	0.9577	0.8949
<i>Ipomoea obscura</i> (L.) Ker-Gawl.	16.70	0.00	16.70	11.10	16.70	0.017	0.000	0.025	0.017	0.017	2.5849	0.8648	0.9143
<i>Merremia hederacea</i> (Burm.f.) Hallierf.	8.30	16.70	25.00	11.10	25.00	0.008	0.050	0.042	0.028	0.033	2.1239	0.8562	0.8832
<i>Operculina turpethum</i> (L.) S. Manso	8.30	16.70	8.30	11.10	8.30	0.008	0.017	0.008	0.011	0.008	2.7307	0.8205	0.9444
<i>Coccinia grandis</i> (L.) Voigt	0.00	16.70	8.30	11.10	0.00	0.000	0.017	0.008	0.011	0.000	1.6743	0.5775	0.8667
<i>Gymnopetalum cochinchinense</i> (Lour.) Kurz	0.00	16.70	8.30	11.10	0.00	0.000	0.017	0.008	0.011	0.000	2.2324	0.6778	0.9333
<i>Gymnopetalum integrifolium</i> (Roxb.) Kurz	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.008	0.000	0.008	1.8205	0.4771	1.0000
<i>Momordica charantia</i> L.	0.00	16.70	0.00	5.60	0.00	0.000	0.017	0.000	0.006	0.000	1.4427	0.4515	0.8333
<i>Acalypha lanceolata</i> Willd	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.017	0.011	0.000	1.1162	0.4771	0.8000
<i>Croton hirtus</i> L'Hér.	8.30	0.00	0.00	0.00	8.30	0.017	0.000	0.000	0.000	0.017	1.7372	0.6762	0.8667
<i>Euphorbia heterophylla</i> L.	8.30	33.30	16.70	27.80	0.00	0.008	0.033	0.025	0.033	0.000	1.8034	0.6723	0.8000
<i>Euphorbia hirta</i> L.	25.00	16.70	0.00	11.10	16.70	0.025	0.017	0.000	0.011	0.017	2.5022	0.8225	0.9273
<i>Euphorbia indica</i> Lamk.	8.30	0.00	16.70	11.10	8.30	0.008	0.000	0.017	0.011	0.008	2.7307	0.8205	0.9444
<i>Euphorbia thymifolia</i> L.	8.30	0.00	8.30	0.00	16.70	0.017	0.000	0.008	0.000	0.025	1.3654	0.5693	0.8056
<i>Phyllanthus amarus</i> Schum	8.30	0.00	16.70	0.00	25.00	0.008	0.000	0.017	0.000	0.025	2.4045	0.7242	0.8929
<i>Phyllanthus reticulatus</i> Poir.	8.30	0.00	8.30	0.00	16.70	0.008	0.000	0.008	0.000	0.017	1.3464	0.5162	0.5951
<i>Aeschynomene indica</i> L.	75.00	33.30	33.30	44.40	58.30	0.208	0.083	0.058	0.111	0.142	2.0782	0.8396	0.8379
<i>Centrosema pubescens</i> Benth.	8.30	0.00	8.30	11.10	0.00	0.008	0.000	0.008	0.011	0.000	1.9236	0.6773	0.8929
<i>Desmodium triflorum</i> (L.) DC.	0.00	16.70	8.30	5.60	8.30	0.000	0.033	0.017	0.011	0.017	1.5157	0.6836	0.8462
<i>Macroptilium lathyroides</i> (L.) Urb. var. <i>semierectum</i> (L.) Urb.	16.70	33.30	0.00	16.70	8.30	0.025	0.050	0.000	0.028	0.008	2.1177	0.7636	0.8529
<i>Sesbania sesban</i> (L.) Merr.	8.30	0.00	16.70	5.60	16.70	0.008	0.000	0.033	0.006	0.033	1.5595	0.6622	0.8333
<i>Vigna adenantha</i> (F. G. Mey.) Mar., Masch. & Stain.	25.00	0.00	0.00	5.60	16.70	0.025	0.000	0.000	0.006	0.017	2.1747	0.7186	0.7700

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<i>Basilicum polystachyon</i> (L.) Moench	33.30	33.30	25.00	33.30	25.00	0.042	0.183	0.025	0.089	0.025	1.6265	0.6135	0.7051
<i>Hyptis rhomboidea</i> Mart. & Gal.	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.017	0.000	0.017	1.4427	0.6021	0.8571
<i>Hyptis suaveolens</i> (L.) Poit.	8.30	16.70	0.00	11.10	0.00	0.017	0.033	0.000	0.022	0.000	0.9102	0.4191	0.6667
<i>Ocimum gratissimum</i> L.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.008	0.006	0.000	1.5595	0.6135	0.7821
<i>Utricularia aurea</i> Lour.	8.30	16.70	8.30	11.10	8.30	0.042	0.033	0.033	0.039	0.033	0.9208	0.5616	0.7292
<i>Sida rhombifolia</i> L.	0.00	0.00	33.30	5.60	25.00	0.000	0.000	0.033	0.006	0.025	2.9192	0.8565	0.9273
<i>Urena lobata</i> L.	0.00	16.70	8.30	11.10	0.00	0.000	0.017	0.017	0.017	0.000	1.4427	0.5737	0.8214
<i>Nymphoides indicum</i> (L.) O. Kuntze	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.017	0.000	0.017	1.8205	0.6867	0.8889
<i>Mimosa pigra</i> L.	16.70	16.70	8.30	16.70	8.30	0.017	0.017	0.017	0.022	0.008	2.4218	0.7952	0.8497
<i>Neptunia oleracea</i> Lour.	8.30	0.00	16.70	0.00	25.00	0.017	0.000	0.050	0.000	0.067	0.9854	0.5772	0.7571
<i>Glinus oppositifolius</i> (L.) DC.	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.042	0.000	0.042	0.7059	0.4713	0.6985
<i>Nelumbo nucifera</i> Gaertn.	0.00	0.00	25.00	5.60	16.70	0.000	0.000	0.058	0.011	0.042	1.7648	0.7502	0.8603
<i>Nymphaea nouchali</i> Burm. f.	0.00	16.70	0.00	5.60	0.00	0.000	0.050	0.000	0.017	0.000	0.8341	0.4634	0.7091
<i>Nymphaea pubescens</i> Willd.	8.30	0.00	0.00	5.60	0.00	0.042	0.000	0.000	0.028	0.000	1.1368	0.5609	0.7582
<i>Nymphaea rubra</i> Roxb. ex Salisb.	8.30	0.00	8.30	5.60	8.30	0.017	0.000	0.017	0.011	0.017	1.5533	0.6896	0.7867
<i>Ludwigia adscendens</i> (L.) Hara	25.00	16.70	8.30	11.10	25.00	0.042	0.167	0.017	0.067	0.042	1.3677	0.7101	0.7688
<i>Ludwigia hyssopifolia</i> (G. Don) Exell apud A. & R. Fernandes	91.70	83.30	58.30	66.70	83.30	0.467	0.783	0.250	0.433	0.458	1.7355	0.9236	0.8605
<i>Ludwigia octovalvis</i> (Jacq.) Raven	58.30	33.30	33.30	27.80	66.70	0.217	0.250	0.092	0.178	0.167	1.5972	0.8456	0.8348
<i>Ludwigia prostrata</i> Roxb.	83.30	50.00	66.70	61.10	83.30	0.633	0.750	0.458	0.478	0.750	1.3630	0.7406	0.7836
<i>Passiflora foetida</i> L.	0.00	0.00	16.70	5.60	8.30	0.000	0.000	0.017	0.006	0.008	2.2324	0.6778	0.9333
<i>Persicaria pulchra</i> (Blume) Sojak	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.017	0.011	0.000	1.6097	0.6374	0.8030
<i>Portulaca oleracea</i> L.	25.00	16.70	8.30	22.20	8.30	0.042	0.017	0.017	0.039	0.008	1.6981	0.6583	0.7778
<i>Dentella repens</i> (L.) Forst. & Forst. f.	8.30	0.00	16.70	11.10	8.30	0.008	0.000	0.017	0.011	0.008	1.4270	0.5613	0.6950
<i>Oldenlandia corymbosa</i> L.	50.00	50.00	25.00	44.40	33.30	0.358	0.600	0.417	0.400	0.475	1.5798	0.8921	0.8546
<i>Oldenlandia diffusa</i> (Willd.) Roxb.	41.70	33.30	33.30	22.20	58.30	0.142	0.183	0.100	0.111	0.167	1.3654	0.7338	0.8090
<i>Morinda persicaefolia</i> Buch.-Ham.	8.30	0.00	0.00	5.60	0.00	0.008	0.000	0.000	0.006	0.000	1.8205	0.4771	1.0000
<i>Cardiospermum halicacabum</i> L.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.008	0.006	0.000	1.3029	0.5074	0.7111
<i>Bacopa monnieri</i> (L.) Wettst.	16.70	0.00	8.30	5.60	16.70	0.042	0.000	0.025	0.017	0.042	1.5533	0.7677	0.8600
<i>Lindernia crustacea</i> (L.) F. Muell.	16.70	0.00	16.70	5.60	25.00	0.033	0.000	0.042	0.017	0.050	1.6423	0.7126	0.8238
<i>Lindernia antipoda</i> (L.) Alst.	8.30	0.00	8.30	5.60	8.30	0.008	0.000	0.017	0.006	0.017	1.8205	0.6614	0.8611
<i>Scoparia dulcis</i> L.	16.70	0.00	0.00	5.60	8.30	0.025	0.000	0.000	0.006	0.017	2.0852	0.7130	0.8545
<i>Physalis angulata</i> L.	16.70	0.00	8.30	11.10	8.30	0.033	0.000	0.008	0.022	0.008	2.2156	0.7596	0.8571
<i>Sphenoclea zeylanica</i> Gaertn.	8.30	0.00	16.70	5.60	16.70	0.008	0.000	0.033	0.011	0.025	2.0759	0.8160	0.8889
<i>Melochia corchorifolia</i> L.	33.30	33.30	16.70	22.20	25.00	0.033	0.050	0.008	0.028	0.025	2.0759	0.7809	0.8627
<i>Pentapetes phoenicea</i> L.	16.70	0.00	0.00	5.60	8.30	0.017	0.000	0.000	0.006	0.008	1.7299	0.5024	0.5621
<i>Pilea microphylla</i> (L.) Liebm.	25.00	0.00	8.30	11.10	16.70	0.100	0.000	0.017	0.061	0.025	1.4560	0.6405	0.7484
<i>Pouzolzia zeylanica</i> (L.) Liebm.	0.00	0.00	16.70	5.60	8.30	0.000	0.000	0.025	0.011	0.008	2.0556	0.6731	0.9048
<i>Cayratia trifolia</i> (L.) Domin	8.30	0.00	0.00	0.00	8.30	0.008	0.000	0.000	0.000	0.008	1.8205	0.4771	1.0000
<i>Colocasia esculenta</i> (L.) Schott	0.00	16.70	0.00	5.60	0.00	0.000	0.017	0.000	0.006	0.000	1.4427	0.4515	0.8333
<i>Cryptocoryne ciliata</i> (Roxb.) Fisch ex Schott	8.30	0.00	0.00	0.00	8.30	0.017	0.000	0.000	0.000	0.017	1.0278	0.4686	0.7619
<i>Lemna perpusilla</i> Torr.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.033	0.022	0.000	0.8686	0.4581	0.7111
<i>Pistia stratiotes</i> L.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.025	0.017	0.000	1.0278	0.4361	0.7143
<i>Typhonium flagelliforme</i> (Lodd.) Blume	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.008	0.006	0.000	1.8640	0.5786	0.9000
<i>Commelina diffusa</i> Burm. f.	8.30	0.00	8.30	5.60	8.30	0.008	0.000	0.017	0.006	0.017	1.6681	0.6142	0.7818
<i>Cyperus babakan</i> Steud.	25.00	0.00	0.00	11.10	8.30	0.042	0.000	0.000	0.017	0.017	1.8034	0.7384	0.8583
<i>Cyperus difformis</i> L.	0.00	16.70	16.70	11.10	8.30	0.000	0.033	0.033	0.028	0.008	1.3435	0.6357	0.7209
<i>Cyperus digitatus</i> Roxb.	33.30	50.00	33.30	44.40	25.00	0.317	0.317	0.150	0.272	0.217	1.5822	0.7128	0.7786
<i>Cyperus elatus</i> L.	16.70	16.70	8.30	11.10	16.70	0.025	0.033	0.017	0.017	0.033	2.5514	0.8591	0.8696
<i>Cyperus halpan</i> L.	8.30	16.70	16.70	16.70	8.30	0.008	0.017	0.058	0.039	0.017	1.9850	0.7691	0.8182
<i>Cyperus imbricatus</i> Retz.	16.70	16.70	33.30	16.70	33.30	0.017	0.050	0.092	0.028	0.092	1.7297	0.6793	0.6735
<i>Cyperus iria</i> L.	8.30	33.30	58.30	33.30	33.30	0.067	0.100	0.467	0.194	0.292	2.0011	0.7649	0.7948
<i>Cypeus rotundus</i> L.	16.70	16.70	8.30	5.60	25.00	0.033	0.033	0.017	0.011	0.050	2.3521	0.8937	0.8874
<i>Eleocharis dulcis</i> (Burm. f.) Hensch	8.30	16.70	8.30	11.10	8.30	0.042	0.100	0.025	0.061	0.025	0.8909	0.4647	0.6330
<i>Fimbristylis aestivalis</i> (Retz.) Vahl	8.30	0.00	0.00	0.00	8.30	0.008	0.000	0.000	0.000	0.008	0.5725	0.4745	0.6560
<i>Fimbristylis quinquangularis</i> (Vahl) Kunth	75.00	83.30	75.00	72.20	83.30	3.750	2.833	2.333	3.022	4.467	1.0418	0.7421	0.8004
<i>Kyllinga brevifolia</i> Rottb.	8.30	0.00	0.00	5.60	0.00	0.017	0.000	0.000	0.011	0.000	1.6681	0.6923	0.8727

Cont...

<i>Mariscus compactus</i> (Retz.) Druce	16.70	16.70	8.30	16.70	8.30	0.017	0.050	0.017	0.033	0.008	2.1177	0.7520	0.8382
<i>Scirpus grossus</i> L. f.	8.30	16.70	0.00	11.10	0.00	0.008	0.033	0.000	0.017	0.000	1.4427	0.5737	0.8214
<i>Hydrocharis dubia</i> (Blume) Backer	8.30	0.00	0.00	5.60	0.00	0.017	0.000	0.000	0.011	0.000	0.9618	0.4515	0.7143
<i>Limnocharis flava</i> (L.) Buch.	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.017	0.000	0.017	1.3029	0.5933	0.8222
<i>Chloris barbata</i> (L.) Sw.	16.70	16.70	0.00	5.60	16.70	0.025	0.050	0.000	0.017	0.025	1.4085	0.4160	0.4619
<i>Cynodon dactylon</i> (L.) Pers.	50.00	16.70	58.30	38.90	58.30	0.233	0.033	0.850	0.233	0.750	1.4318	0.7601	0.7972
<i>Dactyloctenium aegyptium</i> (L.) Beauv.	8.30	0.00	8.30	5.60	8.30	0.017	0.000	0.008	0.011	0.008	1.5946	0.5495	0.6206
<i>Digitaria ciliaris</i> (Retz.) Kohler	8.30	0.00	33.30	11.10	25.00	0.025	0.000	0.117	0.067	0.042	1.3598	0.6200	0.7104
<i>Echinochloa colona</i> (L.) Link.	58.30	83.30	83.30	72.20	75.00	1.200	1.350	0.833	0.744	1.592	1.4772	0.9435	0.8713
<i>Echinochloa crus-galli</i> (L.) Beauv.	66.70	66.70	66.70	61.10	75.00	0.833	0.617	0.700	0.783	0.667	1.5966	0.9320	0.8591
<i>Eleusine indica</i> (L.) Gaertn.	50.00	33.30	58.30	38.90	66.70	0.125	0.217	0.458	0.194	0.400	1.3599	0.7686	0.8098
<i>Eragrostis tenella</i> (L.) Beauv. ex Roem. & Schult.	8.30	0.00	8.30	5.60	8.30	0.017	0.000	0.033	0.011	0.033	1.6616	0.7296	0.7958
<i>Erianthus arundinaceus</i> (Retz.) Jeswiet. ex Heyne	16.70	16.70	16.70	11.10	25.00	0.100	0.033	0.092	0.061	0.117	1.3985	0.7892	0.8421
<i>Eriochloa procerata</i> (Retz.) Hubb	8.30	16.70	25.00	11.10	25.00	0.008	0.233	0.067	0.083	0.067	1.7631	0.7080	0.7707
<i>Hymenachne acutigluma</i> (Steud.) Gilliland	8.30	0.00	16.70	5.60	16.70	0.017	0.000	0.042	0.011	0.042	0.7461	0.4954	0.6494
<i>Leptochloa chinensis</i> (L.) Nees	100.0	100.0	100.0	100.0	100.0	1.925	3.183	3.150	2.017	3.642	1.2658	0.9239	0.8627
<i>Oryza rufipogon</i> Griff.	75.00	83.30	66.70	77.80	66.70	5.150	2.617	1.442	5.128	1.458	1.2971	0.7272	0.7457
<i>Panicum repens</i> L.	25.00	16.70	25.00	22.20	25.00	0.183	0.050	0.075	0.089	0.150	1.6368	0.7958	0.8318
<i>Paspalum conjugatum</i> Berg.	16.70	0.00	8.30	5.60	16.70	0.025	0.000	0.008	0.011	0.017	2.2735	0.7675	0.8571
<i>Paspalum distichum</i> L.	25.00	0.00	8.30	22.20	0.00	0.042	0.000	0.008	0.033	0.000	1.8463	0.6891	0.8095
<i>Paspalum longifolium</i> Roxb.	8.30	0.00	8.30	5.60	8.30	0.008	0.000	0.017	0.006	0.017	2.5022	0.8225	0.9273
<i>Paspalum notatum</i> Flugge	8.30	16.70	16.70	16.70	8.30	0.008	0.033	0.017	0.022	0.008	2.0121	0.7090	0.8485
<i>Paspalum scrobiculatum</i> L.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.017	0.011	0.000	1.5417	0.5871	0.8571
<i>Pennisetum purpureum</i> Schum.	8.30	16.70	0.00	11.10	0.00	0.017	0.017	0.000	0.017	0.000	1.3654	0.5693	0.8056
<i>Phragmites karka</i> (Retz.) Trin. ex Steud.	0.00	0.00	8.30	5.60	0.00	0.000	0.000	0.025	0.017	0.000	0.8507	0.4413	0.5508
<i>Pseudoraphis brunoniana</i> Griff.	8.30	0.00	16.70	11.10	8.30	0.183	0.000	0.050	0.133	0.033	1.4595	0.6298	0.7126
<i>Saccharum spontaneum</i> L.	16.70	0.00	8.30	16.70	0.00	0.033	0.000	0.008	0.028	0.000	1.1078	0.4244	0.4977
<i>Brachiaria mutica</i> (Forssk.) Stapf	83.30	33.30	75.00	61.10	83.30	1.267	0.283	0.383	0.483	1.067	1.3124	0.7759	0.7912
<i>Eichhornia crassipes</i> (Mart.) Solms.	0.00	0.00	33.30	11.10	16.70	0.000	0.000	0.117	0.039	0.058	1.4701	0.7375	0.8322
<i>Monochoria elata</i> Ridl.	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.017	0.000	0.017	1.4427	0.6021	0.8571
<i>Monochoria hastata</i> (L.) Solms.	8.30	0.00	8.30	0.00	16.70	0.017	0.000	0.017	0.000	0.033	1.3654	0.5529	0.7778
<i>Monochoria korsakowii</i> Regel & Maack.	0.00	0.00	8.30	0.00	8.30	0.000	0.000	0.008	0.000	0.008	1.4427	0.3010	1.0000

C1: crop 1, C2: crop 2, C3: crop 3; In: inner dike, out: outer dike.

Table 2 : Frequency of occurrence of seasonal weed species and the environment inside and outside the dike

Category	Group A	Group B	Group C	Group D	Group E
Crop 1	66	16	10	4	5
Crop 2	39	10	3	5	5
Crop 3	81	19	4	5	2
In dike	77	15	3	8	1
Out dike	98	23	6	5	5

Table 3 : The five highest densities of rice fields surveyed in An Giang

Species	Crop 1	Crop 2	Crop 3	In dike	Out dike
<i>Brachiaria mutica</i>	1.267				1.067
<i>Echinochloa colona</i>	1.200	1.350			1.592
<i>Leptochloa chinensis</i>	1.925	3.183	3.150	2.017	3.642
<i>Fimbristylis quinquangularis</i>	3.750	2.833	2.333	3.022	4.467
<i>Oryza rufipogon</i>	5.150	2.617	1.442	5.128	1.458

Table 4 : Similarity index of weed species composition between crops and two sides of dike system in paddy field

Category	Crop 1	Crop 2	Crop 3	In dike	Out dike
Crop 1					
Crop 2	79.52				
Crop 3	67.39	67.27			
In dike	35.93	31.85	31.25		
Out dike	28.41	25.05	30.87	69.13	

Table 5 : Biodiversity indices of weeds collected from study sites

Category	d	H'(log10)	1- $\bar{e}$
Crop 1	12.8879	1.2039	0.8712
Crop 2	8.4957	1.0700	0.8448
Crop 3	14.7128	1.3448	0.9057
Inside dike	13.2900	1.2647	0.8895
Outside dike	13.8069	1.2076	0.8592

conducted in the rice-growing area in the dike, it was not possible to grow rice outside the dike due to flooding depth of 1-4 m, so the species composition was less diverse than in Crop 1 and Crop 3.

The number of weed species (112 species) outside the dike was more diversity than that of inside the dike (104 species); because the fields outside the dike had more aquatic plants due to the longer time the field is flooded. The typical species were found in this area including *Marsilea quadrifolia*, *Neptunia oleracea*, *Hydrocera triflora*, *Cryptocoryne ciliata*, *Monochoria* spp., *Limncharis flava*.

The frequency of occurrence and density of weed species are detailed in Table 1. The grouping of species by frequency of occurrence is shown in Table 2.

Table 2 shows that the number of species belonging to groups C, D, E had the most in Crop 1 with 19 species, followed by Crop 2 with 12 species and Crop 3 with 11 species. Crop 1 often had hot and humid weather with heavy rain, hence, it was suitable for the growth and development of herbaceous plants. In contrast, Crop 3 experienced lack of water, drought, weeds grow poorly. The number of species with very high frequency of occurrence (Group E) was most encountered in Crop 1 with five species (*Leptochloa chinensis*, *Alternanthera paronychioides*, *Ludwigia hyssopifolia*, *Ludwigia prostrata*, *Brachiaria mutica*) and Crop 2 with five species (*Leptochloa chinensis*, *Ludwigia hyssopifolia*, *Fimbristylis quinquangularis*, *Echinochloa colona*, *Oryza rufipogon*). Crop 3 had only two species (*Leptochloa chinensis* and *Echinochloa colona*). *Leptochloa chinensis* especially appeared in all rice crops in the year ($F\% = 100\%$).

Table 2 shows that the number of species in groups C, D, E in outside-dike (16 species) was higher than that in the inside-dike (12 species). In particular, species belonging to group E such

as *Ludwigia hyssopifolia*, *Ludwigia prostrata*, *Fimbristylis quinquangularis*, *Leptochloa chinensis*, *Brachiaria mutica* were mainly found in outside-dike fields. These herbs grew and developed rapidly due to availability of humidity and water.

Table 1 shows that the highest weed density (19.525 weeds m^{-2}) was in Crop 1; followed by Crop 2, with an average of 16.363 weeds m^{-2} and the lowest is Crop 3, with an average of 14.725 weeds m^{-2} . Due to favorable weather of Crop 1, the density of weeds was higher than that Crops 2 and 3. The mean density in outside-dike fields was 19.350 weeds m^{-2} , which was higher than inside-dike fields (17.228 weeds m^{-2}). Five species with high individual densities of 1-6 weeds m^{-2} in crops and farming environments are shown in Table 3.

Table 3 shows that three species including *Leptochloa chinensis*, *Fimbristylis quinquangularis* and *Oryza rufipogon* were all present in high densities in all three crops, both inside and outside the dike. These three species were also common weed species in wet rice fields in Vietnam (Suk et al., 2000).

Similarity of weed species composition among three crops and two sides of dike system in paddy field is presented in Table 4. In terms of crop, the most similar value was between crops 1 and 2 (79.52%) and the least one was between Crops 2 and 3 (67.27%). Likely, the flora in the inside dike was similar to that in outside with the similarity index at 69.13%. The composition of weed species was not significantly different among three crops and two sides of dike system (PERMANOVA, $p > 0.05$).

The values of d, H' and λ of three crops, and two sides of dike were high and are presented in Table 5. Table 5 shows that the d, H' and $1 - \lambda$ reached the highest point in Crop 3 and the lowest in Crop 2 when the paddy field was flooded. Consequently,

weeds could not survive in paddy rice fields in the outer of dike system. Regarding sides of dike system, the values of indices d , H and $1-\lambda$ differed slightly. This result shows that the dike systems had little effect on the weed species diversity between the inner and outer paddy rice fields of dike. Because in these areas, there were many canals circulating between the two rice growing areas inner and outer the dike, so spreading of weeds was easy between fields.

The weed composition in the paddy rice in An Giang was a diversity of 137 species belong to 103 genera of 42 families in 2 phyla. In which, Poaceae, Cyperaceae and Compositae had the highest number of species. The largest number of species present were in crop 3 and in fields outside the dike system. Most weeds appear with very low frequency (Group A, $F \leq 20\%$), only a few species appear with high frequency (Group E, $F > 80\%$). The highest weed density was in Crop 1. Values for the indices d , H and $1-\lambda$ were highest in Crop 3. The dike system has little effect on weed composition in rice fields in An Giang province.

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Authors' contribution : M.D. Quan: Experiment design, sample collection and classification, data analysis, manuscript writing; T.T. Hang: sample collection; S.T. Nam: data analysis, manuscript writing.

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