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Role of Agriculturally Important Microorganisms in Climate Smart Agriculture

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SUMMARY

Climate smart agriculture (CSA) is the sustainable approach to increase the crop production in changing scenario of climate. CSA draws attention for growing agriculture systems not only to ensure food security under climate change yet alleviate green house gases (GHG) and to improve carbon stability in soil. Agriculturally beneficial microorganisms assume significant role in climate smart agriculture through adoption to climate change, mitigation of climate change and carbon stability in soil. Microbial based technology is ecofriendly technology to furnish the food for increasing human population in current unequilibrium climate.

INTRODUCTION

Climate change refers to any significant statistical change in the distribution of weather patterns over an extensive period of time which can range from decades to millions of years (Enete and Amusa, 2010). Rise in atmospheric concentrations of greenhouse gases (GHGs), e.g., CO_2, CH_4 and N_2O), is the principal cause of global climate change (IPCC, 2013). Changes in the climatic conditions are directly or indirectly affecting the life on earth by significantly impacting not only human or animal life but also that of plants and microorganisms. Climate change affects agriculture in a number of ways these include changes in average temperatures, rainfall, growing season, pests and diseases incidence, nutritional quality of some foods, soil erosion due to intermittent floods and drought (World Bank, 2008).

Microorganisms are the most important components of agricultural ecosystem (Mohanty and Swain, 2018). They play essential functions in biogeochemical cycling of nutrients such as carbon, nitrogen, phosphorus and sulphur. They are responsible for both production and consumption of greenhouse gases such as carbon dioxide, methane and nitrous oxide. The large diversity of microbes provides an opportunity to explore and exploit untapped microbial resources for improving the efficiency of agricultural production systems by enhancing the adaptation and mitigation options to the negative effects of climate change to achieve the goal of climate-smart agriculture. A thorough understanding of microbial ecology and soil-plant-microbe interaction in a changing climate scenario is essential to make best use of microbial technology for climate change adaptation and mitigation.

Role of microbes in climate smart agriculture

Effect of environmental change on agriculture is as of now distinguishable. In the present situation of rising temperature, elevated CO_2, unseasonal rainfall; flood; cyclone and drought; the idea of climate smart agriculture (CSA) started so as to make agriculture more flexible to environmental change. Microorganisms are indispensable to various biological activities in agroecosystem. Application of beneficial microorganisms as biofertilizers and biopesticides help in achieving the sufficient food for increasing human population in sustainable way and also help in alleviating adverse effect of agrochemicals on soil health (Wagg et al., 2014). Biofertilizers and biopestisides are key elements of climate smart agriculture because these are major components of integrated nutrient management and insect-pest management. Plant beneficial microorganisms (PGPM) are fundamental to different bio-geological process in soil viz. organic matter decomposition, carbon cycle, nitrogen cycle, phosphate solubilization and mobilization, nitrogen fixation and acquisition of micronutrients. Microorganisms also facilitate the crop plants to withstand in changing climatic situation or abiotic stresses viz. elevated temperature, elevated CO_2 or green house gases, moisture stress, salinity stress and metal toxicity. Methanotrophs, methylotrophs and photosynthetic microorganisms play the important role in mitigating the green houses gases .

Adaptation to climate change

Microorganism can be utilized to encourage adjustment to environmental change by advancing development and improvement and giving resistance against a few abiotic stresses. They offer a chance to depend on the biological processes instead of environmental change initiating synthetic substances. Soil microorganisms are engaged with soil formation and aggregation, direct its attributes, maintain its fertility and productivity, detoxify the polluted soil and increase the sustainable agriculture production and advance soil ecosystem in durable way. Plant growth promoting microbes encourage adaptation to climate change by imparting resistance to biotic and abiotic stresses.

Impart resistance to biotic stresses

Novel biocontrol agents can be utilized to confine the destructive effect of newly rising insect-pest in a changing atmosphere situation. *Neozygites fresenii* and *Maravalia cryptostegiae* has been used to control of cotton aphid *Aphis gossypiii* and weed rubber vine respectively. *Bacillus thuringiensis* (Bt) has been commersilized to control of Lepidoptera and Diptera larvae. Bt produces crystalline like protoxin, which entered inside the mid gut of larvae through feeding of leaves of plants Joshi et al. (2010). Proteolysis is occurred inside the alkaline mid gut of larvae and produces toxic peptides, consequences poring of epithelial cell of larvae and larvae die. Bioaugmentation and biostimulation are two basic principle of biological control of soil borne phytopathogens in soil, can help adapt to climate change. Beneficial microbes when interact with plants improve nutrient procurement, produce phytohormone and adjust physiological and biochemical properties of the host plant and in this manner help in securing the plant roots against soil borne pathogens. Bacterial genera, *Pseudomonas, Bacillus, Rhizobium, Azospirillum, Streptomyces* and *Serratia* are common in this group (Gaur et al. 2004). These plant-microbe interactions can be abused for quicker plant development and improved disease resistance in changing atmosphere conditions. Recently distinguished *Rhizobia* species related with *Medicago sativa* can possibly work under different abiotic conditions, for example, salinity, low or high temperature or pH or low degrees of organic matter in the soil. Thus unexplored microbial diversity gives huge chance to recognize novel genes for pest control, nitrogen fixation and biodegradation by using newly discovered genomic tools.

Impart resistance to abiotic stresses

Elevated CO_2 induces moisture deficit conditions to plants and also enhance the nutritional requirements of plants. Literature reported that mycorhiza increase the plant adoption to raised CO_2 level. Mycorhiza fungus *Glomus intraradices* has been played significant role in moisture stress alleviation at raised CO_2 level. This mycorhiza increase the gene expression level of *PIP2* (plasma membrane intrinsic protein) in *Lactuca sativa* seedlings roots. Elevated temperature induces different types of physiological and biochemical changes in plant body, induces moisture stresses in soil and water imbalances in plant body resulting plant yield decreases. Beneficial microorganisms *Burkholderia*, *Pseudomona*, *Bacillus* can improve the plant growth and yield under abiotic stresses viz. acidity, salinity, heat stresses. In our previous studies different types of osmo-tolerant bacteria were isolated from rhizosphere of wheat, maize, mung bean and guar crops and play the important role in moisture stress alleviation. Inoculation of arbuscular mycorrhiza fungi *Glomus fasciculatum* also contribute significant role in heat stress alleviation of *Cyclamen persicum* plants. Mycorhiza association also may be more beneficial to increase the plant yield under salinity stress. Inoculation of AM fungi was also found beneficial to protect the different types of enzymatic activities affected by more salt concentration.

Climate change or Green house gas (GHG) mitigation

Soil microorganisms and their metabolic movement can affect soil-air carbon exchanges from various perspectives, while these can be comprehensively partitioned into various groups, like, those that influence the ecosystem by methane and carbon dioxide eater and also control carbon loss from the soil through methane generation and respiration. Methanotrophs are specific group of microorganisms which oxidized methane or other C1 carbon compounds like- formate, methyl amine, dimethyl amine, methanol to carbondioxide and release it to the environment. Methanotrophs represents just ~5% of the worldwide sink of atmospheric CH4. Methanotrophs likewise oxidizes up to 90% of the CH_4 delivered in the soil before it getaways to the air. However, they show very slow growth and embedded with soil particles therefore very difficult to isolate them. Literature reported that many strains of Methylotrophic microbes can be used as plant growth promoter. A recently discovered methanotrophic bacteria-*Methylokorus infernorum* can utilize CH_4 gas about 11 kg per year (Yim et al., 2012). Therefore, it may be very useful to mitigate CH_4 gas produce from anthropogenic process. Besides it, another bacteria *Methylobacterium extorquens* also consume many C1 carbon compounds like methane, methanol and methylated amines and converted into CO_2 and provide it for autotrophic microbes. Zuniga *et al*. (2011) found that *Methylobacterium organophilum* CZ-2 and *Methylosinus trichosporium* OB3b transformed methane gas into poly-β-hydroxybutyrate with limited CO_2 emission. Thus methanotrophs/methylotrophs play the significant role in mitigation of GHG emission. Aside from that there are some soil microorganisms that convert carbon dioxide into calcium carbonate. Some denitrifying microorganisms are known to change over nitrous oxide into nitrogen gas. These organisms can possibly alleviate GHG emanations. Furthermore, utilization of advantageous microorganisms expanded profitability, subsequently influencing GHG pool in terms of GHG discharge per unit food production. Advantage occurred by utilization of beneficial microorganisms can be considered as a commitment of organism to environmental change alleviation. Group of microbes that consume CH_4 as their energy and carbon source, for example, Methanotrophs can be abused for environmental change moderation; anyway isolation, culture and inoculation of these microbes are as yet a test to be tended.

Microorganisms add to the greenhouse gas budget of agriculture in different manners. The GHG budget for agriculture framework can be assessed straightforwardly as far as the ozone harming substances discharged per unit of food delivered, or less legitimately as far as the measure of land required per unit of food production. Further, microorganisms can enhance crop production through numerous approaches, such as, enhancing nutrient uptake and drought resistance, and diminishing the impacts of pathogens. Sometimes there might be ozone depleting substance cost related with a portion of these advantages. For instance, if a biocontrol agents uses to a field and is applied utilizing a tractor, the subsequent ozone depleting substance cost of the tractor utilize must be calculated into the spending limit. In the event that the advantage in expanded profitability is more prominent than the expense of the tractor use, at that point biocontrol agents contribute to environmental change alleviation.

One of the positive highlights of numerous beneficial microbes is that their exhibition depends less on high GHG costs than the production of manufactured pesticides does. For instance, naturally occurring biocontrol agents won't bring about the expenses related with the creation, transport and use of engineered items. In the event that the biocontrol agents can be kept up or improved without petroleum product use, they may give environmental change alleviation. Since the significance of numerous microorganisms isn't comprehended, we presumably as of now think little of this role in environmental change relief. Particularly microorganisms that have role in plant nutrition, for example, mycorrhiza and rhizobia, can make significant commitments of this type in system with low external inputs. Not exclusively do they by and large increment plant efficiency per unit of land, yet the GHG emission related with their utilization are lower than those related with fertilizer production and transport. It will be critical to build up our comprehension of microorganisms to GHG budget to ensure that the budget are right and that significant micro-organisms are conserved accordingly.

The three kinds of energizes (methane, bioethanol and biodiesel) and the power delivered by micro-organisms speak to incredible potential for acquiring vitality without expanding the GHG budget (Pfromm et al., 2011). Notwithstanding, every one of them require moderately a lot of biomass as raw material. A few kinds of biomass, including molasses and cellulose, can be utilized by the yeast *Saccharomyces cerevisiae* to deliver bioethanol. Particularly the utilization of cellulose as a substrate by yeast holds incredible guarantee as it is abundant and at present underutilized, however the innovation required to do this is as yet inadequate. Methanogenic Archaea produce methane from different sources including waste water, and animal and metropolitan waste. Green algae can be utilized to deliver biodiesel legitimately from daylight, however this innovation additionally is as yet not completely created.

Microorganisms assume a key role in environmental change buffering, which we characterize as reducing of the effect of environmental change. Soil microorganisms play the significant role in soil organic matter decomposition and making it accessible to crop plants. During the organic matter decomposition different types of by product are released like CO_2, CH_4 and nitrogen. Around the world, an expected 70–140 million tons of nitrogen are fixed by nitrogen fixing microbes. Soil microorganisms decrease the utilization of agrochemicals which are responsible for climate change and increase the soil biodiversity. Expanded biodiversity gives expanded biological system flexibility, which can support and settle environmental change impacts. Microorganisms increase the ecosystem stability, can likewise assume a key role in climate change buffering. For instance, biocontrol agents can settle population levels of plants and herbivores, making them stronger to environmental change.

Soil carbon storage

Microorganisms can have a crucial role in alleviating climate change. For instance, agriculture itself bring about environmental change, indirect way using petroleum products and land use, and directly through GHGs emergence from farming practices. Green house gas outflows are particularly identified with methane discharges from ruminant domesticated animals and rice field, yet in addition to nitrous oxide discharges from fertilizers application, which represents 80 percent of overall nitrous oxide emanations. Expanded land use for agriculture brings about CO_2 emissions connected to deforestation and because of the expanded utilization of soil. It additionally prompts enhanced CO_2 concentration in the atmosphere because of decreased carbon re-take-up, and increased green house gas discharge.

The carbon sink limit of the soil, which is interceded by microorganisms, has significant ramifications for climatic change. As soil is such a huge store of global carbon, one of the significant role of microbes in environmental change lies in their sequestration of carbon in SOM and their role in discharging carbon as CO_2 from the degradation of SOM. Environmental change modifies soil carbon stockpiling through organic matter decomposition or mineralization, altering the aggregation and accumulation of soil organic matter, and affecting soil erosion and respiration.

Soil microorganisms are imperative in the carbon cycle, assuming a crucial role in the sequestration of carbon in soil organic matter (SOM) and furthermore the arrival of carbon as carbon dioxide (CO_2) from the degradation of SOM. Soil is the second largest reservoir of carbon followed by atmosphere which is more dynamic. CO_2 emitted from soil organic matter degradation by microorganisms is one of the significant GHG. Besides CO_2, soil microbes can also control motions of different GHGs, for example, methane (CH4), which is delivered during the carbon cycle, and nitrous oxide (N_2O), which is produced as a major aspect of nitrogen cycle. These methane and nitrous oxide are more potential than CO_2 for global warming. Accumulation of carbon in soil is a major approach for climate change alleviation. Soil microorganisms assume a vital role in the carbon stabilization process by changing dead organic matter into simple carbon molecules that are bound to be ensured and sequestered. At each point on this decay pathway, various kinds of carbon of contrasting size and synthetic intricacy are created that can be incorporated with sediment and soil particles or fused into soil aggregates.

Fungi assume a moreover significant role in soil carbon stabilization or sequestration by amplifying the amount of carbon assigned to the soil and delivering exacerbates that improve soil aggregates stability. Arbuscular Mychorrizal Fungi (AMF) show symbiotic relationship with plant roots, giving plants soil supplements while plants give AMF basic sugars (Govindarajulu et al., 2005). As plants feed AMF, their biomass enhances adequately expanding the amount of carbon in soil. Besides, AMF also produce an sticky protein called glomalin that hold soil particles together, helping to conserve soil carbon. Wilson et al. (2009) reported that AMF positively correlated with soil aggregation and carbon sequestration. Besides soil fungi, soil bacteria also assume a significant role in organic matter decomposition.

Nitrifying microorganisms convert complex nitrogen mixes from dead organic matter into simple forms that are easily accessible for plants, while Actinomycetes are liable for the disintegration of more complex organic substrate (lignin, cellulose or hydrocarbon). These degradation processes are fundamental for microbial biomass creation and carbon sequestration into stable structures in soil. Overseeing soils for soil microorganisms by giving adequate and different plant inputs and by decreasing tillage can improve the carbon sequestration (Six et al., 2006).

CONCLUSION

Environmental change marvel, for example, increment of mean temperature, changing pattern of rainfall and expanding recurrence of outrageous climatic occasions like cyclone, dry spell and flood will affect agriculture. It is most important to reorient and change agriculture to make it stronger to environmental change. Appropriate management and utilization of microbial formulation such as, biofertilizer, biopesticides and plant growth promoting rhizobacteria can contribute to both climate change adjustment and relief. Environmental change influences growth and development of crop plants as well as development and movement of microorganisms in rhizosphere. A proper understanding of microbial ecology and soil–plant–microbe interaction in a changing climate scenario is essential to use microbial technology for climate change adaptation and mitigation.

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