PLANTS SUITABLE FOR CULTIVATION IN TEMPERATE WETLANDS - PALUDICULTURE

(with a grain of phantasy)

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Traditional economic use of wetlands:

From: H. Čížková et al.: INTECOL Wetlands Conference, Brazil, 2008

What kind of paludiculture are we going to deal with?

- **PALUDICULTURE *sensu lato* as CULTIVATION OF WETLAND CROPS in water-logged and/or shallowly flooded habitats, often with fluctuating water table.**

- **Accent on plants that can grow and (prospectively) can be cultivated in Europe, i.e., under temperate climatic conditions.**

Why wetland agriculture (paludiculture)?

- **Wetlands have always offered various plants suitable for human use.**

- **European agricultural land is often short of water which cannot be stored in the soil in view of ecological requirements of most temperate-zone crops (origin: dry regions). Mitigation of water shortage by paludiculture.**

- **Need for wetland crops whose cultivation is compatible with sustainable (wise) use of wetlands.**

Questions:

- Which wetland crops, including potential ones, do we know at present?
- What should be done to obtain both economically and ecologically feasilble crops for different wetland ecophases (*sensu* Hejný, 1957)?

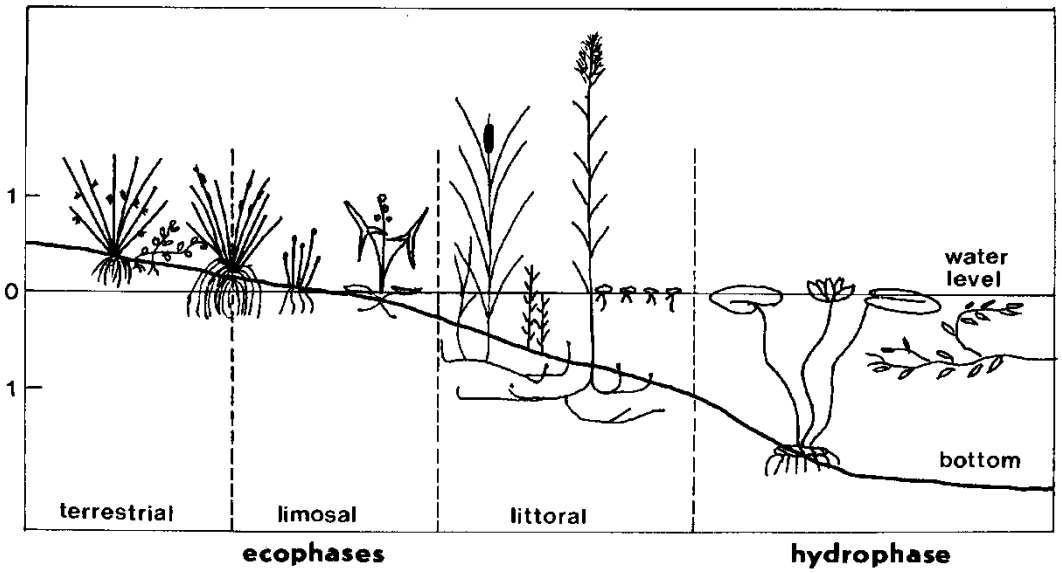


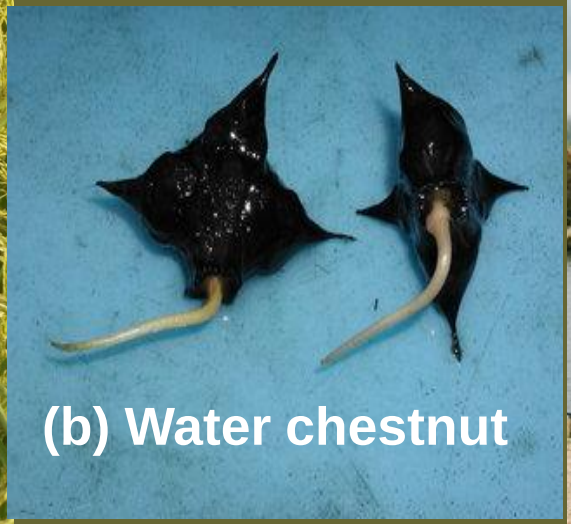
Fig. 1. Schematic illustration of ecophases in a fishpond littoral. *Vertical axis*: distance from actual water level in m

Drawing:
Š. Husák

Types of wetland crops

- (a) Cereal (grain) crops and tuber crops
- (b) Vegetables
- (c) Forage, technical and energy crops


(a) Rice


(b) Water chestnut


(c) Reed

(a) (POTENTIAL) WETLAND CEREAL and TUBER CROPS

Rice – world wetland crop no. 1

Salinity-tolerant paddy rice planting in S.E. Asia

(Photo: IRRI, Manila)

Rice – a predominantly wetland crop:

The world´s 2nd most important cereal crop!

Where is it cultivated?

over 90% of rice fields´ area in India, SE Asia, China (mostly "paddy rice"), Japan (often "upland rice"); other areas in Africa, America, Australia and Oceania and South Europe.

Highest grain yields (in expts.):

19 až 22 t.ha^{-1} (India and China)

Source: Wikipedia

Rice paddies in S.E. Asia

(Paddy rice, with the possibilty of polyculture)

Source: J. Pokorný
ENKI o.p.s.

Average annual rice production, areas harvested, and yields:

Country or region	**Production** (million tons) *	**Area harvested** (Million ha)	**Yield** (t/ha)
China	188.5	28.7	6.5
India	142.5	42.8	3.3
Indonesia	58.3	11.7	5.0
Bangladesh	42.5	10.9	3.9
Vietnam	36.0	7.5	4.8
Thailand	30.5	9.9	2.6
Myanmar	32.0	8.9	3.6
Philippines	17.5	4.6	3.8
Japan	10.9	1.7	6.4
Other Asian countries	35.8	10.9	3.3
Asia	594.5	137.6	4.3
Brazil	12.1		
World	597.8	155.0	3.9

Source: Ricepedia

Principal rice-producing countries (2018):

	10^6 ha	10^6 tons of paddy rice	
India	43.20	166.5	
China	30.35	210.3	
Indonesia	12.16	73.9	
Bangladesh	12.00	53.0	
Thailand	9.65	33.7	
Vietnam	7.66	42.8	
Myanmar	6.80	29.5	
Philippines	4.80	19.3	(Brazil 12.3)
Cambodia	2.90	10.4	(Japan 10.4)
Pakistan	2.70	11.1	

Source: FAO

Rice under temperate climatic conditions:

- Rice originates in tropical lowlands and requires a long, warm growing season.
- Also cultivated: California, S.E. USA, Mediterranean regions of Eurasia, lowlands of Bulgaria, Romania, Hungary, Moldova, S. Ukraine, S .Russia, Caucasus countries, Turkey, Central Asia, South Korea, Japan, etc.
- Nighttime temperatures above 15 ^{o}C (59^{o}F) for min. 3 months.
- Source: Haifa ¨

Paddy rice cultivation in northern Spain Photo: J. Květ

Rice cultivation in Europe I.:

- **Total rice-growing area in the EU: about 450.000 ha**
- **Average annual production: about 3.1 .10^6 t of paddy rice (0.4% of world production)**
- **Average annual rice imports: about 1.1. 10^6 t**
- **EU self-sufficiency in rice: about 70%.**
- **Rice restricted to a few southern European countries. Italy and Spain together 75 % of a total area of around 0.5 million hectares. Japonica rice varieties dominate.**
- **Planted in spring and harvested in autumn. All rice fields irrigated.**
- **Average yields per hectare between 4 and 8 tons. In some regions 10 tons.**

- Source: Ricepedia

Rice cultivation in Europe II.:

- **Acreage of Clearfield (long-grained) rice continuously growing.**
- **Irrigated rice = habitat for many organisms, e.g., migratory birds, biodiversity promotion in general.**
- **Greenhouse gas emission and heavy metals concentrations = problem of the past.**
- **Reduction of these problems: new cultivation methods , esp. reduced water consumption and new rice varieties.**
- Source: Ricepedia

Rice cultivation in Europe III.

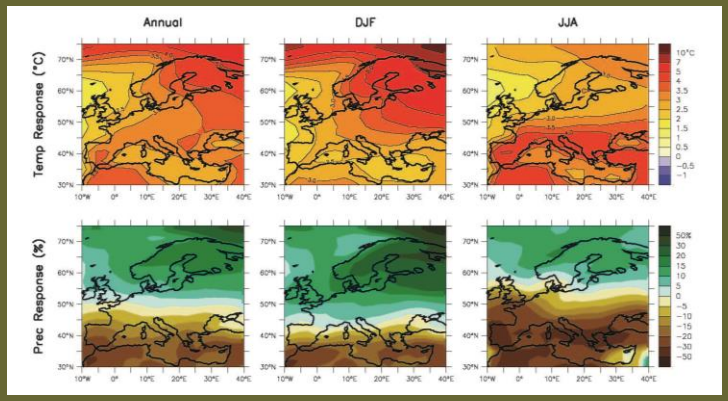
- **Insect pests: most frequent *Hydrellia griseola* (Diptera, leaf mining), *Chilo suppressalis* (Lepidoptera, stem boring), *Eysarcoris inconspicuus* (Hemiptera, leaves) and *Lissorhoptrus oryzophilus* (Coleoptera, root feeding).**

- **Fungus diseases: esp. *Magnaporthe grisea* (Sordariomycetes, grains), *Cochliobolus miyabeanus* (Ascomycetes, leaves) and *Gibberella fujikuroi* (Sordariomycetes, excessive extension growth).**

- **Weeds: Monocot weeds prevail, esp. *Echinochloa, Cyperus* and *Heteranthera.***

- **Numerous chemical and biological products registered for rice protection. But lack of product innovation.**

Rice and climate change in Europe



IPCC 2007

Climatic warming may shift limits to rice culture to higher latitudes/altitudes. Meso- or microclimate modification possible .

Rice culture - high evapotanspiration = high water demand (both paddy and upland rice). Longer dry periods – risk of water limitation = low yields

Coastal areas - salt water intrusion: salinity-tolerant rice varieties needed!

Source: Ricepedia

Genetic source for breeding a commercially feasible “rice“ for the temperate regions of N. America (and Eurasia?)

Zizania aquatica, Z. palustris. Z. texana – *N*. America*:* Wild rice, Northern r., Indian r.;

Z. latifolia – East Asia.

But: fragmenting of panicles!

Invasive?

Author: F. Ratzel

Photo: F. Virant

Indian rice - *Zizania palustris*

North America, Native Americans (Indians) have a monopoly for harvesting its caryopses (grains)!

Photo: Eli Sagor

Genetic source for breeding a “rice“ for cool regions of the temperate zone in Eurasia?

Cockspur (*Echinochloa crus-galli*)

Used as a substitute cereal in the middle ages

Source: Herbarium Wendys on Facebook

Wetland agriculture (paludiclure): Rice substitute for moderately warm regions of Eurasia?

Example of a potential crop: Cereal Cockspur or Cereal Millet

(Echinochloa crus-galli* subsp. *frumentacea)

Cereal cockspur or Ceral millet – *Echinochloa frumentacea* Link

Synonyms:

Echinochloa crus-galli subsp. edulis A.S. Hitchc.

Echinochloa crus-galli var. frumentacea (Link) W. Wight

Panicum frumentaceum Roxb., non Salisb.

Source: BioLib

“Cereal millet is sown mainly in E. India, where it is called “sawa“, and also in Japan, Africa and S. Europe. Its flour-rich caryopses are mainly eaten by the poorer classes in much the same way as we eat our millet.“ (F. Polívka, 1912)

Tuber crop: Chufa sedge, nut grass, yellow or tiger nuts edge, earth almond (*Cyperus esculentus*)

Native also to S. Europe. Winter-cold regions: grown in warm season, Overwintering: tubers survive soil temperature to -5 °C, but preferably stored in frost-free enironment. Photoperiods >14 h – no tuber formation.

High starch content, vitamins, oils.

Consumed: softened tubers, nuts, drinks.

(b) WETLAND VEGETABLES (examples)

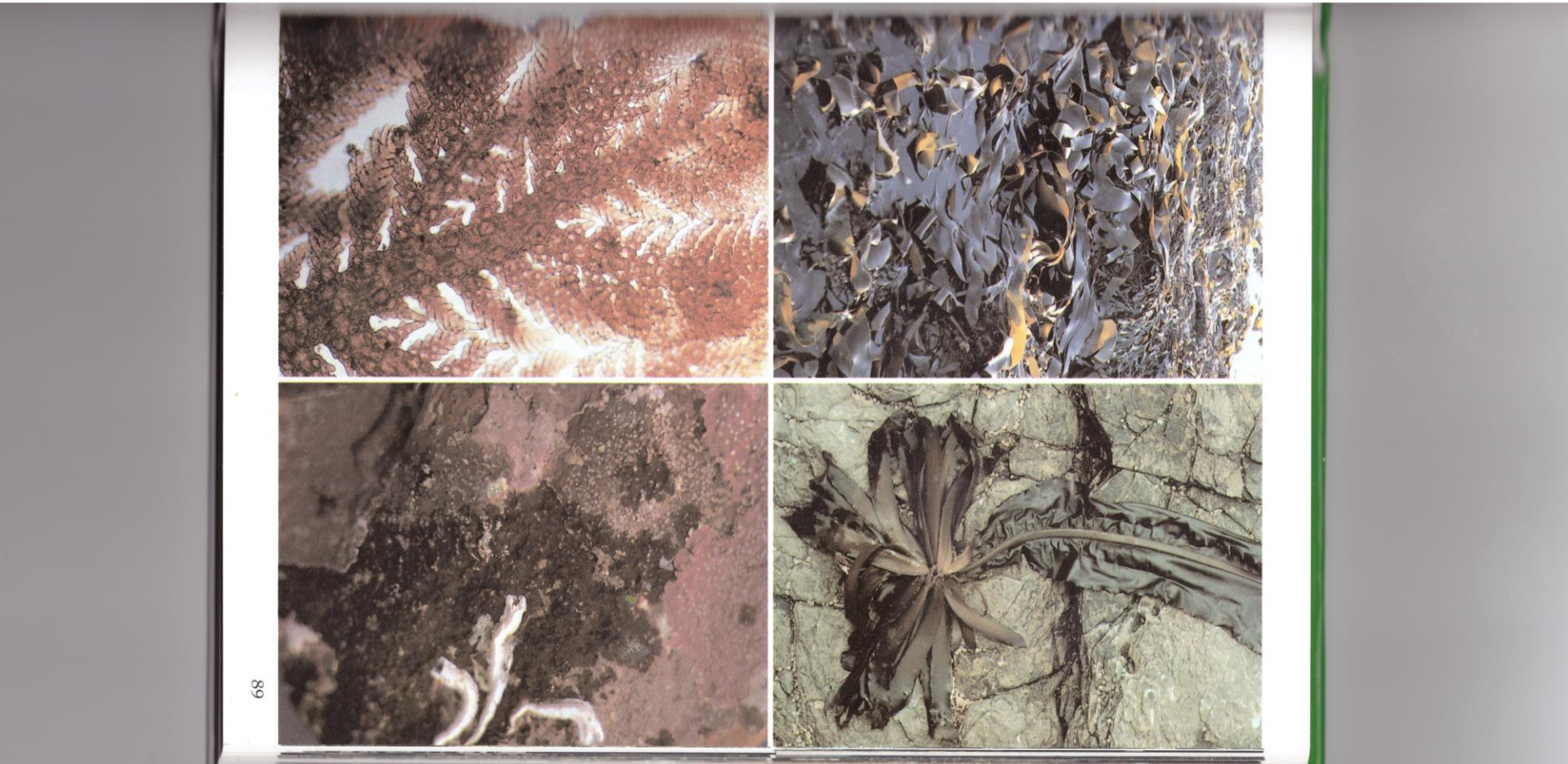
Special case: Floating gardens in Kashmir – Srinagar

under construction **complete**

Floating and semiemergent aquatic macrophytes as vegetables or forage crops

Classical example: Edible seaweeds (marine macroalgae)

From: Reichholf et al. (1999)



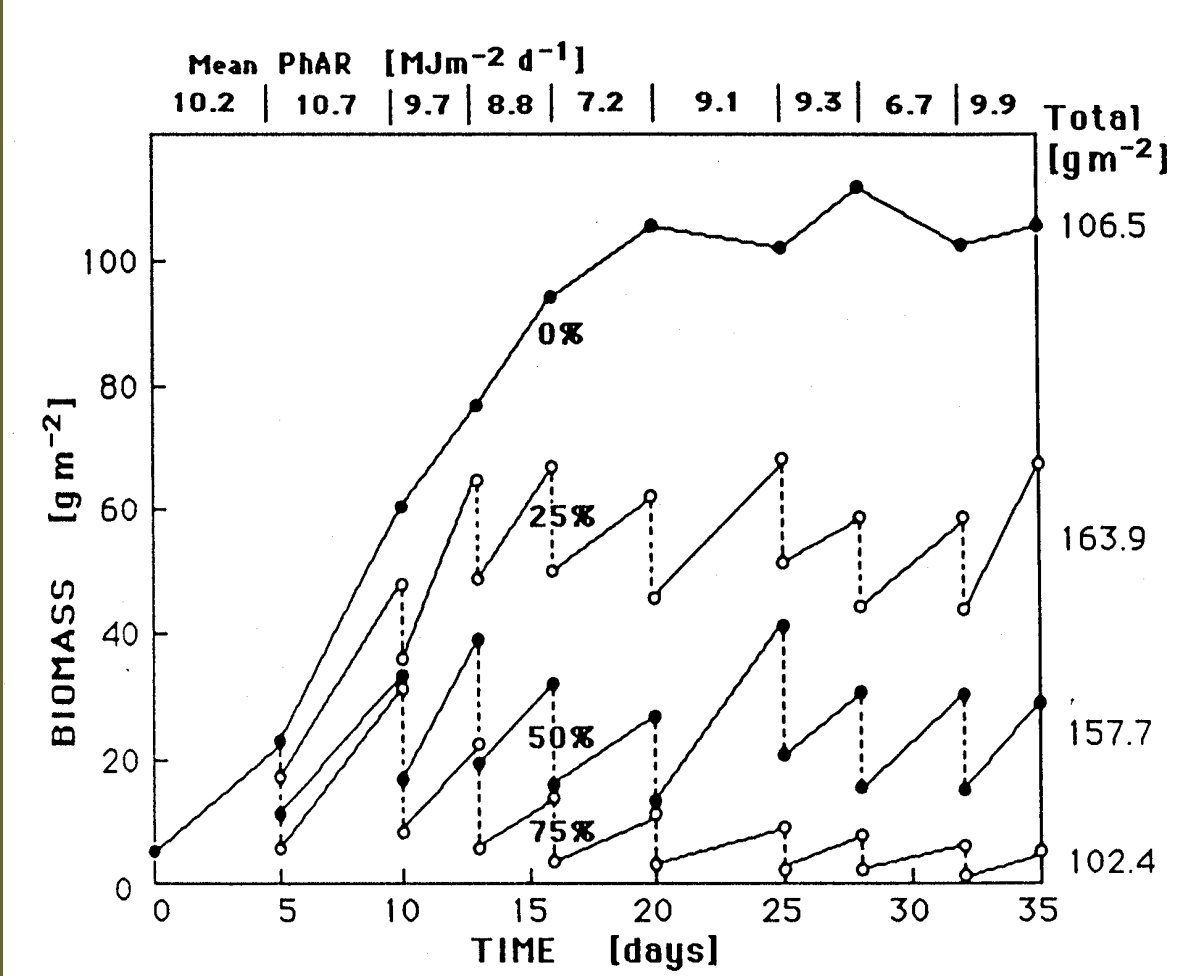
Duckweeds (*Lemnaceae,* now *Araceae*) – main uses:

- Feed, (maily for aquatic poultry, high protein content up to 5 % in dry mass).
- Temperate species survive winter (formation of turions);
- Source of vitamins – general supplementary feed;
- Composting;
- Nutrient removal from waste- and/or hypereutrophic water.

Photos: J. Květ

Optimization of duckweed harvest frequency

Experimental harvesting of 0, 25, 50 and 75% of the cover of great duckweed - *Lemna* (*Spirodela) polyrhiza* - at intervals of 3 to 5 days for a 35 days´ period affected the cumulative yield of duckweed biomass (dry mass).



Total yields:

25%: 163.9 g.m^{-2} =optimum

50%: 157.7 g.m^{-2}

75%: 102.4 g.m^{-2}

0%: 106.5 g.m^{-2}

Values at the top: daily average amounts of incoming PhAR (photosynthetically active radiation).

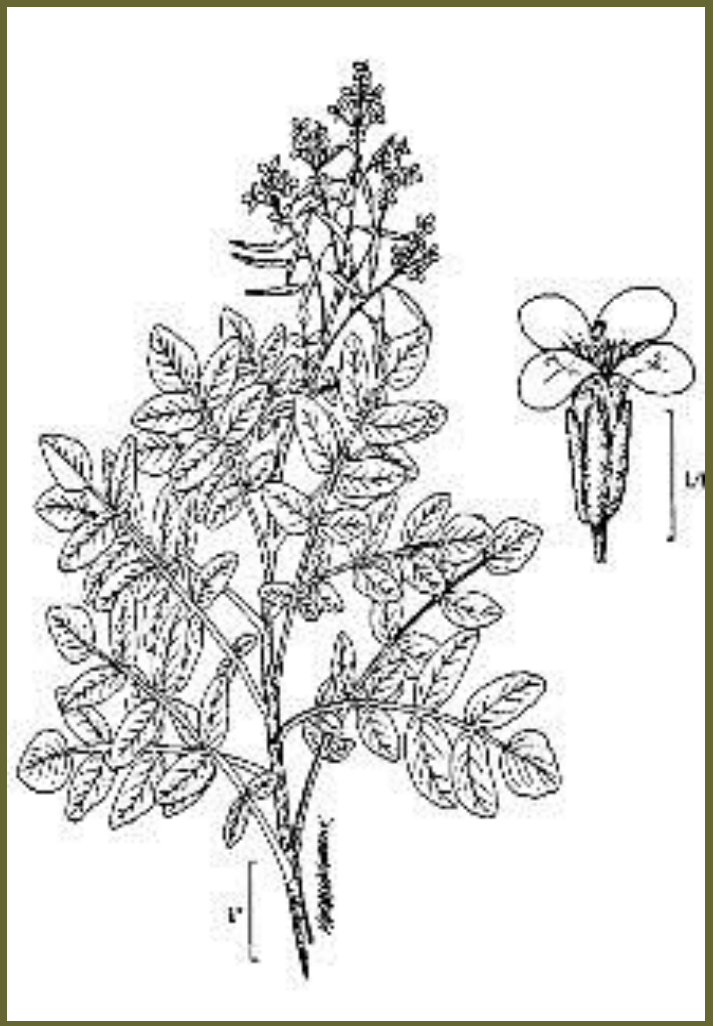
Rejmánková et al. (1990)

Water chestnut (*Trapa natans*)

Annual plant; nuts without their hard pericarp are edible; archeological evidence; now a luxury delicatessen food.

Sources: Wikipedia, photos: Š. Husák, J. Květ

Water cress (*Nasturtium officinale*
(many synonyms)



Vegetable, medical plant , rarely cultivated in the C.R.. Popular in W. Europe (esp. UK). Protected in the C.R., elsewhere it can be invasive. Requires clean running water.

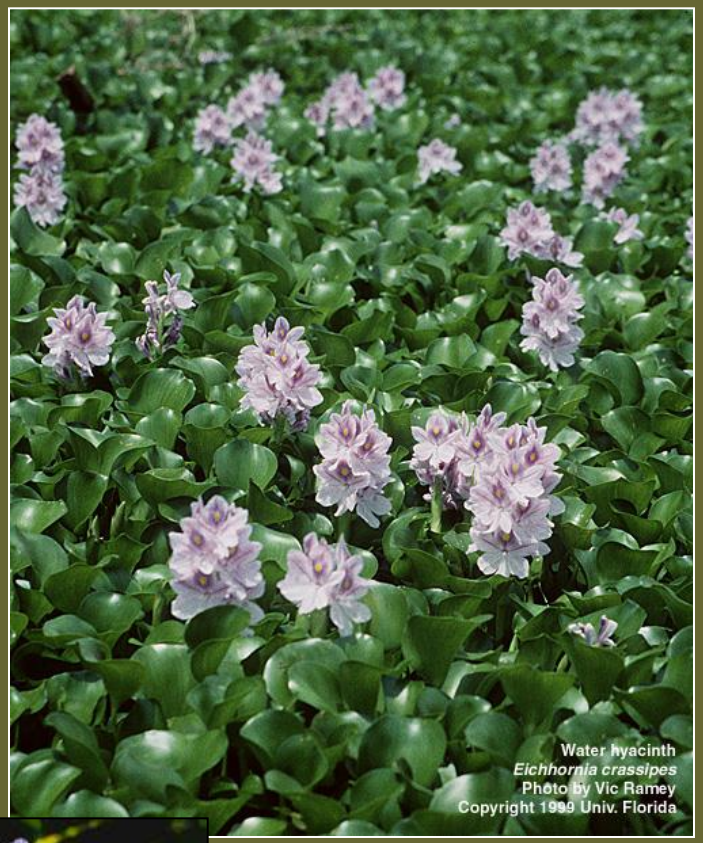
Source: USDA Plant Profile

Source: Invasive.org

Source: Příroda.cz

Water hyacinth - *Eichhornia crassipes*

Aquatic weed, fodder crop, energy crop.
Plant suitable for wastewater treatment.
Outdoor cultivation: May to September.



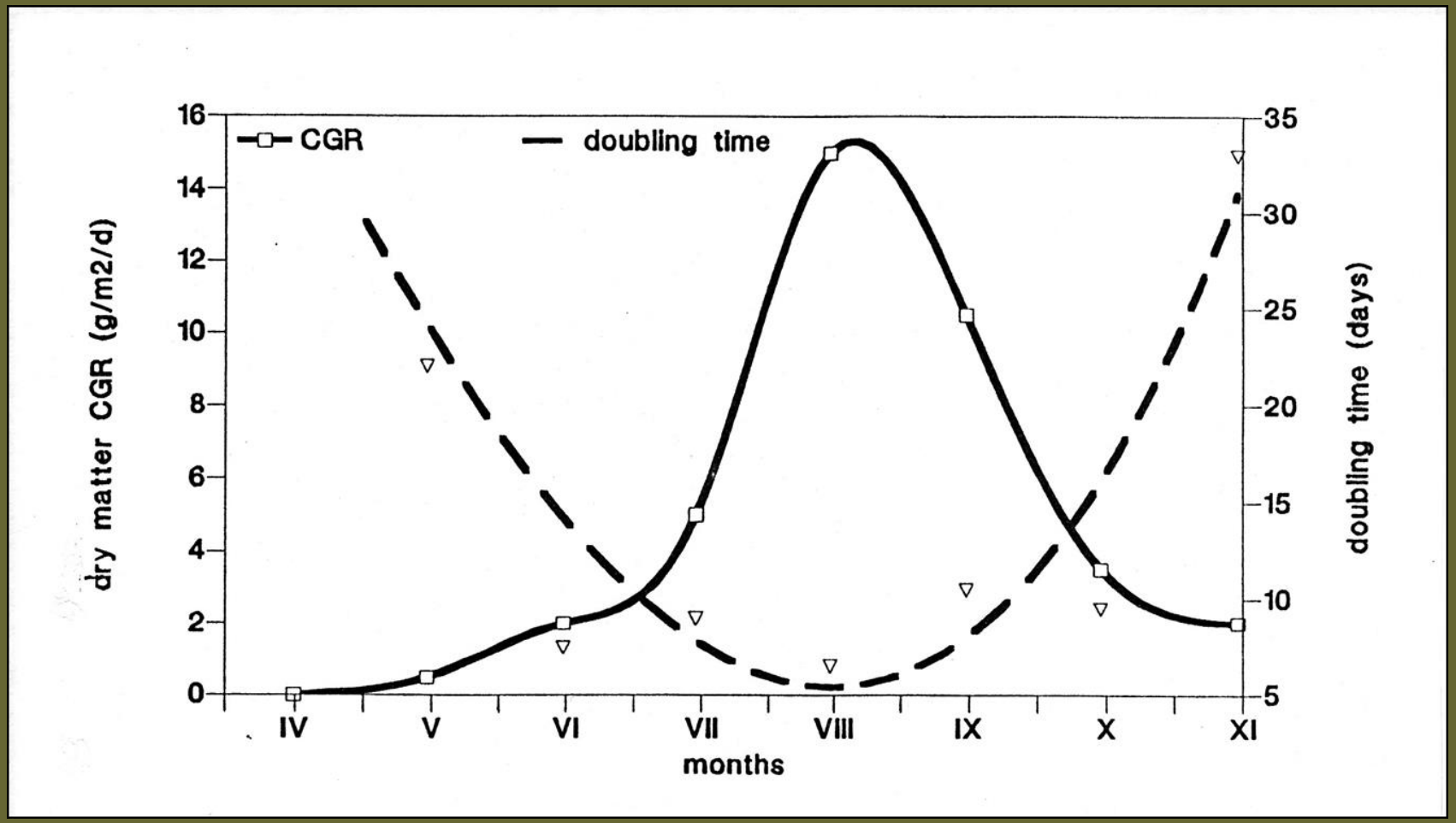
At present its cultivation and spreading forbidden in the EU countries (even those with regular winter frosts).

Source: University of Florida, Gainsville

Comparison: water lettuce (*Pistia stratiotes)* and water hyacinth *(Eichhornia crassipes)* in biologically treated municipal wastewater (Brno, CZ, 1986)

From: Z. Žáková, 2014

Growth characteristics of water hyacinth in biologically treated municipal wastewater (wastewater tratment plant, Brno, CZ, 1986)



CGR – crop growth rate ($g.m^{-2}.d^{-1}$)

From: Z. Žáková 2014

(c) WETLAND FORAGE, TECHNICAL AND ENERGY CROPS

Vegetation of wet grassland – source of (a) fodder; (b) raw materials; (c) energy.

Photo:
J. Pokorný

Forage or energy crop: Reed canary grass (*Phalaris arundinacea*), Břehov root-zone treatment plant

Photos: J. Vymazal

Wetland forage and technical crops.

Example: Phenology and use of wet grassland (near Třeboň, CZ), dominated by *Phalaris arundinacea*

Most suitable phase for harvesting quality forage

Most suitable phase for harvest of energy crop (for burning as biogas)

From:
H. Čížková et al.

Lužnice River floodplain near Třeboň

with extensive stands of *Phalaris arundinacea*

Photo: D. Pithart

Aboveground dry matter production ($g.m^{-2}.year^{-1}$) in alluvial meadows with dominant reed canarygrass (8.4) or foxtail (8.5.) in the Lužnice River floodpla

Table 8.4. Harvestable aboveground biomass and protein production (dry weight, $g \cdot m^{-2}$) in a grassland community dominated by *Phalaris arundinacea* in the Lužnice floodplain in 1986 and 1987. (After Tetter *et al.* 1988).

	Year:	1985	1986
1.	Live biomass production of:		
	a) Monocotyledons	1159.2	644.7
	b) Dicotyledons	99.9	–
	c) Total (= 1a + 1b)	1259.1	644.7
2.	Digestible protein in 1c	70.3	43.9
3.	Standing dead material + current year's litter	487.7	676.0
4.	Maximum estimate of net production (= 1 + 3)	1746.9	1320.7

Table 8.5. Harvestable aboveground biomass and protein production (dry weight, $g \cdot m^{-2}$) in three grassland communities dominated by *Alopecurus pratensis* in the Lužnice floodplain in 1986 and 1987. (After Tetter *et al.* 1988).

	Site:	I		I		III	
	Year:	1986	1987	1986	1987	1986	1987
1.	Live biomass production of:						
	a) Monocotyledons	883.0	988.6	809.0	849.4	1181.6	1430.4
	b) Dicotyledons	38.0	10.0	89.3	143.0	51.7	95.0
	c) Total (= 1a + 1b)	921.0	998.6	898.3	992.4	1233.3	1525.4
2.	Digestible protein in 1c	90.0	57.3	108.4	54.9	79.7	114.2
3.	Standing dead material + current year's litter	128.8	71.0	140.4	70.3	98.4	70.0
4.	Maximum estimate of net production (= 1 + 3)	1049.8	1059.6	1038.7	1062.7	1331.7	1595.4

From: Květ et al. 1996

Common reed (*Phragmites australis*)

Manifold use:

Technical: thatching, construction materials, energy yield – burning of biogas, etc.

Amelioration: land formation/reclamation, shore-erosion control

Wild growing: wildlife value – feed, shelter, nest-building

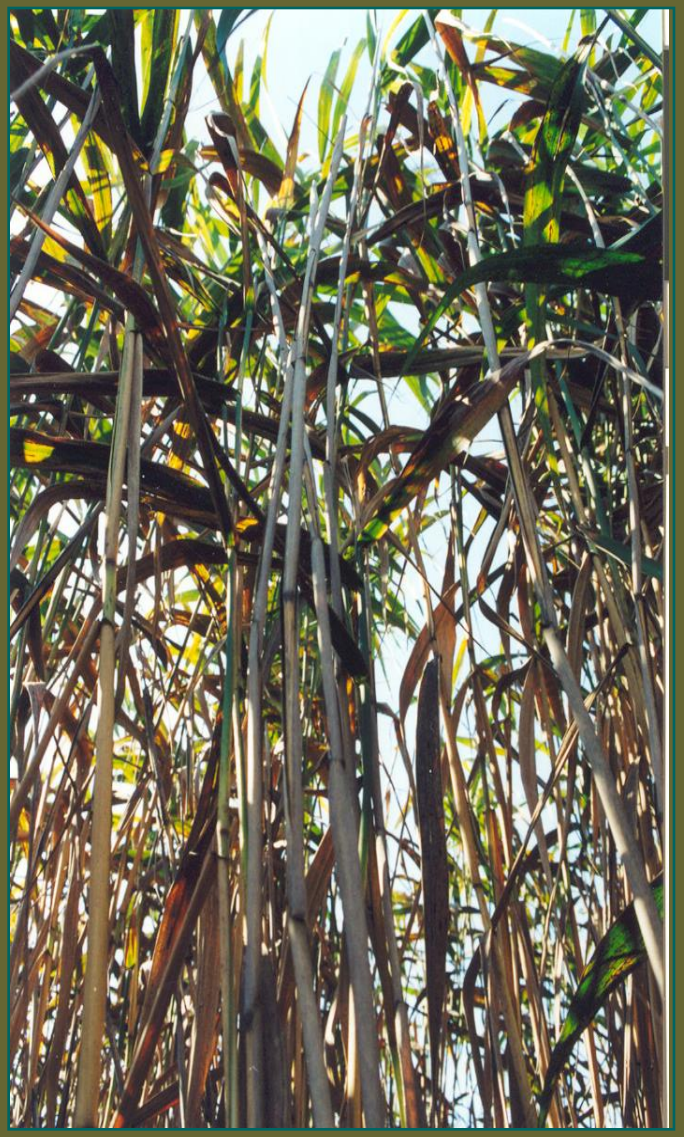


Photo: H. Čížková

Common reed *(Phragmites australis)*

technical, energy and amelioration crop/wild growing plant

Photo J. Dušek: Slavošovice root-zone treatment plant

Paludiculture in acidic habitats: *Sphagnum* spp. cultivation

- N. Germany
- Canada
- United Kingdom

Author: H. Čížková at: Conference “Climate Formation for the Future“, Liberec, CZ, 26.-27.1.2016

Continuous mass cultivation of unicellular green algae

Example: Cascade cultivation unit with forced re-circulation of the algal suspension *(Chlorella)*

Inst. of Microbiology Czech Ac. Sci., Třeboň. Photo: M.A. Borowitzka
BEAM - Australian Algae Research Network

Use of algal biomass:

Human food,
Animal feed (high protein content)
Biologically active substances for pharmaceutical industry
Biosyntheses

Main conclusions I:

- Wetlands and shallow waters traditionally offer various actual or potential plant products.

- Necessity to develop energetically and economically effective cultivation techniques compatible with the conservation and/or sustainable (wise) use of wetland habitats, acceptable to stakeholders responsible for land use and/or its agricultural management.

Main conclusions II:

- **Cold-tolerant genotypes of both upland and paddy rice needed for wetland cereal paludiculture in temperate regions getting warmer due to climate change.**

- **Need to breed ecologically + economically feasible wetland crops on the basis of prospective wild-growing wetland plants. Gene manipulation can help?**

- **A temperate “rice“desirable for promoting water conservation in agricultural regions.**

Wetlands returning spontaneopusly to waterlogged or inundated agricultural land.

Feasibility? Pros and contras!

Source: Internet, origin unknown,

Thank you for your attention!
Questions and remarks?

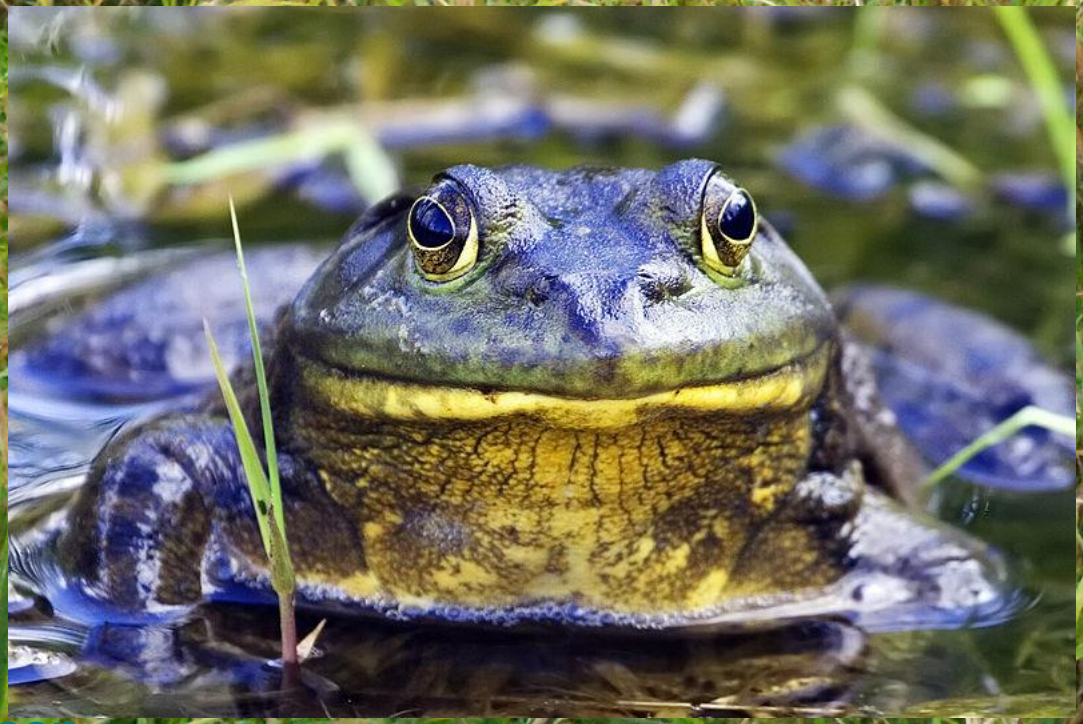


Foto N.O. Anderson

Photos: N.A. Anderson and J. Ševčík


Enjoy the rest of the Workshop!
Photo: J. Ševčík
Rožmberk Fishpond (almost 500 ha),
September 2008
WWW.ZE-VZDUCHU.CZ