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DEALING WITH HALOPHYTES: AN OLD PROBLEM, THE SAME CONTINUOUS EXCITING CHALLENGE

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Abstract: It's common sense to usually recognize some concepts as being very simple and accessible. Often, this could lead to a reductionist way in which some problems are regarded and understood. In plant ecology, many concepts are volatile and in nowadays we are using some of them mainly as standard definitions. But in the nature, there are no standards. Only a continuum flux of energy and stable instability that would imply caution and attention in the interpretation of ecological groups of plants. In this work we try to sensitize and pay attention to the complexity of some concepts in plant ecology, and to focus on halophytes, as an example of our intention.
Key words: halophytes, plant ecology, complexity, salinization.

Introduction

Despite have certainly been recognized since the time of Goethe (ca. 1790, cf. [19]), halophytes were taken into scientific attention through the papers of Schimper [49; 50] and especially Warming [58; 59; 60; 61]. But despite the fact that halophytes have been recognized for hundreds of years, their definition remains equivocal [20]. There were a lot of halophytes' definitions; some of them reflect the scientific background of the researchers who define these plants. In the same time, we can notice a "historical" evolution regarding the halophytes, taking into account the accumulated data in their biology.

Why it's so difficult to define such a "simple" term?

The definition of halophytes is manifold. This fact can be explained, however, by the following considerations:

Halophytes represent in fact a heterogeneous ecological group of plants; not only the high salinity represented the single factor "building" the history of these plants during the evolution, but here were also several additional ecological factors that contributed to this. So, describing halophytes only in relation to salinity could be reductionist. Researchers working in various aspects on halophytes actually have adopted them unilaterally. This is, of course, natural if we think about their "professional" expertise in the field of halophytes. Here seems logical that an approach following one single criterion often leads to acceptance and internalization of a single standard-definition, which scientists have taken into account in their research. This is one of the reasons explaining that each author has given a specific definition of halophytes. A definition which had a personal "signature" in the respective context and also preserved after several decades;

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b. The concept of salinity himself and hence those terms related to saline habitats are also subjected to the relativity and even ambiguity. We have to note that the term *salinity* it is not, *per se*, a biological one; thus the scenario could become complicate, when adopted by other Earth science. Ecologically speaking, we think that halophytes must be considered all species which vegetate in saline habitats [23; 24; 26; 27]. This definition seems simple and accessible but only at first side, because the saline habitats are again imprecisely defined;

c. As the knowledge about halophytes has been progressively accumulated, the directions of research have been expanded and deepened accordingly. At the beginnings the attention was focused on their ecology and distribution. This quite simple interest was based mainly on intuition, allowing thus that some correlations with morpho-anatomical adaptations to be done. But gradually, many aspects focused on physiology, salt tolerance, cellular and molecular biology or genetics were revealed. This new context has not provided the "ideal" premises which would have lead to a convergence in unifying the halophytes definition. Moreover, the degree of spread in this way has amplified. Sometimes, in sciences, new discoveries deepened the old findings, which provide a "good" opportunity to open new challenges;

d. Another problem arises from the fact that there is a semantic field related to halophytes (especially regarding their classification). This filed is composed by different terms, formulated by different authors; but sometimes these terms are more or less synonymous with each other. Some previous terms were adopted by further researchers and in this way the "new" terminology does not implies a new clarification in the language referring on halophytes. Our work in the survey of an extended literature dealing with halophytes suggests that often the tendency to synonymize or traducing a term from a language in a different one leads to "dilution" of main sense of a term.

Conceivably, in several situations, the impossibility of traducing a single term from a language also by a single term in another, forced the researcher to find, for translation, a syntagm comprising more than one term. In this way, we can talk about a "historical" evolution of a language related to halophytes terminology. In the Table I, we can notice some examples of semantic fields occurring in English and Romanian languages.

For instance, some authors tried to translate the term *halophytes* (the simplest and following the old Greek etymology) by *salt tolerant plants*. It is obvious that according to the great majority of definitions, all halophytes are salt tolerant plants, but we must understand that also many *glycophytes* have some mechanisms assuring them a certain degree of tolerance (or resistance) to salinity. In addition, using a term such as *high salinity tolerant plants* conduct inevitably, to the context in which the author must to guess what high salinity tolerance could mean.

Table I: Semantic field with words related to halophytes (after Grigore, [25])

Romanian	English
Halofite; plante de sărătură; plante halofile; plante iubitoare de săruri; plante de locuri sărate.	Halophytes; salt tolerant plants; salt plants; high salinity tolerant plants; salt loving plants; halophylous plants; halophytic plants; maritime plants

e. Not in the last, we must say that here are some difficulties working in experimental conditions, when efforts for establishing salt tolerance thresholds are carried out. The experimental scheme never reproduces completely the natural conditions, where the environmental factors are always variable. The intensity and variability of these factors are less predictable; in the lab, we can choose the intensity of salinity we want to test, but in the natural ecosystem, the salinity and hydric status of the soil are not constant.

One of the most important attribute of halophytes is their salinity tolerance. This property of halophytes seems to offer for euhalophytes real advantages for the competition with sensitive plants (glycophytes) [33]. Unfortunately, the many available definitions especially for *salinity tolerance* (threshold of salinity tolerance) complicate a uniform description and the comparisons between species [33]. This is because:

a. Phytosociologists are using this term only for plant growing naturally in saline habitats. In the field, phytosociologists need to get quick information on salinity tolerance; the vegetation analysis is very useful and salinity tolerance numbers are widely applied for qualitative approximations [16].

b. Another scientists describe salinity tolerance with polygonal diagrams of the mineral composition in the plants;

c. The threshold level of salinity tolerance is described in some definitions as the point (salt concentration) when the ability of plants to survive and to reproduce is no longer assured [43]. Anyway, attention should be paid on the fact that survival and reproduction of a plant are not always impeded in the same level of salinity [54]. However, the definition of Pasternak [43] is rather important for the interpretation of ecological dissemination and can be used as a reliable basis for physiological studies regarding the survival strategies of plants;

d. Generally, classification of the salinity tolerance of crop species (glycophytes) is based on the threshold of electrical conductivity and the percentage of yield decrease beyond threshold [22]. Often, salinity tolerance is assessed as the percentage of biomass production in saline versus control conditions over a prolonged period of time [40]. The substrate-concentration leading to a growth decrease of 50 % (in the terms of fresh weight, in comparison to plants without salinity) is largely used by ecophysiologists as a definition for the threshold of salinity tolerance. This approach is also arbitrary, in some extent, but it leads to a precise specification of a comparative value for halophytic species and is especially expressive for applied aspects such as economic potentials of suitable halophytes;

e. One definition can be also given referring on glycophytes; especially in agriculture it is very common to speak about salinity tolerance if a variety of a glycophytes, such as *Hordeum vulgare* survives at a higher salinity level than another variety of the same species. But the tolerated NaCl-substrate concentrations are in both varieties far beyond seawater salinity [2; 31].

A short historical evolution of Halophytes definition

Since the definition of halophytes is still obscure and since the existing definitions are manifold, we tried to summarize some of these in the Table II, following a chronological order.

Table II: A chronological list of halophytes definition

Definition or descriptions related to halophytes	References	Comments
A plant containing a large quantity of common salt in its composition, and which thrives best in salty places	[12]	Despite its earlier character, this definition is interesting because suggest the capacity of halophytes to accumulate salt in higher amounts. Nowadays, we know that here is a group of halophytes accumulating salts, in contrast with those secreting it
Salt –loving plants (are in the most of their characters, strikingly similar to the xerophytes)	[4]	Many plant ecologists consider halophytes a particular case of a xerophytes (see further comments in this table)
Species of saline and alkaline soils (salt plants)	[10]	Saline and/or alkaline soils are more precise than other words designating saline environments
A certain amount of soluble salts must be present before halophytic vegetation is called into existence	[61]	How precise the term "certain" could be?
Plants which grow where the water contains salt; the effect upon them is seen in their fleshy habit	[5]	In fact, always the soil solution contains "salt"; the problem is about concentration. Not all halophytes display fleshy tissue
Strand plants, or Halophytes, living along the margin of salt water, and therefore condensed and otherwise adapted to the difficult absorption thereof	[21]	We must discriminate that not all halophytes are strand plants; they could appear also in the inland salt marshes
Halo-philous/phytes, plants of sea-coasts and salt-steppes, where the presence of salt, by checking absorption, compels a reduction of transpiration	[63]	Here we can notice the introduction of "physiological drought" hypothesis, affecting the saline soils. This is "famous" for a certain period of plant ecology (see Grigore and Toma, 2010a)
Plants which at any stage of their life are subjected to a	[53]	The salt concept is ambiguous one (see above

concentration of salt, which is more than "normal" glycophytic plants can bear without dying		extended discussions). It's difficult to well establish if the plants are exposed all the time to salt, in any stage of their life-cycle
Salt plants; Typical halophytes; true halophytes; *absolute halophytes**; the obligate halophytes are plants which for their normal development need certain ions of the alkali metals and halogens, and which, therefore, can exist and bear seed only in soils containing salt	[6]	A good definition of obligate halophytes; * this is the single place when this syntagm was found (!)
Plants that grow in saline soil or in salty water are called halophytes and they are strikingly xeric	[38]	A interesting definition stated that halophytes are a peculiar case of xerophytes (for large comments, see Grigore and Toma, 2010a)
All plants that are capable of growing in an environment where there is more than 0.5 per cent sodium chloride	[8]	Chapman's comments: "its (definition, n.n.) use will not imply that the species is either common or rare in such habitats nor will the term involve the assumption that a plant cannot grow under any other conditions". The salinity is a very changeable ecological factor: choosing a number for drawing a line between two different plant groups could be hazardous
Plants that can tolerate the concentrations of salts found in saline soils are termed halophytes	[42]	This is an accessible definition of halophytes
Plants tolerant of various mineral salt in the soil solution, usually sodium chloride	[36]	Actually, the soil solution also contains other salts, in addition to sodium chloride
Plant that grow exclusively on salt soil	[14]	"Exclusively" could also suggest that the author actually think only to eu-halophytes
Plants growing in saline soils	[17]	
Salt-tolerant plants	[9]	Neither salt or tolerant are not well defined terms

[..] the extremely saline soils which are inhabited only by specially adapted plants (halophytes); plants which habitually grow in very salty soils - halophytes, or at least *can* grow in such soils (facultative halophytes); Halophytes are plants which can tolerate a considerable degree of salinity	[45]	A good definition of eu-halophytes; growing doesn't necessarily means reproducing?...
Plants of salty or alkaline soils	[11]	
1. Plants which grow and complete their life cycle in habitats with a high salt content. 2. Usually, the term is reserved only for plants which appear in salty habitats constantly and specifically	[57]	1. It's very difficult to precisely say what high salt content represents. 2. This remark of Waisel suggest that the term to be applied only to eu-halophytes (true halophytes)
Plants that can tolerate sea water, pure or diluted	[15]	The sea water concentration it is not a universal standard, so pure or diluted could be regarded as quite relatively adjectives
Plants of salty environments; plants adapted to live in a saline environment, be it seawater, a salt-water marsh or a salt-desert. Plants found growing under naturally saline conditions; for terrestrial plants, this means a minimum salt concentration of about 100 mM in the soil solution. Plants adapted to complete their life cycles in salinities about that of seawater.	[19]	This is perhaps among the first physiological definition of halophytes
The term halophyte literally means salt plants, but is used specifically for plants that can grow in the presence of high concentrations of Na salts	[52]	Perhaps referring also to the character of eu-halophytes.
Those species for which saltmarsh is a major and, in any cases, only habitat.	[1]	A good ecological definition

Plants that grow in saline conditions	[29]	
Plant species with a set of ecological and physiological characteristics allowing growth and reproduction in a saline environments. Arbitrarily a salinity of 0.5 % NaCl in soil water should be tolerated by halophytic plants	Gorham (1995) [cf. 47]	
Halophytes are defined as those plants which grow and complete their entire life-cycle in saline habitats. Coping with salinity needs adaptations on all levels from the autecological, the issue and cellular level to subcellular and biochemical adaptations	[7]	"Entire" means inclusively producing seeds for assuring plant survival, colonization and stabilization in any habitat. A holistic definition
Plants that occur naturally on soils or in water too salty for the average plants are usually designated as halophytes	[13]	
[The growth] of halophytes is optimal at relatively high levels of NaCl, a response which can be explained only in part by the role of sodium as a mineral nutrient in these species	[37]	This is an example of an indirect definition of halophytes
Halophytes are adapted to survive in a range of saline environments	[62]	
Halophyte species are those occurring in naturally saline conditions *only*	[3]	Also suggesting the "obligate" character of (some) halophytes
The vegetation of saline habitats is designated "halophytic"	[44]	Saline habitats are defined by these authors as those whose soils contain a high percentage of soluble salts, and one or more of these salt components is usually in excess
Salt tolerant plants (halophytes, including salt marsh and mangrove plants) are highly evolved and specialized organisms with well-adapted morphological and physiological	[32]	A good holistic definition,

characteristics allowing them to proliferate in the soils possessing high salt concentrations.		
Plants that can grow on soils with a high salt content are termed halophytes	[18]	
Plants that can survive in or benefit from an environment with a high level of salt (i.e., sodium chloride), as in saline soils and seawater	[39]	
A plant or microorganism that grows well in soils having a high salt content	[64]	
Halophytes are salt-resistant or salt-tolerant plants that thrive and complete their life cycles in soils or waters containing high salt concentration	[41]	
Halophytes are able to adapt faster and to tolerate extreme salinity	[51]	A deeper physiological definition
Plants that are able to grow on mildly to strongly saline soils (halobiomes). Halophytes which tolerate or endure high levels of salt are known as euhalophytes	[30]	Mildly, strongly, high levels.. are not so well defined terms. But these authors are among the single distinguishing between “halophytes and salt-tolerant plants”, a remark very subtle but pertinent in the context of our previous discuss about semantic field
Plants that survive to reproduce in environments where the salt concentration is around 200 mM NaCl or more	[20]	
Halophytes grow naturally in very salty soils; they still have not lost their resistance mechanisms to salt-stress conditions	[34]	
Plants of saline habitats	[28]	
Plants able to complete their life cycle on saline substrates	[35]	
Plants that are tolerant of excess salt	[48]	

As we can notice at a glance from above definitions included in the Table II, there is only a vague uniformity in defining halophytes. Often, a definition is in fact a previous modified and adapted one, so perhaps the "paternity" of a definition could be even obscure. Anyway, despite the large number of definitions attributed to halophytes (and this table is not, of course, exhaustive) some general statements could be delimited:

1. Many definitions are in fact only syntagms composed by an adjective and a noun (see Table I). There is nothing to be detailed, since the "salt" concept is subjected to controversial discussions. These definitions are very simple, if we stop thinking more deeply about salt and salinity;
2. Some definitions could be considered as "ecological", every time the plants are correlated with habitats (saline). This seems very logical, taking into consideration the fact that we deal with an ecological group of plants. Sometimes, the authors talk about the condition of "completing life cycle" characterizing halophytes. Here, some additional comments are required. Complete life cycle means, of course, that the plant needs to flowering, in order to produce fruits with seeds. These will germinate and thus will ensure the plant survival and its stability in a given habitats. Germination in a saline environment is a very delicate and sensitive issue regarding halophytes biology (see Ungar [56] and references therein). We think that the halophytes definitions including the absolute necessity to completing the entire life cycle must be discussed with caution. It is well known that the success of halophyte populations, especially for *annuals* which have only one opportunity in their life history for reproducing, is greatly dependent on the germination responses of their seeds [56]. The germination of seeds for most halophytes occurs during periods of the year when soil salinity levels are reduced [55]. In addition, laboratory investigations with halophytes suggest that optimal germination percentages are usually found in nonsaline conditions. Anyway, it must be emphasized that generally, the seeds of halophytes can tolerate higher salinity concentrations, than those of glycophytes. In a salt marsh, the halophytes must adopt, therefore, different survival strategies. It was shown that the majority of salt marsh species are *perennial* and in fact relatively few species of annuals have become adapted to the true salt marsh habitat [46]. This would imply that perennial halophytes, having rhizomes, for instance, would be able to assure the persistence at a location on the salt marsh for several decades. So, they would be able to survive in a saline habitat, without "completing entire life cycle" (hypothetically, without flowering, producing seeds which will germinate generating seedlings);
3. Among above mentioned definitions, some of them induce a subtle nuance: halophytes are those species growing in saline habitats *only* (or in conditions of an excess of salts, high levels of salt or plants that need a high concentration of salts in their media for an optimal growth). This is, more likely, a definition of euhalohytes (obligatory halophytes). But we think that this could be also a hazardous or even reductionist definition. There are still many discussions regarding the "absolute" requirement of these species for a high salt content and the remaining types of halophytes would be eliminated for the halophytes category. We have to think in the terms of certain arbitrary and relativity when asserting such affirmations. In fact, here is a continuum flux of adaptations to salinity in a saline environment and would be better to left behind some borders when including halophytes in one or another category;

4. Some definitions could be regarded as "physiological" ones. Establishing a numerical boundary between halophytes and glycophytes could be useful for some standardization, but perhaps many of these definitions are the result of experimental approaches, when the natural situation is completely different. But the value of these definitions shouldn't be denied, especially when we need to compare different species in their salinity tolerance.

Perspectives in halophytes

Further interdisciplinary and holistic researches in halophytes biology could provide additional data regarding the understanding of relationships between these plants and ecological factors. But it is of interest to be aware that the progress in plant sciences and especially in halophytes it is not a *sine qua non* condition for a simplification in perceiving the true nature of halophytes.

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