PURIFICATION OF EUTROPHIC HYDRO-ENVIRONMENTS AND THE UTILIZATION FOR NEW BIOMASS FORAGE RESOURCES BY AQUATIC PLANTS IN ASIA

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ABSTRACT
Water pollution, especially eutrophication, has become a serious world-wide problem in recent years. On the other hand, forage is in short supply during the dry season in Asia (especially in Southeast Asia). The purpose of this paper is to describe the development of new forage resources from among aquatic plants. In conclusion, it is suggested that three emergent plants (*Zizania latifolia* Turcz., *Pontederia cordata* L., *Paspalum distichum* L.) are useful as new forage species because of their absorptive ability for nitrogen and phosphorus from eutrophic water and their superior feeding value following ensiling.

KEYWORDS
Water purification, Eutrophication, Aquatic plant, Forage resource, Aquatic biomass, Emergent plant, Feeding value, Ecosystem

INTRODUCTION
There are more than 400 aquatic plant species in Japan. Aquatic plants are mainly classified according as emergent, submerged and natant. Kabata *et al*.(1993) and Lowilai *et al*.(1995) reported that *Eichhornia crassipes* (water hyacinth, natant plant) was useful to remove the nutrient elements from eutrophic water and for use as silage material. Furthermore, Middleton(1992) and Sutton *et al*.(1991) have investigated the useful emergent plants.

The purpose of this study is to determine the useful aquatic plants for the purification of eutrophic water and as potential new forage crops for Asia.

MATERIALS AND METHODS
The experiment was carried out on the pasture of Tokai University (32°55'N, 131°6'E) with a mean annual air temperature of 12.6°C.

Aquatic plants were cultivated at the eutrophic lake (Lake Ezu; 32°46'N, 130°45'E) which is situated east of Kumamoto city, Japan, from 1990 to 1996. At the first, 36 aquatic species were harvested. However, 21 species were removed because of low yield.

The other 15 species were chopped and dried in the oven at 60°C for 48 hours. Then, the chemical components of these species were analysed. Items measured were crude protein (CP), crude ash (CA), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), gross energy (GE), water soluble carbohydrate (WSC) and *in vitro* dry matter digestibility (IVDMD). Furthermore, in order to determine the utilization as silage, ammonia-nitrogen (NH4 -N), pH, lactic acid and volatile fatty acids were also measured.

RESULTS AND DISCUSSION
Hydrospheres such as rivers, lakes and oceans have become eutrophied by nitrogen and phosphorus. We examined the feed production of aquatic plants under the concept of material circulation within a closed system.

There are more than 400 aquatic plant species in Asia. However, there is little practical use of aquatic plants for feed. Furthermore, the green feed supply is generally inadequate during the dry season in this region.

We have investigated the biomass, the resistance to water pollution and the feeding value of selected plants from among a number of aquatic plant species. Table 1 shows the chemical components of 15 species of emergent and submerged plants. *Nasturtium officinale*, *Vallisneria asiatica* and *Egeria densa* etc. showed high CP. *Ranunculus kadzusensis*, *Oenanthe javanica*, P*olygonum thunberrgii* and *Nasturtium officinale* showed high IVDMD, respectively.

Zizania latifolia, *Pontederia cordata* and *Paspalum distichum* showed high yield and high resistance to water pollution (Fig.1) and suitable fermentation quality for use as silage (detailed data not published). The lactic acids (% of dry matter) are 3.0 to 4.5 % in the silages of *Zizania latifolia* and *Pontederia cordata*. And the WSC contents are 18.0 to 19.2 % in both plants.

With regard to *Paspalum distichum* (knotgrass), Ikeda (1989) reported the characteristics and utilization of this species. *Zizania latifolia* has been mainly investigated in China and Taiwan, but it is inadequate for practical use. *Pontederia cordata* was introduced from North America to Asia in recent years. In general, there has been little investigation on the utilization of aquatic plants for water purification and aquatic biomass in Asia.

In conclusion, it is suggested that *Zizania latifolia* and *Pontederia cordata* are useful in ecological forage production systems using eutrophic hydro-environments.

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Table1
The chemical components of aquatic plants.

species	CP[z]	GE[y]	CA[x]	IVDMD[w]
	---%---	---cal • g^{-1}---	---%---	---%---
Phragmites australis (Cav.)Trin. ex Steud.	16.7±2.2	4148±44.4	12.6±0.2	47.5±2.7
Zizania latifolia Turcz.	9.0±1.8	3816±43.1	13.0±0.3	44.0±3.0
Paspalum distichum L.	15.8±1.5	3778±19.1	10.5±0.2	48.2±6.2
Schoenoplectus triqueter (L.) Palla	9.5±0.3	4132±37.6	11.6±0.1	47.7±4.6
Polygonum thunberrgii Sieb. et Zucc	13.4±0.4	3825±49.5	9.4±0.3	69.9±5.5
Oenanthe javanica (Blume) DC.	17.6±0.8	4077±28.4	14.6±0.3	75.3±1.4
Nasturtium officinale R. Br.	22.4±1.6	3895±8.0	18.6±0.9	68.6±0.4
Myriophyllum aquaticum (Vellozo) Verdc.	17.6±1.2	3926±64.3	10.9±0.2	59.4±5.4
Acorus gramineus Soland	13.1±0.7	4120±1.4	10.6±0.1	48.7±4.2
Pontederia cordata L.	9.3±1.4	3813±20.1	14.3±0.2	41.2±3.8
Ranunculus kadzusensis Makino	16.7±0.2	3895±14.1	12.8±0.3	77.5±3.4
Ceratophyllum demersum L.	16.6±0.1	3637±11.3	14.4±0.4	44.4±4.6
Potamogeton malaianus Miq.	17.5±0.3	3903±10.6	12.9±0.7	40.7±4.8
Vallisneria asiatica Miki var. higoensis Miki	18.8±1.0	3775±11.0	18.8±0.1	65.3±2.3
Egeria densa Planch.	17.9±0.3	3612±1.0	19.5±0.2	50.6±4.0

[z]CP : Crude Protein, [y]GE : Gross Energy, [x]CA : Crude Ash, [w]IVDMD : *in vitro* Dry Matter Digestibility

Figure 1
New aquatic plants resource for feedstuff

H.R. to W.P. [z]	H.Yield	H.CP [y]	H.CA [x]	H.IVDMD [w]
Phragmites australis	*Phragmites australis*	*Phragmites australis*	*Nasturtium officinale*	*Polygonum thunberrgii*
Zizania latifolia	Zizania latifolia	Oenanthe javanica	Vallisneria asiatica	Oenanthe javanica
Paspalum distichum	Egeria densa	Nasturtium officinale	Egeria densa	Nasturtium officinale
Polygonum thunberrgii	Paspalum distichum	Myriophyllum aquaticum		Ranunculus kadzusensis
Myriophyllum aquaticum	Pontederia cordata	Ranunculus kadzusensis		
Egeria densa		Vallisneria asiatica		
Pontederia cordata		*Egeria densa*		

[z] H.R. to W.P. ; High Resistance to Water Pollution [y] H.CP ; High Crude Protein [x] H.CA ; High Crude Ash
[w] H.IVDMD ; High *in vitro* Dry Matter Digestibility

First selection	Emergent plant	:	*Phragmites australis* Zizania latifolia Paspalum distichum Oenanthe javanica Nasturtium officinale Myriophyllum aquaticum Pontederia cordata
	Submerged plant	:	*Vallisneria asiatica* Egeria densa
Second selection	Emergent plant	:	*Zizania latifolia* Pontederia cordata Paspalum distichum