METHYLOBACTERIUM SP.: THE NEXT GENERATION OF CROP PROTECTION

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Plants and microbes are coevolved together in the process of evolution. Microbes associated with plants not only maintain plant health but also improve their tolerance to abiotic stress. However, the increased abiotic stress due to climate change has resulted in decline in crop productivity. Climate change is observed in the form of increased temperature, greenhouse gases, soil salinization and ozone layer depletion. Managing the associated risks is a serious concern. Micro-organisms play e a central role in deriving major ecological processes, controlling flux of gases into the atmosphere and maintain a significant balance between soil health and plant productivity. Moreover, plant associated microbes helps plant adapt to the stressful conditions. Therefore, assembling stress resistant microbes in the plant can develop strategies to tolerate harsh climatic events.

AGRICULTURE & CLIMATE CHANGE

Agricultural crops are more vulnerable to climate change as they are exposed to external environment. The Global mean surface temperature has risen from 0.5 to 1.0^o C turning majority of terrestrial ecosystem into water stressed areas. It has been predicted that drought affected area at 2^o C level rise of temperature is 13 % whereas at 1.5^o C is 6.5 %. A recent study has predicted that climate change can have larger impact on seed yield (-3.5 X 1013 kcal year^{-1}) and its nutritional value will be decreased by 0.8 % globally (Ray et al. 2019). Loss is much likely to be seen in crops such as wheat (-0.5 MT) and rice (-2.2 MT), which are also staple food of many countries. Depending on plant type whether C_3 or C_4, it could be expected that under elevated CO_2 conditions C_4 plants (sorghum, maize, and sugarcane) in future will derive little benefit from CO_2 fertilization effect whereas C_3 plants (soybean, wheat, and rice) having low CO_2 efficiency will benefit from CO_2 fertilization effect.

Radiation Stress Tolerant Microbes: The ozone layer in the stratosphere is depleting due to emission of greenhouse gases and other anthropogenic activities resulting in increased UV B radiations in the sunlight reaching the earth surface. Scientists predict that the climate situation could worsen in the future. However, certain micro-organisms such as *Methylobacterium extorquens*, *Bacillus megaterium*, *Rhodospirillum rubrum* etc., accumulate pigments that have possible role in blocking harmful UV rays to protect their nucleic acid, proteins and lipids from degradation. Carotenoids, the natural functional pigments, are found in all life forms, including plants, fungi and several families of bacteria like *Actinobacteria*, *Basidiomycetes*, *Sordariomycetes*, *Chlamydomonadales*, *Methylobacteriaceae* which are known to be efficient producers of carotenoids. Pigments such as lycopene, zeaxanthin, beta carotene, canthaxanthin, rhodoxanthin, astaxanthin, oscillaxanthin and xanthophylls are present in the inner membrane of the cell attached to hydrophobic areas, and are involved in protecting photosynthetic reaction centre from free radical damage, particularly D1 protein of PSII system. UV B in sunlight has damaging potential as well as reduction in yield and nutritional value and decrease of crops and biomass. A study of mUV B radiation (5^{-15} KJm^{-2} day^{-1}) on soybean plants found that increase in seed oil content but with high undesirable polyunsaturated linoleic acid and linolenic acids and low content of monosaturated oleic acid, while protein, carbohydrate and fatty acid content overall decreased (Reddy et al. 2016). In a similar study it has been predicted, 20% increase in UV B content leads to 6 % reduced yield of crops. Carotenoids act like sunscreen and have potential in protecting plants against harmful UV rays (Agogue et al. 2005).

Figure 1. *Methylobacterium* (a) seed coating and (b) foliar spray on pigeon pea (c) experimental field of ICAR-Indian Institute of Soil Science, Bhopal

Drought Tolerant Microbes: Plants are a vulnerable group because they are exposed to harsh weather events. Temperature is a key factor that has direct impact on plants and is expected to rise by 1.5°C to 1.8°C by 2100. Increased temperature causes drought and reduction in water vapour that limits photosynthesis in important crops such as wheat, rice and maize.

In plants root bacteria are enriched in a narrow zone called rhizosphere and show maximum metabolic activity. *Azospirillum, Azotobacter, Bacillus, Burkholderia and Pseudomonas*are abundant in rhizosphere are key in regulating drought stress by producing ACC deaminase enzyme thereby reducing ethylene levels.

Under drought ABA elicit stress related genes and regulates stomatal opening of plants to reduce transpiration. Another phytohormone indole acetic acid can also stimulate root growth and increase in lateral root formation that enhances water uptake from soil. The accumulation of proline, glycine, betain, glutamate and trehalose helps to overcome osmotic stress. Bacteria also secrete exopolysaccharides that maintains cell membrane integrity and protect them from harsh environmental conditions.

Certain microbial group can withstand abiotic conditions by adaptations in cell wall or secreting such molecules that can stimulate mechanisms to counteract abiotic stress in microbes. *Bacillus* and *Klebsiella* sp. enrich themselves in endosphere and improve drought tolerance by altering root architecture and controlling vacuolar proton pumps of plants at gene level. Certain bacterial groups Actinobacteria, Firmicutes and Chloroflexi enrich themselves in sorghum roots during drought due to the secretion of root exudates. In addition to the rhizosphere, phyllosphere micro-organisms also have capability to survive in water stressed environments. One such microorganism is *Methylobacterium* sp. They secrete phytohormones like absicic acid, jasmonic acid and gibberellic acid also has a role in drought tolerance by increasing antioxidant level, regulates stomatal opening and thus control evapotranspiration. *Azospirillum* sp. maintains hydration as a result of decreasing water potential in leaf.

GHG Metabolizing Microbes: Another alternative to combat climate change is to use greenhouse gas metabolizer like methanotrophs that have capability to consume methane and turn it into stable molecule that can be utilized by microbe e.g. *Methanobacterium bryantii, Methanobrevibacter gottschalkii* etc. Similarly, methanol derived from methane emission can be utilized by methylotrophse.g.*Methylovorus, Methylobacterium*. Microbes can also potentially limit nitrous oxide emission e.g., *Rhizophagus irregularis*. Through genetic engineering genes encoding enzymes like nitrate reductase, methane monoxygenase could be engineered in such a way that it acts as sink to harmful GHGs. Earlier *Cupriavidus necator* and *Pyrococcus furiosus* has been engineered to directly assimilate CO_2 using H_2 as substrate and converting it to a stable biofuel.

Salinity Tolerant Microbes: Genera *Bacillus, Pseudomonas, Agrobacterium, Streptomyces* and *Ochromobacter* mitigate salt stress by controlling gene transcription. Under high salinity ACC deaminase, osmoprotectants, EPS, VOC's are secreted by *Pseudomonas, Variovorax, Paradoxus* and *Rhizobium* are also known to be good stress alleviators. *Rhizobium* and *Pseudomonas* lowers osmotic potential due to enhanced proline production resulting in higher water potential in leaves. *Klebsiella*is is known to upregulate RuBisCo enzyme and increases photosynthesis under saline stress. EPS is involved in controlling stomatal opening, transpiration and maintain turgor pressure in cells.

It has been found that members of Actinobacteria and Firmicutes are first responders to soil moisture when soil is subjected to prolonged drought and Actinobacteria group dominate in water deficit soil. Therefore, replenishment of these groups can alleviate stress response. Plant associated microbes confers several benefits that includes improved antioxidant activity, osmolyte accumulation, proton transport machinery, salt compartmentalization, nutrient status, reduce osmotic stress and ion toxicity. *Bacillus megaterium* also regulates hydraulic conductivity and transpiration rate. Stomatal regulation is under influence of microbes like *Azospirillum brasilense* and

Pantoea dispersa under salinity increased stomatal conductance and photosynthesis in *Capsicum annuum*. Over expression of trehalose 6-phosphate gene is reported likely to induce salt tolerance in nodules of *Phaseolus vulgaris*.

BENEFITS OF USING *METHYLOBACTERIUM SP.* AS BIOFERTILIZERS

1. *Methylobacterium* is a drought tolerant bacterium, which has the ability to tolerate the growth and development of plants by tolerating water stressed conditions and also high temperatures
2. By spraying carotenoid pigment secreted by *Methylobacterium* on the leaves, harmful effect of ultraviolet radiation could be reduced on leaves. Such pigment producing methylotrphs becomes an important category of microbes to protect plants agains harsh climatic conditions.
3. Instead of spraying chemicals on leaves methylobacterium could be used to protect plant parts and also its associated pigments.

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