Photosynthetic plants that thrive without humus-rich soil

[1,2,3]I. Valentin Petrescu-Mag, [4]Maria Popescu, [2]Claudiu Gavriloaie

[1] Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania; [2] Bioflux SRL, Cluj-Napoca, Romania; [3] University of Oradea, Oradea, Romania; [4] Equine Clinic, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania. Corresponding author: C. Gavriloaie, claudiugavriloaie@gmail.com

Abstract. This short paper highlights the colonizing potential of some plant species even in the absence of soil. The diversity of photosynthetic plants that do not require humus-rich soil illustrates the remarkable adaptability of plant life. From mosses and lichens that initiate soil formation on bare rock to succulents and grasses that stabilize and enrich sandy soils, these plants are vital to ecological succession and the colonization of harsh environments. Their unique adaptations not only allow them to survive but also to transform these landscapes, making them more hospitable for future plant and animal life. As we explore and utilize land for agriculture, conservation, and development, understanding and preserving these resilient plant species becomes increasingly important. Such types of plants are the target of studies for terraforming other planets or natural satellites in extraterrestrial space.
Key words: challenging environments, colonizers, lichens, liverworts, mosses, rocky terrains, sandy soils.

Introduction. Plants are incredible organisms that have adapted to a wide range of environments, some of which are inhospitable to most life forms. Among these are certain groups of photosynthetic plants capable of growing in conditions where traditional soil, particularly humus-rich soil, is absent. These plants are well-suited for colonizing rocky or sandy terrains, where the substrate provides minimal nutrients and organic matter. This paper explores several groups of such plants, highlighting their unique adaptations that allow them to thrive in these challenging environments. Such types of plants are the target of studies for terraforming other planets or natural satellites in extraterrestrial space (Armstrong 2021).

Bryophytes - mosses and liverworts. Bryophytes, including mosses and liverworts, are among the first plants to colonize bare rock and sandy soils (Graham 2003; Rosentreter 2020) (Figure 1). These non-vascular plants lack true roots, instead possessing structures called rhizoids that anchor them to surfaces. Mosses can absorb moisture and nutrients directly through their leaves, which makes them well-suited for environments where soil is thin or nonexistent (Smirnova et al 2022). They play a crucial role in soil formation by breaking down rock surfaces and accumulating organic matter, gradually creating a substrate for other plants.

Succulents - cacti and other water-storing plants. Succulents, such as cacti, are another group of plants that can thrive in nutrient-poor soils, including sandy and rocky areas (Kirschner et al 2021) (Figure 2). These plants have evolved to store water in their thick, fleshy leaves or stems, allowing them to survive in arid conditions with sporadic rainfall. Many succulents possess shallow, widespread root systems that can quickly absorb water from brief showers. Additionally, some, like the cacti, can perform a modified form of photosynthesis called CAM (Crassulacean Acid Metabolism), which reduces water loss (Gilman & Edwards 2020). CAM is a specialized photosynthetic pathway found in certain plants, particularly those in arid or drought-prone environments. CAM plants open their stomata at night, instead of during the day like most plants, to minimize water loss. At night, they absorb carbon dioxide (CO_2) and convert it into organic acids, storing it in vacuoles (Heyduk et al 2019). During the day, when the stomata are closed, these acids release CO_2 for photosynthesis. This process allows CAM plants to conserve water by reducing transpiration, the loss of water vapor through the stomata (Gilman & Edwards 2020). CAM is a highly efficient adaptation for water conservation, enabling these plants to thrive in conditions with limited water availability (Heyduk et al 2019; see Figure 3).

Figure 1. Bryophytes are among the first plants to colonize bare rock and sandy soils (original picture).

Figure 2. Succulents, such as cacti, are another group of plants that can thrive in nutrient-poor soils, including sandy and rocky areas (original picture).

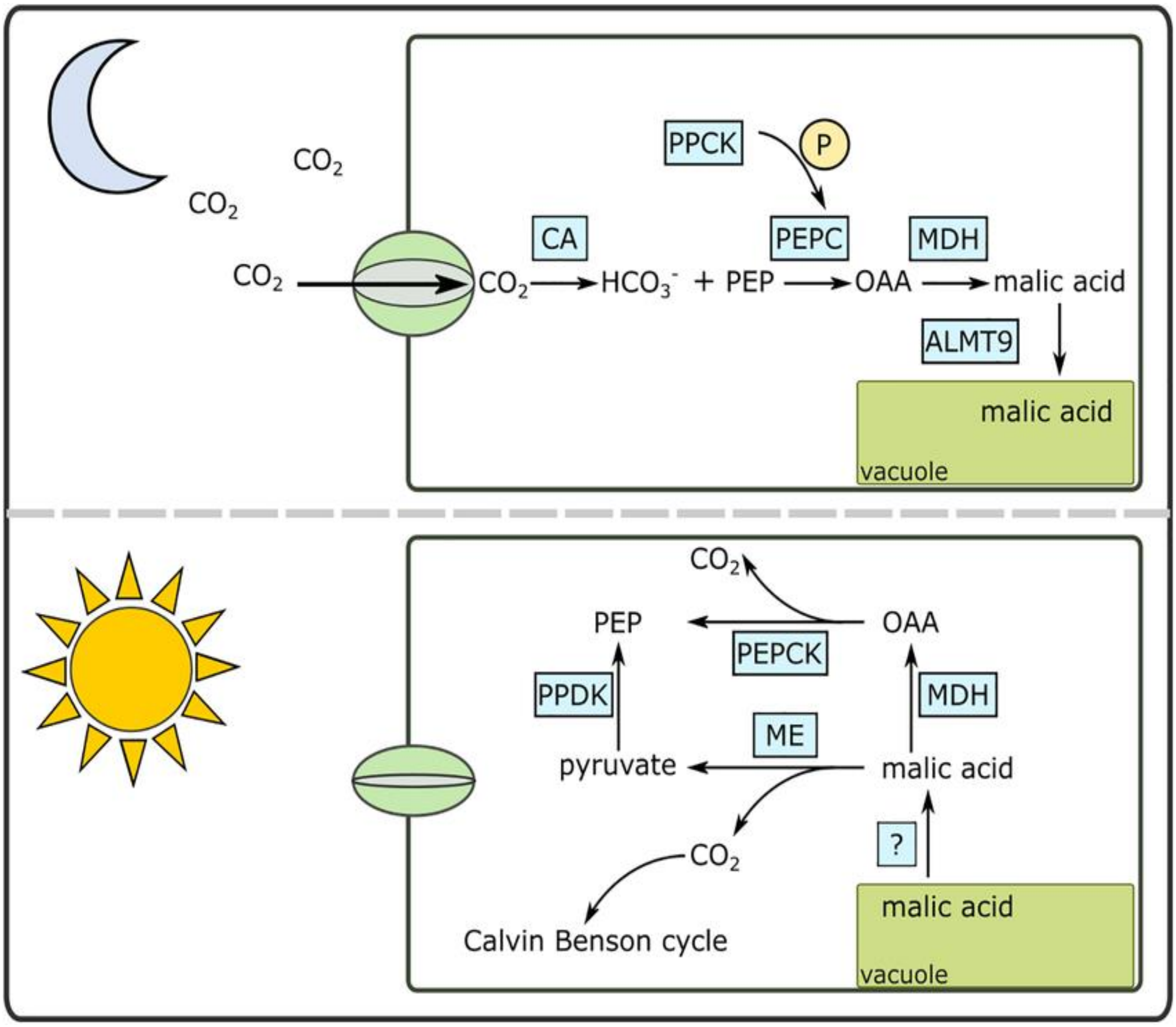

Figure 3. A simplified diagram of the Crassulacean acid metabolism (CAM) pathway under day and night conditions. ALMT9, aluminum activated malate transporter; CA, carbonic anhydrase; MDH, malate dehydrogenase; OAA, oxaloacetate; ME, malic enzyme (NAD or NADP); P, phosphate; PEPC, phosphoenolpyruvate carboxylase; PEPCK, PEP carboxykinase; PPCK, PEPC kinase; PPDK, pyruvate, phosphate dikinase (source Heyduk et al 2019).

Pioneer plants - grasses and sedges. Grasses and sedges are pioneer species often found in newly disturbed or barren areas, including sandy and rocky environments (Li et al 2020). These plants have extensive root systems that can penetrate and stabilize loose substrates. Grasses such as marram grass (*Ammophila*) are particularly adept at colonizing sandy soils, using rhizomes to spread and anchor themselves. Their ability to grow in poor soil conditions makes them essential in preventing erosion and creating conditions that allow more diverse plant communities to establish.

Lichens - symbiotic associations. Lichens are fascinating organisms that result from a symbiotic relationship between fungi and photosynthetic partners, usually algae or cyanobacteria. These resilient organisms can colonize bare rocks and nutrient-poor soils, playing a pivotal role in the weathering process that eventually leads to soil formation (Petrescu-Mag 2023). Lichens can survive in extreme conditions, from arctic tundras to desert landscapes, due to their ability to photosynthesize while enduring long periods of drought. They contribute organic matter and nutrients to the ecosystem, paving the way for other plant species (Armstrong 2021).

Nitrogen-fixing plants - legumes and actinorhizal plants. Nitrogen-fixing plants, including certain legumes and actinorhizal plants, can thrive in soils lacking in organic matter and nitrogen (Hu et al 2023). These plants form symbiotic relationships with bacteria that fix atmospheric nitrogen, converting it into a form that plants can use (Hu et al 2023). This ability allows them to grow in soils that are otherwise too poor in nutrients for many plants. For instance, species like lupines (*Lupinus*) and alder trees (*Alnus*) can colonize barren landscapes and contribute to soil fertility, facilitating the establishment of other vegetation.

Conclusions. The diversity of photosynthetic plants that do not require humus-rich soil illustrates the remarkable adaptability of plant life. From mosses and lichens that initiate soil formation on bare rock to succulents and grasses that stabilize and enrich sandy soils, these plants are vital to ecological succession and the colonization of harsh environments. Their unique adaptations not only allow them to survive but also to transform these landscapes, making them more hospitable for future plant and animal life. As we explore and utilize land for agriculture, conservation, and development, understanding and preserving these resilient plant species becomes increasingly important.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Armstrong R. A., 2021 The potential of pioneer lichens in terraforming Mars. In: Terraforming Mars. Beech M., Seckbach J., Gordon R. (eds), Scrivener Publishing LLC, pp. 533-553.

Gilman I. S., Edwards E. J., 2020 Crassulacean acid metabolism. Current Biology 30(2): R57-R62.

Graham J. M., 2003 Stages in the terraforming of Mars: the transition to flowering plants. AIP Conference Proceedings 654(1):1284-1291.

Heyduk K., Hwang M., Albert V., Silvera K., Lan T., Farr K., Chang T. H., Chan M. T., Winter K., Leebens-Mack J., 2019 Altered gene regulatory networks are associated with the transition from C_3 to Crassulacean Acid Metabolism in *Erycina* (Oncidiinae: Orchidaceae). Frontiers in Plant Science 9:2000.

Hu B., Flemetakis E., Liu Z., Hänsch R., Rennenberg H., 2023 Significance of nitrogen-fixing actinorhizal symbioses for restoration of depleted, degraded, and contaminated soil. Trends in Plant Science 28(7):752-764.

Kirschner G. K., Xiao T. T., Blilou I., 2021 Rooting in the desert: a developmental overview on desert plants. Genes 12(5):709.

Li L., Chen J., Han X., Zhang W., Shao C., 2020 Sandy grassland ecosystem. In: Grassland ecosystems of China: a synthesis and resume. Springer, pp. 365-400.

Petrescu-Mag I. V., 2023 Trebouxia - a key player in the formation of many different lichen species. AES Bioflux 15(1):47-49.

Rosentreter R., 2020 Biocrust lichen and moss species most suitable for restoration projects. Restoration Ecology 28(2):67-74.

Smirnova E. V., Kushnevskaya H. V., Panova E. G., Orlova E. E., 2022 Effects of bryophyte vegetation on the chemical composition of sandstone. In: International Symposium Biogenic-abiogenic interactions in natural and anthropogenic systems, September 2022, Springer International Publishing, Cham, pp. 273-293.

Received: 29 October 2023. Accepted: 28 November 2023.
Authors:
Ioan Valentin Petrescu-Mag, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Calea Mănăştur 3-5, 400372, Cluj-Napoca, Romania, European Union, e-mail: zoobiomag2004@yahoo.com
Maria Popescu, Equine Clinic, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Calea Mănăştur 3-5, 400372, Cluj-Napoca, Romania, European Union, e-mail: maria.popescu@usamvcluj.ro; maria.popesc37@gmail.com
Claudiu Gavriloaie, SC Bioflux SRL Cluj-Napoca, 54 Ceahlau Street, 400488 Cluj-Napoca, Romania, e-mail: claudiugavriloaie@gmail.com

How to cite this article:
Petrescu-Mag I. V., Popescu M., Gavriloaie C., 2023 Photosynthetic plants that thrive without humus-rich soil. AAB Bioflux 15(2):122-126.