# Short communication
# Classification of soil microorganisms based on growth properties: a critical view of some commonly used terms

# Kurzmitteilung
# Klassifikation von Bodenmikroorganismen anhand von Wachstumseigenschaften: eine kritische Betrachtung einiger allgemein verwendeter Begriffe

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Accepted 19 March 2004

**Key words:** autochthonous *vs.* zymogenous / oligotrophic *vs.* copiotrophic / r-selected *vs.* K-selected PNSS P136/2B

## 1 Introduction

The theory that soil microorganisms can be classified on the basis of their growth characteristics, nutritional versatility, and affinity for substrate has surfaced in various forms and at various times throughout the 20th century (*Bottomley*, 1999; *Sylvia* et al., 1999). Therefore, reading today's scientific literature, one can find several different definitions for categorizing soil organisms by trophic characteristics. The authors, however, not always give their exact meaning. Some definition pairs are often used interchangeably and, in other cases, different fields use the same definition. Such a situation causes uncertainty, and confuses the reader. For this reason, we aim to discuss the appropriate usage of three, from the angle of soil microbiology important and commonly used definition pairs in this paper. We try to clarify the origin of certain definitions, which are sometimes used incorrectly and attempt to give suggestions for a proper use of the definitions discussed. So we would like to start a discussion about these terms within the scientific community rather than to give strict guidelines. Figure 1 gives a theoretical survey about the relationship among the terms discussed.

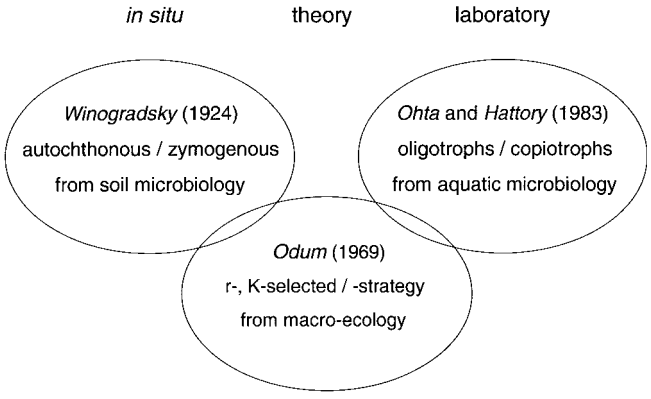


**Figure 1:** Theoretical relationship of the presented classifications and related fields.
**Abbildung 1:** Theoretischer Zusammenhang der dargestellten Klassifikationen und Anknüpfungspunkte.

## 2 Autochthonous *vs.* zymogenous

These are terms for describing nutritional differences among bacteria in particular for soil microbiology. In the autochthonous and zymogenous separation first used by *Winogradsky* (1924), the "autochthonous" was used to determine those organisms living in soil containing more recalcitrant material (*e.g.*, no abundant supply of easily oxidizable substrate occurred). These true inhabitants of an ecosystem are sometimes characterized as indigenous microorganisms. According to *van Gestel* et al. (1993), indigenous soil microorganisms have adapted mechanisms to survive in natural conditions with extremely low nutrient supplies.

In contrast, zymogenous organisms were those showing rapid growth when high energy-containing nutrients were added to soil (*Paul* and *Clark*, 1996). A change between active and inactive phases is characteristic for such microorganisms (*Schinner* and *Sonnleitner*, 1996). According to this grouping, *Gordienko* (1990) and *Garnier* et al. (2003) use the same terminology: "The microbial population is split into an autochthonous biomass that decomposes humified organic matter and a zymogenous biomass that decomposes fresh and soluble organic matter". This strict differentiation, however, is not always transferable to the species level because it is possible that autochthonous microorganisms are not only obligate autochthonous but also zymogenous under nutrient rich conditions (Munch, personal communication).

Autochthonous (permanent) is sometimes used with allochthonous (transient) as antonyms (*Metting*, 1993). In this case, however, allochthonous is not a synonym of zymogenous. The identification allochthonous should be reserved for

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organisms that cannot occupy a niche in a given habitat (*Schinner* and *Sonnleitner*, 1996). Allochthonous organisms are normally quickly eliminated from the soil.

## 3 Oligotrophy *vs.* copiotrophy

This word pair originates from the aquatic microbiology. Oligotrophy and copiotrophy are terms to characterize cultivation under laboratory conditions (*e.g.*, pure culture studies) (*Ohta* and *Hattori*, 1983; *Kanazawa* and *Filip*, 1986).

An oligotrophic organism is able to live in extremely nutrient-poor environments; sometimes defined as an organism, which is able to grow when C flux is 1 to 15 mg soluble C $l^{-1}$ (*Paul* and *Clark*, 1996). A copiotroph organism can, however, grow and reproduce only in C-rich environments (*van Bruggen* and *Semenov*, 2000) that provide about 1000 mg soluble C $l^{-1}$ (*Paul* and *Clark*, 1996). According to Munch (personal communication), these terms describe not the growth properties of organisms but their nutritional status (*e.g.*, well-supplied *vs.* under-supplied). He suggests the substitution of oligotrophic *vs.* copiotrophic by the terms oligotraphent *vs.* copiotraphent because these terms describe the demand of organisms despite that fact that these terms are not established.

## 4 r-selected *vs.* K-selected

This word pair originates from macro-ecology, and is used in ecological theory (*Odum*, 1969; *Metting*, 1993). The classification or differentiation between the two is based on various commonly used criteria simultaneously (see Tab. 1).

It is important to notice that the individual organisms may exhibit both r- and K-selected behavior. For instance, a microbial population might exhibit biphasic growth in response to an environmental perturbation, displaying characteristics of an r-selected species under a first set of conditions and of a K-selected species under a second. Furthermore, seasonality may also cause both r- and K- selection in the same population.

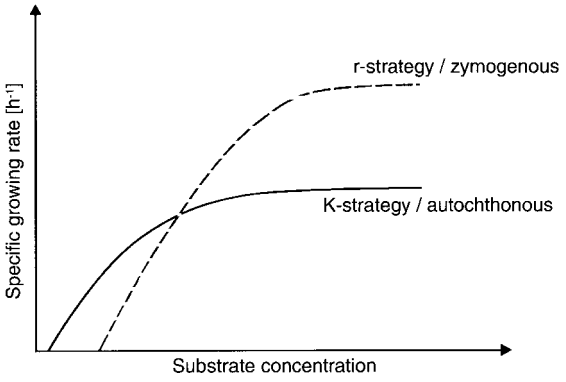


**Figure 2:** Microbial adaptation strategies to different substrate concentrations (*Fritsche*, 1999; modified).
**Abbildung 2:** Mikrobielle Anpassungsstrategien an verschiedene Substratkonzentrationen (*Fritsche*, 1999; modifiziert).

According to the first two criteria listed in Tab. 1, K-selected includes the definition "autochthonous" and r-selected the term "zymogenous" (see Fig. 2). But the other way around, it is not the case because for the usage of the category r-, K-selection, more than the first two criteria have to be tested and fulfilled.

## 5 Discussion and conclusions

According to *Paul* and *Clark* (1996), the terminology autochthonous *vs.* zymogenous is no longer widely used because it is substituted nowadays by oligotrophic *vs.* copiotrophic. However, *Tate* (2000) has continued to use autochthonous *vs.* zymogenous.

**Table 1:** Some attributes of r- and K-selected microorganisms that are relevant to a discussion of soil microbial ecology.
**Tabelle 1:** Einige für die bodenmikroökologische Diskussion relevante Merkmale von Mikroorganismen mit r- und K-Strategie.

| Selection criterion | r-selected species | K-selected species |
|---|---|---|
| Growth rate | rapid growth rate | moderate growth rate |
| Substrate utilization | nutrient-demanding | moderately nutrient demanding |
| Use efficiency | relatively less efficient | relatively more efficient |
| Substrate diversity | simple, readily available | able to use diverse, complex materials |
| Phenotypic plasticity | polymorphic to monomorphic | monomorphic |
| Dominant morphology | small cells, diffuse mycelium | larger cells, more developed mycelium |
| Reproductive method | relatively less, more simple, | relatively more complex |
| | genetic exchange | exchange of genetic material |
| Population dynamics | explosive, density-independent | density-dependent by |
| | non-quilibrium, frequent | competition, equilibrium |
| | recolonization, high | dynamics, low migration |
| | migratory tendency | tendency |
| Tolerance to niche overlap | relatively larger | relatively smaller |

Source: *Andrews* (1984) and *Lynch* (1988), in: *Metting* (1993)

*Panikov* (1999) states that the term "K-selected" is synonymous with autochthonous and oligotrophic, whereas the term "r-selected" is synonymous with copiotrophic and zymogenic. Similar to this statement, one can find on the homepage of the Soil Science Society of America (*Soil Science Society of America*, 2003) the following definitions: "autochthonous flora … also termed oligotrophs; zymogenous flora … synonymous with copiotrophs".

In contrast to *Paul* and *Clark* (1996), *Gordienko* (1990) states that the couples of terms cannot be considered as synonyma. The proper usage of these terms depends on the field of research activity (see Fig. 1). Therefore, we suggest:

(i) If a study is done *in situ* with natural soil and natural substrate amendment (*e.g.*, farmyard manure, green manure, harvest residues, SOM, humus, etc.), the words autochthonous *vs*. zymogenous should be used (*Paul* and *Clark*, 1996; *Schinner* and *Sonnleitner*, 1996).

(ii) For evaluating laboratory experiments with artificial substrates or culture media, the terms oligotrophic *vs*. copiotrophic are recommended (*van Bruggen* and *Semenov*, 2000; *Baudoin* et al., 2002). Artificial substrates stand for concentrations and combinations of substrates that are not found in the nature but are selected by human.

(iii) If a conclusion towards stress (*e.g.*, suboptimal conditions, reduced metabolic activity, etc.) or succession (replacement of one assemblage/community by another) is drawn, the terms r-, K-strategy/-selection should be applied (*Swift*, 1986; *Kozdrój*, 1995).

Evidently, in some case the differentiation is very difficult because of overlapping research fields. Nevertheless, for a correct usage one should try to classify the experimental design and approach for interpretation of results at first. This might avoid misunderstandings. More attention toward exact use of terminology could help the development of soil microbiological ecology as well.

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