Ecophysiology of Mineral Nutrition of Carnivorous Plants

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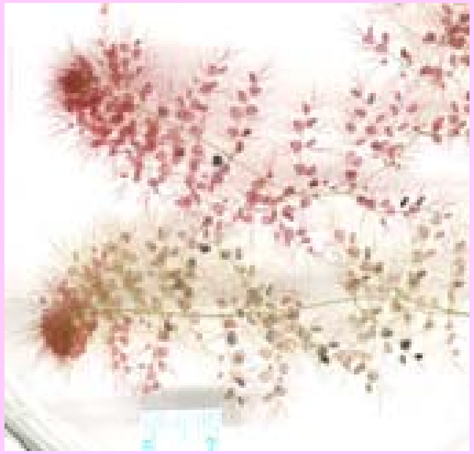


AIMS OF THE LECTURE

To elucidate the principal characteristics of mineral nutrient cycling in carnivorous plants (CPs) from an ecophysiological point of view:

- what is the relative importance of foliar and root nutrition of CPs?
- what is the importance of carnivory under natural conditions?
- which nutrients (elements) from prey bodies are of principal importance for growth?
- what is the efficiency of mineral nutrient uptake from prey bodies and of mineral nutrient re-utilization in senescent shoots?
- stimulation of root nutrient uptake by foliar nutrient uptake: explanation?

Criteria for Carnivorous Plants

Over 650 species of CPs, from a total of about 300,000 species of vascular plants.

- **catching or trapping of prey (traps)**
- **absorption of metabolites from prey**
- **utilization of these metabolites in their growth and development.**

(criteria as prey attraction and production of own digestive enzymes are not principal)

HOLOCARNIVORY (e.g**.,** *Drosera, Dionaea, Utricularia, Nepenthes, Sarracenia, etc.*)

***vs*. HEMICARNIVORY (e.g., *Brocchinia, Heliamphora, Roridula*, etc.)**

Ecological Factors in Terrestrial Habitats of Carnivorous Plants

- wet bog and fen organic soils
- soil hypoxia or anoxia, low redox potential, phytotoxins, high Fe^{2+} and Mn^{2+}
- mostly acid soils (pH 3-6)
- low available mineral nutrient content in soils
- high air humidity

Ecophysiological Characteristics of Terrestrial Carnivorous Plants

CPs are adapted to both **low nutrient availability** and **anoxia** in soils.

- S-strategy
- slow growth (T_2: 38-69 d)
- efficient mineral nutrient economy in plants (N, P, K re-utilization)
- a weakly developed root system (root:total biomass ratio: only 3.4 - 23 %)
  - weakly branched and short roots
  - easy regeneration of new roots
  - aeration mechanism and exodermal barriers – main anatomical adaptations
  - great metabolic and physiological activity of roots per unit biomass (respiration, water exudation)

➔ **roots are very important for CPs**

Carnivory is only **one of many possible adaptation strategies to unfavourable conditions.**

Mineral Nutrition of Carnivorous Plants

- about 50 species of CPs and 60 studies since the 1950s
- mostly the level of growth experiments: feeding on prey and/or substrate fertilization, accumulation of biomass and mineral nutrients, natural catch of prey
- animals (prey) are a rich source of **N** and **P**, but a poor source of **K**, **Ca**, **Mg**
- similar mineral composition of CPs as that in non-CPs

Macronutrient composition of some CPs. Mean values in % (DW).
A, terrestrial species; **B**, aquatic species.

Species	Organ	**N**	**P**	**K**	**Ca**	**Mg**
A. *Drosera rotundifolia*	whole plant	1.2	0.08	1.0	0.1	0.28
Pinguicula vulgaris	-“-	0.7	0.07	0.25	--	--
Sarracenia flava	leaf	0.9	0.06	0.8	0.14	0.19
B. *Aldrovanda vesicul.*	young shoot	1.0	0.30	2.1	0.32	0.21
Utricularia vulgaris	shoot	2.5	0.19	1.7	1.5	0.53

Mineral Nutrition of Carnivorous Plants under Greenhouse Conditions

- considerable simplification of the ecological factors (e.g., lack of competition)
- results reflect the potential abilities of CPs to take up nutrients through roots or leaves and to regulate these processes, rather than plant responses in natural habitats or the ecological importance of carnivory

- all CPs tested can grow **without** any feeding or soil fertilization on natural soils
- utilization of **mineral nutrients** from prey (mainly **N** and **P**) is of a primary importance
- **three groups of CPs** according to their ability to produce new biomass and accumulate mineral nutrients on the account of nutrients which could be taken up by **roots** and **leaves**:

  ”nutrient-requiring species” (high nutrient uptake by roots and leaves)

  ”root-leaf nutrient competitors” (low nutrient uptake by roots and leaves, competition)

  ”nutrient-modest species” (low nutrient uptake capacity by roots, mainly foliar uptake)

- **high efficiency** of utilization of leaf-supplied nutrients for plant nutrient accumulation
- the leaf (and/or soil) nutrient supply may lead to **stimulation of nutrient uptake by roots**
- efficient **re-utilization** of mineral nutrients in senescent organs
- **tissue nutrient content** is an unreliable measure of nutrient uptake by CPs
- growth of CPs can be covered by nutrients coming from only one source

Mineral Nutrition of Terrestrial Carnivorous Plants in Natural Habitats

- includes competition, mortality, **robbing** of prey by opportunistic predators (kleptobionts, kleptoparasites), **washing out** by rains
- usually manipulation with prey and soil nutrient availability, **seasonal catch of prey**
- the experiments show the **ecological importance of carnivory** (incl. the benefit, cost, and limitations) for natural growth and development, **seasonal nutrient gain** (% from prey)

- CPs can utilize much **more prey to promote growth** than they really catch (great
- capacity of utilization of prey); quantity of caught prey is mostly a major factor for the CPs' vigour
- seasonal catch of prey is **greatly variable** (>10x) among individuals, sites, and species
- catching of prey is much more important for seedlings than for big adult plants: it leads to faster **growth** and earlier **maturity** ➔ abundant **flowering** and **seed set**
- CPs can take up a **great % of their seasonal gain** of **N** (**7-100** %) and **P** (**6-100** %) from carnivory, but only a **small proportion** of their **K** (**1-16** %), and perhaps also **Ca** and **Mg** ➔ dominant uptake of these cations by roots

Mean **seasonal nutrient gain** covered from carnivory (%)

Species	**N**	**P**	**K**
P. vulgaris	26-40	36	7-16
P. alpina	8-14	12-19	1.3-1.9
P. villosa	7-15	6-10	3-12
D. rotundifolia	63	95	1.1
D. intermedia	92	100	1.6
D. erythrorhiza	11-17	--	--
-"-	100	100	2-3

Efficiency of Nutrient Absorption from Prey

Efficiency of nutrient absorption from fruit flies and mosquitoes (**%** of total content)

Species	Element	Fruit flies	Mosquito	Ref.
D. capensis	**N**	43-62	44	*1*
D. capillaris	**P**	90-97	61	
	K	60-96	94	
	Ca	-11- -206	58	
	Mg	57-77	92	
D. erythrorhiza	**N**	76	--	*2*
3 ***Pinguicula*** sp.	**N**	39-50	--	*3*
D. rotundifolia		(greenhouse)		
-"-	**N**	29-42	--	*3*
		(field)		

1, Adamec (2002); *2*, Dixon et al. (1980), *3*, Hanslin and Karlsson (1996)

Re-utilization of Mineral Nutrients in Senescent Organs

- efficient **re-utilization of mineral nutrients** (**N, P, K**) in senescent organs of CPs (differences among CP species)
- comparison with **bog** and **fen plant species**: **CPs** are on average by **25** % (**N**) and **20-25** % (**P**) more efficient

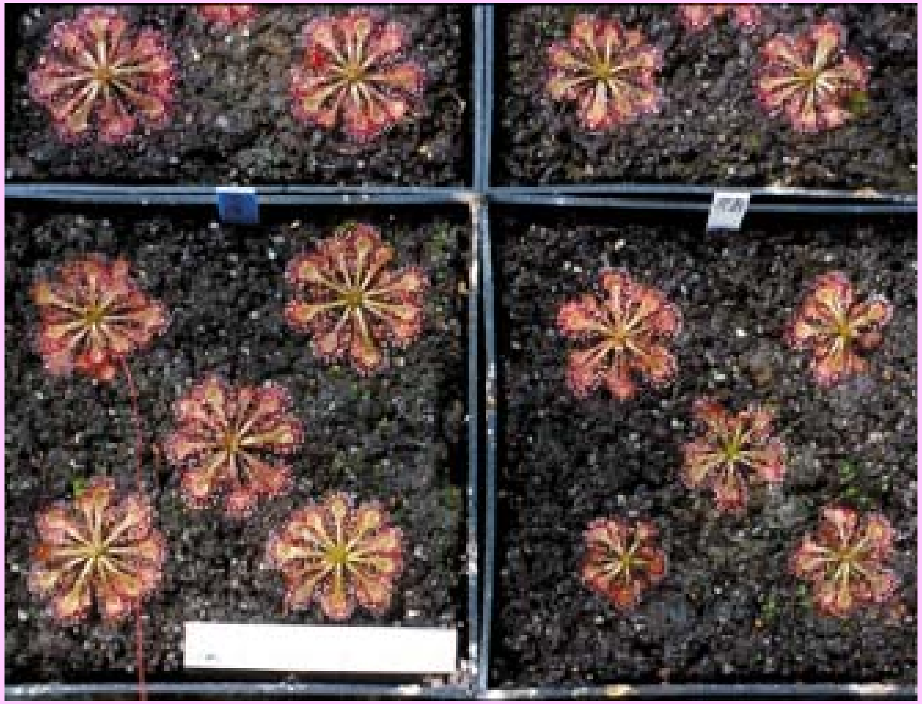
Mineral **nutrient re-utilizatio**n in CPs (% of initial content)

Species	Organ	N	P	K	Ca	Mg	Ref.
3 ***Drosera*** sp. +***Dionaea musc.***	Leaf	70-82	51-92	41-99	-31- -187	33- -75	*1*
D. erythrorhiza	Leaf	79	88	56	25	63	*2*
-"-	Tuber	95	98	99	-56	83	*2*
D. erythrorhiza	Leaf	94	--	--	--	--	*3*
-"-	Stem	99	--	--	--	--	*3*
3 ***Pinguicula*** sp.	Shoot	58-97	--	--	--	--	*4*
D. rotundifolia	Shoot	81	--	--	--	--	*4*
Sarracenia purp.	Leaf	56	75	89	--	--	*5*

1, Adamec (2002); *2*, Pate and Dixon (1978); *3*, Dixon et al. (1980);
4, Hanslin and Karlsson (1996); *5*, Small (1972)

Stimulation of Root Mineral Nutrient Uptake by Foliar Nutrient Uptake

- confirmed in about 10 CP species so far, both in greenhouse and the field
- the effect is mediated by **foliar** or also **root** uptake of **mineral nutrients** (**P**; which other nutrients ?)
- tissue nutrient content is not important (it may not be increased)
- the effect is of a **quantitative** character as dependent on quantity of extra prey
- the **efficiency** of foliar nutrient supply for nutrient **acummulation** may vary within: **N**, 1.6-14; **P**, 4-16; **K**, 21-27; **Ca**, 5.4-8.7; **Mg**, 6.4-13 (3 *Drosera* sp., *Pinguicula*)
- possible explanation of the effect in 3 *Drosera* sp.:
  - increased **root biomass** (*ca.* 70-85 % of the effect)
  - increased **root length** (*ca.* 17 % of the effect)
  - increased **root uptake rate** per unit biomass (*ca.* 15-30 % of the effect)
  - increased **root respiration rate** (0 % of the effect)



Conclusion

German physiologist K. Goebel (1893):

'Carnivory is useful for plants but it is not indispensable.'

Recent generalization:

‘Carnivory is not indispensable for greenhouse growing CPs, but it is almost indispensable for CPs in natural habitats.‘