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Phyllosphere microorganisms: Composition, Origin and Factors affecting their Survival

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1. **Introduction:** The aerial parts of living plants including leaves, stems, buds, flowers and fruits provide a habitat for microorganisms termed the phyllosphere. The term phyllosphere given by Ruinen, a Dutch microbiologist. Bacteria are considered to be the dominant microbial inhabitants of the phyllosphere, although archaea, filamentous fungi and yeasts are also present. These microbes can be found both as epiphytes on the plant surface and as endophytes within plant tissues. These may arrive on the leaf surface through insect, atmosphere, seed or even soil (Whipps *et al.*, 2008). In addition to abiotic factors like climate, season, and nearby land use, and biotic factors like leaf features and host plant species, the makeup of this community and also influence the composition of the phyllosphere (Lindow and Maria, 2003).
2. **Composition:** A variety of bacteria, filamentous fungi, and yeasts naturally colonize the phyllosphere region, followed by less frequent protozoa and nematodes colonization (Lindow and Maria, 2003).

Generally, the phyllosphere contains four major species of bacteria such as Proteobacteria, Firmicutes, Bacteroides, and Actinobacteria. It has been found that the alpha-, beta- and gammaproteobacteria and firmicutes are the dominant bacterial inhabitants of the phyllosphere. Besides, *Acidobacteria*, *Actinobacteria*, and *Cyanobacteria* are the less frequent colonizers of the phyllosphere environment. The cultivable yeast genera such as *Cryptococcus*, *Rhodotorula*, *Sporobolomyces* and their species have mainly inhabited the plant leaf.

Examples:

1. **Bacteria:** *Beijerinckia*, *Azatobacter*, *Azospirillum*, *Pseudomonas*, *Erwinia*, *Phytomonas*, *Sarcina*, *Methylobacterium.*
2. **Blue Green Algae:** *Anabaena*, *Calothrix*, *Nostoc*, *Scytonema etc.*
3. **Actinobacteria:** *Actinomyces*, *Streptomyces*
4. **Yeasts:** *Candida*, *Cryptococcus*, *Rhodotorula*, *Saccharomyces.*
5. **Filamentous fungi:** *Cladosporium*,

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Alternaria, Cercospora, Penicillium, Aspergillus, Mucor, Rhizopous, Trichoderma etc.

Hotspots on leaves: They are not distributed uniformly on phyllosphere instead they are present majorly in some parts namely, Base of trichomes, Stomata, Epidermal cell wall junction, Grooves along veins as the nutrient's availability is more in theses parts and these sites provide required conditions for their survival.

3. **Origin or Sources of phyllosphere microorganisms:**
   - Soil, air, seeds, herbivores or insects are the primary sources of phyllosphere microorganisms.
   - Roots - through vascular system.
   - Opening leaf stomata and wounds: transformation and migration between endophytes and epiphytes and also allows external microorganisms from aerosols and insects to colonize the plant.

4. **Factors:**

The composition of phyllosphere microorganisms is mainly affected by ecological and abiotic factors. The assembly of phyllosphere microorganisms is subject to multiple drivers. The colonization of phyllosphere microorganisms is mainly affected by the plant genotype and species complex and variable environmental conditions and complex interactions between organisms of multiple trophic levels, abiotic environmental factors, including geographical location, solar radiation, pollution, and nutrients, affect the microbial community structure and diversity as well as biological factors, such as the leaf age and presence of other microorganisms (Nuohan *et al.,* 2022).

a. Impact of Plant Species, Genotype and Age:

The plant species, genotype, and age play a decisive role in the type and number of microorganisms attached to the leaves. Different plant species can provide a different microenvironment to control microbial communities, such as differences in the availability of essential nutrients, water availability, and presence of secondary metabolites. The genotype of the cultivar is also a crucial factor to shape this microbial community. In addition to the plant genotype, the plant physiological stage or age is also the primary factor to drive phyllosphere microorganisms by secreting hormonal and other active substances (Whipps et al., 2008).

b. Environmental Factors:

i. **Ecological factors:** There is a phenomenon in the phyllosphere microbial community i.e, as the geographic distance between plants increases, the microbial communities related to a single plant become more

and more diverse. This phenomenon could arise as a result of constraints on phyllosphere microbial dispersal, differences in leaf characteristics (structural, phenological, or physiological), or differences in climatic conditions. Geographic location, soil type (e.g., cities and rural areas) and local vegetation also influence the composition of phyllosphere microbial communities.

ii. **Abiotic Factors:** Different environmental and plant factors influence the microbial communities in the phyllosphere region like temperature, water availability, season, light etc., Temperature fluctuations are observed with the changes in day and night regimes in the phyllosphere region. Temperature affects both the plants, microorganisms, and their interactions which affects the rates of physical, chemical, and biological processes in the region. Microbial colonizers of the phyllosphere region are subjected to diurnal and seasonal fluctuations of heat and moisture. Leaf temperature is slightly higher than air temperature. If water availability is less or more leads to desiccation, osmotic stress, cell or tissue death etc. With season the carbohydrates, proteins, amino acids, organic acids produced by plants will vary with season. The microorganisms in the phyllosphere region, unlike that in the rhizosphere, are influenced by the light. Bacteria and fungi utilize sunlight to produce different chemical products that promote their growth and plant growth. Light also affects several aspects of plant physiology which influences plant secretions, affecting microbial growth. UV radiation affects the production of plant secondary metabolites, diversity of the microbial population, and the behavior towards biological control agents.

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