Chapter 11
Application of Extremophiles in Sustainable Agriculture

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ABSTRACT

With the increasing demands for foods and other agriculture-based products, sustainable agricultural practices are the cornerstone for improving low-input agricultural production. In contrast to crop production, plant-microorganism interaction (PMI) plays a crucial role. PMI significantly raises productivity as well as maintaining the overall health of the crop. During harsh and extreme physiological conditions, plant-associated extremophilic microbes (PAEM) are known to contribute to crop production, survivability, and fitness. Thus, the application of extremophiles either in the form of biofertilizer or biopesticides is highly beneficial. Extremophiles have been adapted to withstand diverse harsh environmental conditions. They possess unique mechanisms at the molecular level to produce enormous potential extremozymes and bioactive compounds. Consequently, extremophiles represent the foundation of efficient and sustainable agriculture. This chapter introduces the significance and application of plant-associated extremophilic microbes in sustainable agriculture.

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INTRODUCTION

Unfavorable soil conditions counted as a serious threat to agriculture and its productivity. This condition includes variation in soil pH from alkalinity to acidity, elevated temperature, drought, salinity, and involvement of several chemical and heavy metal contaminants in the soil ecosystem. However, several practices have been implemented in order to overcome these stressed conditions and increase agricultural productivity, like the development of stress-tolerant plants, several chemical components, etc. Recently, extremophiles including fungi (AMF), rhizospheric bacteria, and archaea (PGPR and PGPA) have been reported in plants to coping the environmental stress potentially (Akinola & Babalola, 2020).

An extremophile is a term used to describe organisms that live in environments that could be considered "extreme" due to their exceptional living conditions. These organisms thrive and love 'extreme' conditions such as pH, temperature, salinity, etc (Rampelotto, 2013). Also, some of the organisms can survive in extreme metal or chemical conditions (e.g. reduced content of oxygen). However, the vast majority of extremophiles are unicellular organisms from the bacterial and archaeal domains of life. There are many plant-associated extremophilic organisms under various abiotic and biotic stresses which have been documented including bacteria, archaea, and eukarya domains (Rampelotto, 2013) (Fig. 1). It is obvious that these extreme ecosystems harbor unique biodiversity of organisms with the ability to adapt to a variety of environmental stress. Some adaptive traits have allowed these extremophiles to thrive optimally in one or more extreme environments. Poly-extremophiles, on the other hand, thrive in a variety of environmental stresses (Merino et al., 2019).

These organisms could be implemented asbio-inoculum by agricultural practitioners in order to conquer soil stresses (Akinola & Babalola, 2020) (Fig. 1). Under abiotic/biotic stresses, plant-associated extremophiles were reportedly involved in plant growth and adaptations. Thus, these plant-associated microbes are termed "plant-associated extremophilic microbes" (Yadav, 2017) which simply can be considered as "PAEM". Although, all domains from archaea to eukarya are known to involve in PAEM. Additionally, these practices are effectively working as biofertilizers, and biocontrol agents not ended by soil pollution and known to maintain soil health, fertility (Igiehon et al., 2019) and cost-efficient in sustainable agricultural practices (Yadav, 2017).

EXTREMOPHILES: AN OVERVIEW

Extremophiles are divided into groups based on the type of habitat in which they may thrive and reproduce, as shown in Figure 2. These include temperature extremes tolerant - psychrophiles, thermophiles, and hyperthermophiles; xerophiles (tolerate low water activity), barophiles/piezophiles (thrive under high pressures), halophiles (high salinity), extreme pH lovers - acidophiles and alkaliphiles, and radioresistant organisms (Kaushik et al., 2021; Merino et al., 2019). Some extremophiles, such as thermoalkaliphiles and halophilic alkali thermophiles, are adapted to numerous types of extreme environments (poly-extremophiles), further complicating the classifications. *Sulfolobus acidocaldaricus* is a polyextremophilic archaeon that thrives at pH 3 and 80 degrees Celsius (Rastädter et al., 2021). *Paenibacillus* and *Bacillus* spp., which exist in hot springs (India) with temperatures ranging from twenty to eighty degrees Celsius and pH values of 5-14, are examples of microbes that can withstand a wide range of pH as well as high temperatures. The majority of these pH-tolerant microorganisms are neutrophiles (Hussain et al., 2020).