Diversity and Allelopathic Potential of Weeds in Swampland

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ABSTRACT

Weeds are plant disturbing organism that affect yields through competition and allelopathy. However, not much is known about weed diversity in swamps, so research is needed to identify their types and compounds as a weed control strategy. This study was conducted using a survey method from January to March 2020 at the Barito Kuala District, South Kalimantan. Thirty villages were randomly selected from each of the eight chosen subdistricts. Out of the twenty-six weed species identified, there were ten species of grasses, seven sedges, and nine broadleaves. The results showed that the weed species were dominated by *Cyperus halpan, Eleocharis dulcis,* and *Cynodon dactylon* (L.), with an SDR of 23.46, 16.73, and 10.03, respectively. The analysis of GC-MS showed that the weeds contained four similar compounds: neophyte diene, palmitic acid, linoleic acid, and stigmasterol. The largest compound content in *C. halpan* was diisocotyl phthalate (48.49%), while in *E. dulcis* and *C. dactylon* the largest were o-phthalic acid and mono-2-ethylhexyl-ester (69.36 and 40.23%). Moreover, weed allelochemicals are classified into fatty acids, steroids, esters, and other volatile compounds, where some have the potential for allelopathy that inhibits crop growth.

Keywords: Abundance; Allelochemical; Density; Dominance; Weed Groups

ABSTRAK

Gulma merupakan salah satu organisme pengganggu tanaman yang mempengaruhi hasil melalui kompetisi dan alelopati. Namun, keanekaragaman gulma di lahan rawa belum banyak diketahui, sehingga perlu dilakukan penelitian untuk mengidentifikasi jenis dan kandungannya sebagai salah satu strategi pengendalian gulma. Penelitian ini dilaksanakan mulai bulan Januari sampai Maret 2020 di Kabupaten Barito Kuala, Kalimantan Selatan dengan menggunakan metode survey. Selanjutnya, dipilih 30 desa secara acak dari 8 kecamatan yang terpilih. Berdasarkan 26 jenis gulma yang teridentifikasi, terdapat 10 jenis dari golongan rumput-rumputan, 7 jenis dari golongan teki, dan 9 jenis dari golongan berdaun lebar. Jenis spesies yang mendominasi adalah Eleocharis dulcis, Cynodon dactylon (L.), dan Cyperus halpan dengan nilai SDR masing-masing 23.46; 16.73; dan 10.03. Berdasarkan analisis GC-MS menunjukkan bahwa ketiga gulma mengandung 4 senyawa yang sama, yaitu neophytadiene, asam palmitat, asam linoleat, dan stigmasterol. Kandungan terbesar pada C. halpan adalah diisocotyl phthalate (48.49%), sedangkan pada E. dulcis dan C. dactylon adalah o-phthalic acid (69.36%) dan mono-2-ethylhexyl-ester (40.23%). Alelokimia gulma dikelompokkan dalam asam lemak, steroid, ester, dan senyawa volatil lainnya, yang beberapa di antaranya memiliki potensi alelopati dalam menghambat pertumbuhan tanaman.

Kata kunci: *Kelimpahan; Alelokimia; Kerapatan; Dominansi; Kelompok gulma*

INTRODUCTION

The increasing population in Indonesia, especially in Java, has changed the function of land from agricultural to non-agricultural fields. Therefore, developing agriculture in swampland that is characteristically flooded for a certain period is necessary (Paiman et al., 2020). Swampland is generally classified into two, namely tidal and freshwater swamp. Swampland is distributed in Sumatra, Kalimantan, Sulawesi, and Papua. Tidal swamps are part of the plain influenced by tidal fluctuation, while freshwater swamps are river floodplains not influenced by sea tides (Sulaiman et al., 2019). Generally, swamplands have low soil fertility (low pH, high soil acidity, low nutrient availability) (Hermawan & Sulistyani, 2021) and high concentrations of iron (Fe) up to 400-1200 mg kg^{-1} (Mawardi et al.,

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2020). In addition to these abiotic factors, there are biotic factors that affect plant growth and yield, including pests, diseases, and weeds.

Weeds are all non-crop species in a cultivated field and are the most significant limiting factor in crop production. Meanwhile, crops and weeds compete for limited resources such as light, water, and nutrients. It was reported that the production system differs in the losses due to weeds, which caused a decrease in rice yield by 49% (Johnson et al., 2004) and 35-54% (Juraimi et al., 2009). Weeds cause yield loss due to their ability to produce more seeds, have rapid germination, initial growth, and high density. Furthermore, the morphology of weeds plays an essential role in their competitiveness in an actual field for survival (Keerti et al., 2016). They are also affiliated with pests for their development. The associated pests include insects, mites, nematodes, and rodents (Kumar et al., 2021).

Moreover, the life cycle and reproduction significantly affect the presence of weeds in an area. The tillage and fertilization system also considerably affect the abundance and diversity of weeds (Travlos et al., 2018). There has been an increase in weed abundance, diversity, and evenness, which is affected by the tillage system in the immediate and long term in the arable field (Santín-Montanyá et al., 2013). Appropriate fertilization for crops would promote closed crop stands and light limitation for weed communities growing underneath and affect weed diversity (Tang et al., 2014). According to Mahgoub (2019), the other factors that influence the distribution and structure of weed communities are climate, soil, and crop cultivation. Cultivation like direct seeded rice has severe challenges due to weeds, so weed management is essential in rice production (Singh et al., 2016). The dry-tilled aerobic soil triggers the germination and growth of weeds (Rahman, 2016). Meanwhile, predicting the abundance of weeds is challenging due to the difficulty characterizing seedbanks in the soil (Borgy et al., 2015). The primary source of weeds in rice cropping fields is weed seedbanks in the soil, which is unpredictable and challenging to know.

In addition, weeds also compete with crops through allelopathy. Allelopathy is defined as the interaction between plants and plants or microorganisms through the release of secondary compounds, which could have either stimulatory or inhibitory on the performance of neighbors (Thiébaut et al., 2019). Allelochemicals are secondary metabolites produced by plants or decomposition microbes (Cheng & Cheng, 2015). The allelochemicals are released through decomposition, leaching, volatilization, and root exudates. Furthermore, it substantially impacts the germination or growth of neighboring plants. Many plant species have already been isolated and proven to inhibit other plants. For example, *Miscanthus sacchariflorus* (Maxim.) Hacks contain 22 phenolic compounds, and leaf extracts completely suppress or partially reduce seed germination in other plants (Ghimire et al., 2020). Plants, including weeds, produce allelochemicals that defend against pests, diseases, and competition from other plants (Kong et al., 2019). In addition, Alridiwirsah et al. (2022) found that *Mikania micranta* extract had alkaloids, flavonoids, saponin, and tannins as well as an extract concentration of 20-100%, which effectively suppressed the biomass of barnyard grass weeds by 46.0-63.5% in lowland rice area. Weeds that exist in swampland are not widely known for their compund content. Hence, identifying these substances and their environments is a key to understanding allelopathic interactions. Allelochemicals are released by some plant organs, such as roots, leaves, stems, flowers, and seeds.

Agricultural cultivation can affect the diversity of weed species in the field with both higher and lower effects. In early growth stages, weed species are often difficult to distinguish, so farmers think weeds are crops. This study aimed to identify the dominance of weeds in swampland and analyze their compounds. The research is expected to provide insight into the dominant weed that can compete with rice. Furthermore, the prevalent weed can also inhibit rice growth through allelochemicals. Therefore, this information is essential in rice cultivation to anticipate the higher yield losses due to weeds.

MATERIALS AND METHODS

Sampling Activities

The study was conducted using a survey method from January to March 2020 in Barito Kuala District, South Kalimantan. Barito Kuala is located at 2°29'50"- 3°30'18" S and 114°20'50" -114°50'18" E, and it known as a lowland with the high 0.2-3.0 meters above sea level. The highest rainfall for 2020 accured on February with 532.00 mm during 21 days (BPS, 2021). A total of 30 villages were randomly selected for each of the 8 subdistricts (Figure 1), including Marabahan, Cerbon, Rantaubadauh, Jejangkit, Belawang, Anjir Pasar, Anjir Muara, and Alalak. These subdistricts were selected based on purposive sampling by considering the swampland for rice cultivation, while the village selection was random. Two weed sampling points of 0.5 x 0.5 m were taken in each village. All weeds were taken and separated based on species. Furthermore, primary data were needed to find out rice cultivation techniques from farmers. Data includes cropping patterns and systems, land preparation, varieties, and herbicides.

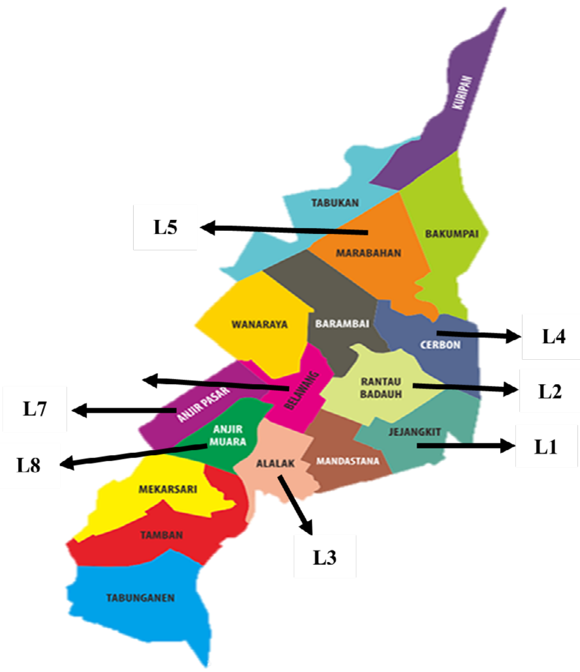

Figure 1. Weed sampling locations in swampland. L1-L8 are sampling subdistricts

Analysis of Secondary Metabolites

The three dominant weeds were analyzed for secondary metabolites using GC-MS. It used a model Agilent Technologies 7890 capillary gas chromatography with a mass spectrometer. The column used a fused silica capillary column (HP Ultra2, length: 30 m, diameter: 0.20 mm, film thickness: 0.11 μm). Parameters for GC-MS detection were an injector temperature of 250°C and an initial oven temperature of 80°C gradually raised to 150°C at a speed of 3°C/min for 2 min and finally increased to 280°C at 20°C/min for 1 min. The total run time was 26 min using helium as a carrier gas at a 1.2 mL/min column flow rate. Furthermore, the interface temperature was fixed at 280°C, and an electron ionization system was set on the MS in scan mode. The separated constituents were identified by comparing their mass spectra with those in the NIST Library.

Data Analysis

Identification of weeds found in each sampling point was made by looking visually at the morphology of the weeds, then matched with the library. The next step was grouping weeds by species and counting. Identification was then carried out to obtain dominance and diversity of weeds in swamp land. The weeds were identified and analyzed of summed dominance ration and diversity index according to Travlos et al. (2018). The interview data collected were analyzed descriptively.

RESULTS AND DISCUSSION

Characteristics of Cultivation

Based on the interviews with farmers, the cropping pattern used in swamplands is one and two planting times. Moreover, rice cultivation applies a transplanting system based on the characteristics of the land, which is almost flooded during growth. Farmers use local varieties only once because of its late maturity, which takes approximately eight to ten months. In addition, the seedling is carried out several times by moving the previous ones that are 2-3 months old before planting. Meanwhile, various herbicides are used by farmers before tillage and during rice growth, as shown in Table 1.

Weed Species

Weed vegetation in swampland recorded 26 weed species, containing grasses (10), sedges (7), and broadleaves (9) (Table 2). Based on the SDR value, there were weed species that had the highest SDR from each weed group, namely *Eleocharis dulcis* (grasses), *Cyperus halpan* (sedges), and *Ceratophyllum* sp (broadleaves). Among all weed species, it was found that 3 species had the higher SDR of 23.46, 16.73, and 10.03, namely *C. halpan*, *E. dulcis*, and *C. dactylon*, respectively. The species' dominance in swamp land might be related to cultural practices, crop history, and the weed species' reproductive capacity. For example, banded fertilization reduced the total weed biomass of *Setaria viridis* in spinach cultivation compared to broadcast fertilization because most annual weeds germinate in the upper soil layer and improve their emergence and growth (Gazoulis et al., 2021). Likewise, *Cyperus rotundus* was the most abundant weed in an area with higher pH, CaCO3, potassium, and organic matter (Ahmad et al., 2016). Furthermore, cropping with a lower nitrogen supply and without herbicides will have greater weed species diversity than cropping with higher nitrogen and herbicides (Hyvönen & Salonen, 2002). Excessive herbicide application might contribute to the ineffectiveness of controlling weeds and cause the spread of weeds (Salaudeen et al., 2022). Cultivation frequency also affects weed species diversity and composition in the Okavango Delta Botswana, where species diversity decreases with increasing cultivation frequency (Nthaba et al., 2018). Sawicka et al. (2020) stated that the common weed population and its composition were affected by two major factors, including crop competition and soil seed bank, which depend on elements of the agrotechnology, such as crop rotation, tillage, sowing time and density, and cultivar choice.

Table 1. Paddy cultivation in swampland

Cropping pattern	:	Paddy; paddy-paddy
Cropping system	:	Transplanting
Tillage	:	No-tillage; manual; hand tractor
Variety	:	High yielding varieties (Ciherang; Inpari 43) and local (Siam)
Herbicides	:	2,4 dimethyl ammonium; glyphosate; paraquat; phyrizosulphuron ethyl; 2,4 D natrium

A community has high species diversity when it is composed of many species. The diversity in the swamp area was in the low and medium category (Figure 2). Alalak and Marabahan have a diversity index below 2 and are included in the low diversity. Meanwhile, the other 6 subdistricts are classified

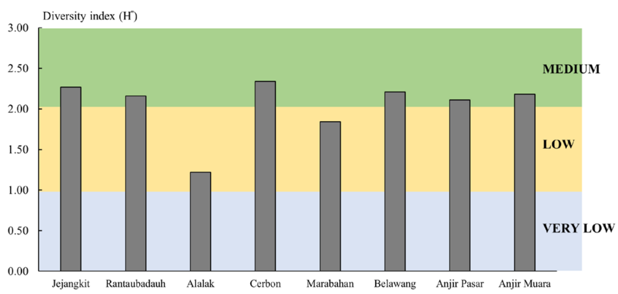

Figure 2. Diversity index of weeds in difference subdistrict

Table 2. Sumed dominance ratio (SDR) of weeds in swampland

Species	Subdistrict								Average
	L1	L2	L3	L4	L5	L6	L7	L8	
Grasses									
Eleocharis dulcis	9.54	18.13	-	34.65	19.80	4.03	7.08	40.6	16.73
Cynodon dactylon (L.)	11.69	12.73	-	7.82	39.29	-		8.70	10.03
Blyxa aubertii Rich.	-	12.57	-	-	-	-	20.24	5.1	4.74
Leptochloa octovalvis	-	-	-	-	3.41	6.24	6.68	8.29	3.08
Paspalum scrobiculatum L.	14.76		-	5.76	-	-	-	-	2.57
Echinochloa crus-galli (L.) P. Beauv	5.13	10.32	-	-	-	-	-	-	1.93
Rottbaellia cochinhinensis	-	-	-		9.88	4.90	-	-	1.85
Fuirena umbellata Rottb	-	-	-	9.82	-	-	-	-	1.23
Leptochloa chinensis (L.) Nees	7.70	-	-	-	-	-	-	-	0.96
Echinochloa colona (L.) Link	-	3.18	-	-	-	-	-	-	0.40
Sedges									
Cyperus halpan	31.68	22.72	33.90	16.54	2.94	32.59	36.64	10.65	23.46
Fimbrystylis miliacea (L.) Vahl	6.46	9.33	41.19	3.93	-	5.11	4.40	6.80	9.65
Cyperus flavidus Retz.	-	-	-	9.42	-	-	-	-	1.18
Scleria sumatrensis	-	-	-	1.59	-	3.15	-	2.12	0.86
Cyperus rotundus L.	-	-	-	1.87	-	-	-	-	0.23
Cyperus compactus Retz.		1.53	-	-	-	-	-	-	0.19
Scirpus juncoides Rocb.	1.16	-	-	-	-	-	-	-	0.15
Broadleaves									
Ceratophyllum sp	-	-	-	-	18.76	17.48	-	6.87	5.39
Monochoria vaginalis (Burm. F.) Presi		1.12	12.68	3.86	-	15.53	9.55	-	5.34
Ludwigia octovalvis (Jacq.) Reven	3.37	6.90	12.22	2.79	-	-	-	-	3.16
Nymphaea tetragona	-	-	-	-	-	6.42	5.29	6.46	2.27
Hydrilla verticillata	-	-	-	-	5.92	2.97	1.97	4.39	1.91
Pteris sp	-	-	-	1.97	-	-	5.47	-	0.93
Portulaca sp	3.04	1.47	-	-	-	1.58	-	-	0.76
Melastoma malabathricum L.	5.47	-	-	-	-	-	-	-	0.68
Ipomoea aquatica							2.68		0.34
Total	100	100	100	100	100	100	100	100	100

L1: Jejangkit L2: Rantaubadauh L3: Alalak L4: Cerbon L5: Marabahan L6: Belawang L7: Anjir Pasar L8: Anjir Muara

as medium. The low diversity can be seen from the small number of weed species, which were 4 (Alalak) and 7 (Marabahan) (Table 2). There is low diversity if the ecosystem comprises a few species and only a few dominant ones. Furthermore, those in the medium category have a minimum number of 10 species. This means all species had the same priority, and the species community manifested the medium biodiversity. There are not too many types of weed species in swamp land. This condition showed that the state was sufficient and balanced. An ecosystem has a high diversity if the weed community is composed of many species with a similar abundance. High species richness is expected to correlate positively with high diversity and low dominance (Jastrzebska et al., 2013). The diversity

Table 3. The peak area of compounds in weeds

Compounds	Peak area (%)		
	C. halpan	*E. dulcis*	*C. dactylon*
Neophytadiene	8.86	4.01	4.44
Palmitic acid	5.29	2.91	8.80
Phytol	1.67	2.32	-
Methyl 98E)-8-octadecenoate	-	-	1.39
(2E)-3,7,11,15-tetramethyl-2hexadecen-1-ol	-	-	1.53
Linoleic acid	8.62	5.41	13.46
Bicyclo[11.3.0] hexadecane-2,14-dione	1.68	-	-
Phyhalic acid, mono-2-ethylhexyl-ester	-	69.36	40.23
Diisocotyl phthalate	48.49	-	-
.gamma-tocopherol	1.54	-	-
Vitamin E	2.14	1.85	-
Campesterol	3.28	2.10	-
Stigmasterol	7.15	2.68	4.48
.gamma.-sitosterol	4.02	4.13	-
1-cyclohexene-4-carboxaldehyde,1-methyl-	1.07	-	-
4,22-stigmastadiene-3-one	1.83	-	1.77
Stigmast-4-en-3-one	1.32	2.05	-
.gamma.-tocopherol	-	1.04	-
2(5H)-furanone,5-ethyl-	-	-	2.38
2,4,7,14-tetrametyhl	-	-	2.05
1,2,4-triazolo	-	-	1.46
Ergost-5-en-ol	-	-	2.25
.beta.-sitosterol	-	-	4.31
Ergost-4-en-3-one-,(24R)	-	-	1.09
Cholest-4-en-26-oic acid,3-oxo-	-	-	1.02

index reflects the composition of communities in much more detail, the number of species, and the relative number of various species (Sawicka et al., 2020).

Weed Allelochemicals

The GC-MS analysis showed that *C. halpan*, *E. dulcis*, and *C. dactylon* contained 14, 11, and 15 compounds, respectively (Table 3). There were 4 types of compounds in these weeds, each containing compounds that were not in the other, namely 4 compounds in *C. halpan*, 1 in *E. dulcis*, and 11 in *C. dactylon*. The highest compound in *C. halpan* was diisooctyl phthalate (48.49%). Meanwhile, O-phthalic acid and mono-2-ethylhexyl-ester (MEHP) were the highest in *E. dulcis* and *C. dactylon*, which were 69.36% and 40.23%, respectively, which belong to the ester group. Some plants that have been reported to contain these compounds include *Allium fistulosum* (Xu et al., 2012), *Lilium brownii* (Cheng and Xu, 2012), and *Salvinia natans* (Zhang et al., 2016). Phthalate compounds are considered a valuable candidates for bioherbicides and allelopathic, antimicrobial, and other biological activities that enhance the competitiveness of plants (Huang et al., 2021). The derivates of phthalate from *Echinochloa crus-galli* root exudates affect the seedling growth of *Medicago sativa*, *Sesamum*

Table 4. Composition of compounds in weeds

Compounds	C.halpan	E. dulcis	C. dactylon
Ester	Diisooctyl phthalate	1,2-Benzenedicarboxylic acid	Methyl (8E)-8-octadecenoate
			1,2-benzenedicarboxylic acid
Fatty acid	Palmitic acid	Palmitic acid	Palmitic acid
	Linoleic acid	Linoleic acid	Linoleic acid
Steroid	Stigmasterol	Campesterol	Stigmasterol
	.gamma.-sitosterol	Stigmasterol	.beta.-sitosterol
	4,22-stigmastadiene-3-one	.gamma.-sitosterol	4,2,2-Stigmastadiene-3-one
	Stigmast-4-en-3-one	Stigmast-4-en-3-one	Cholest-4-en-26-oic acid, 3-oxo-
Others	Neophytadiene	Neophytadiene	Neophytadiene
	Phytol	Phytol	(2E)-3,7,11,15-tetramethyl-2-hexadecen-1-ol
	.gamma.-tocopherol	.gamma.-tocopherol	2(5H)-furanone,5-ethyl-
	Vitamin E	Vitamin E	2,4,7,14-tetramethyl
	1-cyclohexene-4-carboxaldehyde,1-methyl-		1,2,4-triazolo
			Ergost-5-en-ol
			Ergost-4-en-3-one,(24R)

indicum, *Monochoria vaginalis*, *Aeschynomene indica*, and *Oryza sativa* (Xuan et al., 2006). *C. halpan*, *E. dulcis*, and *C. dactylon* have allelopathic potential affecting swampland rice growth.

Weeds synthesize various primary and secondary metabolites, such as volatile organic compounds. These compounds defend themselves from attacking herbivores and pathogens, plants' interaction, attraction to a pollinator, and seed dispersers (Fink, 2007; Dudareva et al., 2012; Effah et al., 2019). The content, as shown in the percentage of the peak area of three swamp weeds, was dominated by the ester group (Table 3; Table 4), while the second-largest content was fatty acids, followed by the steroid. Meanwhile, volatile is an important compound class contributing to aroma characteristics in many fruits, flowers, and leaves. The emission of volatile compounds from leaves has allelopathic effects and impairs the growth of other species (Brilli et al., 2019). Green leaf volatiles in tomato induced resistance against fungal pathogens *Pseudomonas syringe* pv. tomato (López-Gresa et al., 2018).

In these weeds, the compounds discovered were neopyhtadiene, palmitic and linoleic acid, and stigmasterol (Table 4). These volatile compounds have been detected in *Barringtonia asiatica*, *Erythrina lithosperma*, *Nauclea orientalis*, *Annona muricata* (Hidayati and Nuringtyas, 2016), and *Ophiorrizha rugosa* (Adnan et al., 2019). Neophytadiene belongs to the class of sesquiterpenoids and is a potent antimicrobial, anti-inflammatory, and antioxidant compound (Raman et al., 2012). Furthermore, palmitic and linoleic acids were long-chain fatty acids, while stigmasterol belongs to the steroid group. The results showed that the two compounds had the potential as allelopathy that affects other organisms/plants (Nakai et al., 2012; Rial et al., 2018). These compounds are released into the soil to develop their bioactivities. Meanwhile, the release rate and level of allelochemicals are important factors in their environments (Fernandez et al., 2009).

Weeds compete with crops by releasing allelochemicals through chemical pathways to reduce crop growth (Xuan et al., 2016). The interaction of allelochemicals in the soil environment induces other species to produce another compound that interferes with donor plants. On the other hand, changes in abiotic factors in the soil also can affect target plants. Furthermore, it causes deterioration, namely microbial degradation, oxidation, and photolysis, followed by removal or transfer, such as volatilization and adsorption (Vidal & Bouman, 1997). The allelochemicals that plants release into the soil are fundamental for determining phytotoxic effects. The key factors are soil physical and chemical properties. Soil physical properties consist of texture, structure, organic matter, moisture, and aeration, while soil chemicals include reaction, ion exchange capacity, O_2, CO_2, and nutrients (Scavo et al., 2019). This indicates the varying complexity of allelochemicals in the soil, especially the differences in the soil and environments in swampland.

CONCLUSIONS

The composition of weeds in swampland consisted of 26 species, including 10 species of grasses, 7 sedges, and 9 broadleaves. Among these species, *Eleocharis dulcis*, *Cynodon dactylon* (L.), and *Cyperus halpan were dominants*. The three weeds contained four similar compounds: neophytadiene, palmitic acid, linoleic acid, and stigmasterol. The largest compound content in *C. halpan* was diisocotyl phthalate, while in *E. dulcis* and *C. dactylon* was o-phthalic acid, mono-2-ethylhexyl-ester. Meanwhile, some allelochemicals have the potential for allelopathy that inhibit crop growth and can be herbicides in the future.

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