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Impact of Climate Change on Plant-Microbe Interactions

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Abstract

Indiscriminate human activities like burning fossil fuels, deforestation *etc*. increased the level of various greenhouse gases like CO_2 in the atmosphere and ultimately resulted in global warming. Increased atmospheric temperature is the major reason for climate change and extreme weather conditions. It has affected all the living organisms on earth and microorganisms are not an exception for it. Elevated CO_2 level, temperature, frequent drought and low precipitation have affected the microbial population and its interaction with the host plant. Beneficial microorganisms like plant growth promoting rhizobacteria (PGPR) and endophytes *etc*. became less efficient in case of their growth promoting and biocontrol ability. It also increased the spread and severity of various plant pathogens and also led to the emergence of new virulent mutants. All these affected agriculture and production system extensively. Mitigating the climatic stress in crops using various microorganisms from extreme habitat and exploiting their inherent capacity to survive in extreme conditions to provide the crops enhanced stress tolerance is a solution for sustainable agriculture and crop production.

Introduction

The World Health Organization calls climate change as the greatest threat to global health in the 21st century. Contemporary climate change includes both the global warming caused by humans, and its impacts on Earth's weather patterns. Atmospheric CO_2, a major greenhouse gas, has increased by nearly 30% due to anthropogenic sources. Anticipated increases in temperature, ozone, nitrogen deposition and changes in precipitation patterns may substantially affect plant taxa and interactive soil microbes that constitute terrestrial ecosystems.

Soil is as an excellent natural medium that supports the growth and development of plants as well as microbes. Plant-microbe interactions are either beneficial or harmful depending upon the prevailing environmental conditions. Beneficial plant-microbe interactions are caused by symbiotic or non-symbiotic bacteria and a highly specialized group of fungi (mycorrhizal fungi). Beneficial plant-associated bacteria are known to stimulate plant growth and enhance their resistance to degenerative diseases and abiotic stresses. Bacterial genera such as *Azospirillum, Bacillus, Pseudomonas, Rhizobium, Serratia, Stenotrophomonas* and *Streptomyces* fall under this category. But the changing climate and extreme weather conditions resulted in elevated the CO_2 level and temperature in the atmosphere and it adversely affected the efficiency of the microbes to enhance the plant growth and resistance towards various pathogens. It also increased the spread and severity of various plant pathogens and also led to the emergence of new virulent mutants and affected the agriculture system and crop production extensively.

Agriculture is considered as the most vulnerable sector to climate change. Exploiting plant-microbe interaction is a relevant approach to increase food production for the growing population in the current scenario of climate change.

Effects of Climate Change on Beneficial Microorganisms

Change in climatic conditions like elevated CO_2, temperature, UV radiation *etc*. has direct effects on phyllospheric microorganisms like *Actinobacteria*, *Bacteroidetes, Flavobacterium, Pseudomonas*, various fungi and yeasts and change in the root exudate composition and change in moisture content of soil *etc*. will cause indirect effects on rhizhospheric microbes.

Effects of Elevated CO_2

Little is known about the specific impacts of elevated CO_2 on PGPR. Elevation in CO_2 concentrations may alter soil microbial processes, such as microbial biomass, soil respiration and enzyme activity, microbial activities like growth promotion and decomposition, soil carbon dynamics and microbial community structure.

Generally, the number and diversity of rhizosphere inhabiting bacteria depend on root exudates or plant metabolites. Under elevated CO_2 environments, plants tend to stimulate microbes through enhanced carbon flow or rhizo-deposition into rhizospheric soil. Microbial biomass in rhizosphere increases with increase in CO_2 concentration in the soil to an optimum level. Adaptability to CO_2 concentration varies with species.

High level of CO_2 would result in decreased amounts of available N for microorganisms and it affects the growth promoting and degradation ability of soil microbes and may lead to indirect effects on soil structure.

In a study conducted by William *et al*.,(2018) the effects of different atmospheric CO_2 concentrations on *Arabidopsis* rhizosphere colonization by the rhizobacterial strain *Pseudomonas simiae* WCS417 was examined. They concluded that rhizobacterial strain WCS417 showed increasing rhizosphere colonization at rising CO_2 concentrations and can be attributed to the excessive carbon flow from the root exudates of *Arabidopsis* at higher atmospheric CO_2 level and a repressed growth promoting efficiency was observed by the strain WCS417 at elevated CO_2 level.

Effect of High Temperature

Elevated temperature in soil decreases soil moisture content and check the competence of microbes to disperse, survive, and colonize soil spaces. Elevated temperature alters microbial structure and functions also. For example, activation of heat shock proteins (HSPs), a family of proteins that are produced by cells in response to exposure to stressful conditions.

Effect of Drought

Various biochemical strategies adopted by microbes during drought are accumulation of compatible solutes like proline, production of anti-oxidants like SOD, CAT and APOX, production of protective molecules like osmolytes and synthesis of chaperons to stabilize the protein from denaturation. Another strategy adopted by microorganisms under extreme condition is undergoing dormancy by producing surviving structures like endospore, cyst *etc*. Cells in a non-dividing but metabolically active state are likely dormant and sometimes require a signal to awake.

Moving toward attractants and away from repellents, are apparently an effective set of survival strategies in heterogeneous environments. For some bacteria, migration towards the rhizosphere of plants is the most promising way to obtain organic nutrients in soils; root colonization of a plant growth-promoting rhizobacteria like is an example of it.

Programmed cell death in bacteria has also been proposed as a possible strategy for preserving some of the population from stresses through utilization of the nutrients derived from the dead cells.

Impact of Climate Change on Plant Pathogen

The impact of climate change on disease incidence and severity and on the geographic distribution of plant pathogens is hugely important for both agricultural production and the diversity and structure of natural communities. Predicted climatic changes are expected to affect pathogen development, survival rates, and host modulation, resulting in changes in disease development in crops. Earlier reports generalized that the impacts of climate change differ by pathosystem and geographical region. These changes may affect not only the optimal conditions required for infectionbut also the host specificity and mechanisms of plant infection (Moran *et al*., 2005).

Past studies based on FACE (Free Air CO_2 Enrichment) concluded that elevated CO_2 consistently affects the leaf surface wax composition. Such changes would likely alter host pathogen interaction at a molecular scale prior to infection. Moreover, local environmental setup, such as increases in leaf number, leaf area, canopy size, and density, under elevated CO_2 can alter canopy temperature and microclimate humidity which could promote plant diseases of different severity levels. The impacts of elevated CO_2 on plant disease have been deeply reviewed.

Increased precipitation and RH due to climate change increases moisture in atmosphere which help in the activation of bacterial, fungal, and nematode pathogens. In fungal diseases, moisture affects fungal spore formation, longevity, and particularly the germination of spores.

Climate change has resulted in extreme storm and change in wind direction. Wind plays major role in the spreading of various diseases. Wind also injures plant surfaces due to rubbing action of leaf this facilitates infection by many fungi and bacteria and also by a few mechanically transmitted viruses. Uredospores and many kinds of conidia, can be transported by the wind for many kilometers. *Erwinia amylovora,* the causal agent of fire blight of apple and pear, produces fine strands of dried bacterial exudates which may be broken off and are transmitted by wind.

Beneficial Microbes Enhance the Climatic Stress Tolerance in Plants

Plant growth promoting rhizobacteria (PGPR) could play a significant role in alleviation of stress in plants (Rodriguez *et al.*, 2008). These beneficial microorganisms colonize the rhizosphere/ endo-rhizosphere of plants and impart drought tolerance by various mechanisms explained in Figure 1.

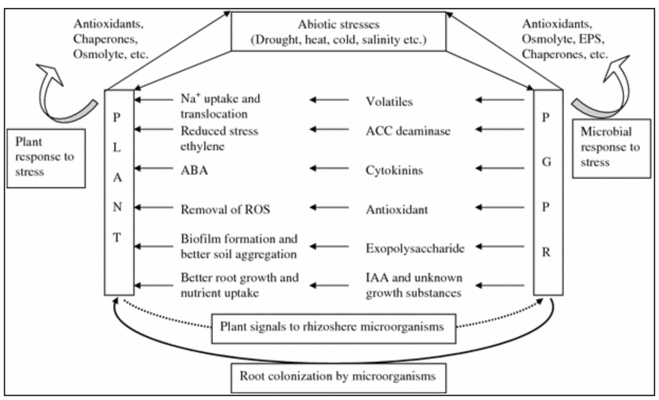

Figure 1: Mechanisms of PGPR for mitigating climatic stress

Isolation of new microbes from extreme conditions which can mitigate various stresses in plants and utilization of various possibility of plant-microbiome concept for stress mitigation is also advisable (Figure 2).

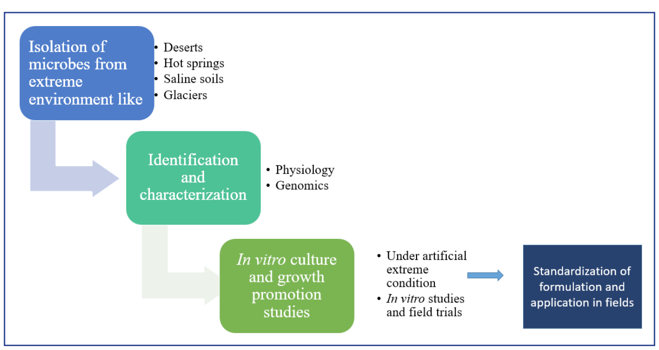

Figure 2: Steps in isolating various bioinoculant for climatic stress mitigation

Conclusion

Climate change is a consequence of anthropogenic activity, leading to drought and salinity which limit crop yields. Crop improvement through conventional plant breeding or biotechnological tools like genome editing or transgenic technology are key steps in obtaining desired characteristics associated with future needs. Impact of climate change in microorganisms has led to a suppression in the growth promoting activity of PGPR and increased the severity of various plant diseases. Hence it is important to find out alternative ways to sustain the climatic stress in the agro-ecosystem.

Microorganisms possess inherent potential to adapt themselves under changing environmental conditions. Microbes can be successfully used as an effective agent for the mitigating climatic stress. Various possibility of plant microbiome concept like breeding of crops with root exudate, attracting microorganisms having stress mitigating capacity, meta-analysis of entire microbiome associated with a plant and its gene expression during stress condition and development of a consortium of bio-inoculant out of it can be considered for climatic stress mitigation.

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