UVR Stress & Defense mechanism in Cyanobacteria

DATE

M.Sc IV
Algology

Plants are subjected to various environmental stresses such as water deficit, drought, cold, heat, salinity & air pollution etc.

Study of functioning of plants under these stresses or adverse environmental condition is called Stress physiology.

Stress is any force applied to an object which changes its dimensions. This change is called Strain.

Biological strains are of 2 types :-

1) Elastic biological strain - are those changes in plant's function that return to optimum level when environmental conditions become normal.
eg. reduced Photosynthesis

2) Plastic biological strain - are changes in plant's function that do not return to optimum levels.
eg. Stresses of water deficit, drought, frost, heat, salinity etc.

Effects of stress are measured in terms of plant survival, crop yield, (biomass) growth, primary assimilatory processes eg Carbon assimilation, mineral uptake which are related to overall growth of plant.

Stress tolerance is the plant's ability to cope with adverse environment.

NOTES DATE

Ultraviolet Stress tolerance in Cyanobacteria

Cyanobacteria are a primitive group of Gram-ve photoautotrophic prokaryotes having cosmopolitan distribution. They are major biomass producers both in aquatic & terrestrial ecosystems. They are a valuable source of various natural products of medicinal & industrial importance. They fix atmospheric nitrogen so are used as Biofertilizers in in rice field.

Increase in ultraviolet radiation (UVR) reaching the earth's surface due to anthropogenically released chemicals as CFCs (Chlorofluoro carbons), CCBs (Chlorocarbons) & OBMs (Organobromides) has become a subject of major concern.

→ Ultraviolet-B (UV-B) radiation has greatest potential for cell damage by directly influencing the structure of proteins & DNA which have absorption maxima in this region & indirectly via production of ROS (reactive oxygen species).

→ Ultraviolet-A (UV-A) radiation has indirect effects via energy transfer from UV-A stimulated

DATE

Chromophores to the DNA target (or) via photosensitized (chlorophylls & phycobilins) production of ROS.

Growth, cell differentiation, motility & photo-orientation are affected by UV radiation on Cyanobacteria.

Cyanobacteria which are exposed to both photosynthetically active radiation (PAR: 400 – 700 nm) & UVR have evolved ~~mitigation~~ defense mechanisms (tolerance mechanisms) to direct & indirect damaging effects of UVR.

These strategies include :-

1) Avoidance.
2) Scavenging of ROS by non-enzymatic & enzymatic antioxidant molecules.
3) Synthesis of UV-absorbing / screening compounds such as mycosporine-like amino acids (MAAs) & Scytonemin.
4) Repair of UV-induced damage of DNA & Resynthesis of Proteins.

1. Avoidance as first line of defense :-

(a) Cyanobacteria when exposed to high solar UVR in their natural habitats migrates from high to low UVR levels in water column.

b) They form mats which contain different cyanobacterial species or

Page No.

DATE

filaments enclosed in amorphous silica matrices.

c.) They change their morphology to increase self shading

d.) They synthesize extracellular polysaccharides.

Vertical gliding motility patterns of Oscillatoria sps. & Spirulina sps. from hypersaline ponds revealed that Cyanobacteria protect their photosynthetic machinery from UV-A & UV-B radiation damage by downward migration

Highest incidence of migration was observed in Microcoleus

Synthesis of extracellular glycans in Nostoc commune was stimulated by UV-B to provide UV resistance by increasing the effective path length for absorption of radiation.

2.) Scavenging as a second line of Defense:-

Once UVR reaches inside the cell, it interacts with oxygen & other organic compounds to produce toxic ROS such as Superoxide (O_2^-), hydroxyl radical (OH^-) or hydrogen peroxide (H_2O_2) resulting in oxidative stress.

To overcome oxidative stress, Cyanobacteria have developed antioxidant

Page No.

DATE

system. This system includes non-enzymatic & enzymatic antioxidants.

Non enzymatic antioxidants are ascorbate (vitamin C), α-tocopherol (Vit. E), carotenoids & reduced glutathione (GSH)

Enzymatic antioxidants are superoxide dismutase (SOD), Catalase, glutathione peroxidase (GSH-Px) etc.

Carotenoids protect cells against photo-oxidative damage by absorbing energy from excited chlorophyll molecules & quenching singlet state oxygen while α-tocopherol prevents lipid peroxidation by scavenging ROS.

Ascorbate directly quenches ROS. Glutathione is involved in α-tocopherol & ascorbate regeneration through glutathione-ascorbate cycle.

SOD scavenges superoxide radicals & converts them to H_2O_2 which is further converted to H_2O & O_2 via catalase-peroxide system.

An increase in activity of SOD & APX was observed in Nostoc sps. & Phormidium sps. as a result of high light (PAR : 400-700 nm).

Exogenous addition of ascorbic acid & N-acetyl cystine antioxidants resulted in higher survival rate of Anabaena sps. due to reduction in chlorophyll bleaching, reduced damage to photosynthetic apparatus, lipid peroxidation & DNA strand breakage. Under UVR induced oxidative damage

Page No.

DATE

3.) **Screening as a third line of Defense:**

Screening of damaging U.V.R by UV-absorbing compounds has been developed by several Cyanobacteria under prolonged UVR exposure.

MAAs & Scytonemin are well known UV-absorbing & screening compounds that provide photoprotection against UVR. These compounds prevent 3 out of 10 photons from hitting cytoplasmic targets in Cyanobacteria. They can also act as antioxidant & prevent damage by ROS resulting from UVR.

Biosynthesis of 3 MAAs in response to UVR was reported in rice-field Cyanobacterium (Anabaena doliolum). They are mycosporine-glycine, porphyra-334 & Shinorine.

Scytonemin is located in extracellular polysaccharide sheath of some Cyanobacterial sps. It has an in vivo absorption maximum at 370 nm. Scytonemin reduces entry of UV-A radiation into cell by 90%. It is highly stable & performs screening activity without any further metabolic investment.

4. **Repair & Resynthesis as a Fourth line of Defense:**

When UVR escapes first, 2nd & 3rd line of defense mechanism & then cause damage to the bio molecules like DNA &

Page No.

DATE

protein, then 4th line of defense mechanism acts.

Presence of multiple copies of genomic DNA in Cyanobacteria nullify the effect of single mutations caused by UVR. Further, existence of several DNA repair mechanisms strengthen Cyanobacteria to cope with radiation effects.

These mechanisms include photoreactivation by photolyase. During photoreactivation Cyclobutane type pyrimidine dimers are monomerized by the enzyme DNA photolyase which is activated by UV-A & blue light.

In excision repair, first damaged DNA is nicked, then short single-stranded segments with base lesions are removed & the gaps are filled with resynthesis.

RecA-like genes from Cyanobacteria complement a recA deletion from E. coli. Activation of the RecA protein by DNA damage is the first step of the SOS repair mechanism. RecA protein cleaves LexA repressor & the SOS genes are expressed.

Increased protein degradation & resynthesis to replace UV-sensitive proteins when damaged is an effective method to conter UV damage.

Increased turnover of D1 & D2

Page No.

DATE

proteins of photosystem II was observed in Synechocystis sp. in response to UV-B radiation.

UV-damaged D1 & D2 proteins are removed from the thylakoid & are replaced by newly synthesized D1 & D2 molecules.

→ UV stress influences a total of 493 proteins comprising of an early shock response influencing 214 proteins & a late acclimation response influencing 279 proteins.

Cyanobacteria also undergo apoptosis or programmed cell death when cell is damaged beyond repair.

D1 protein is encoded by psbA II & psbA III →

UV inducible gene products in Cyanobacteria

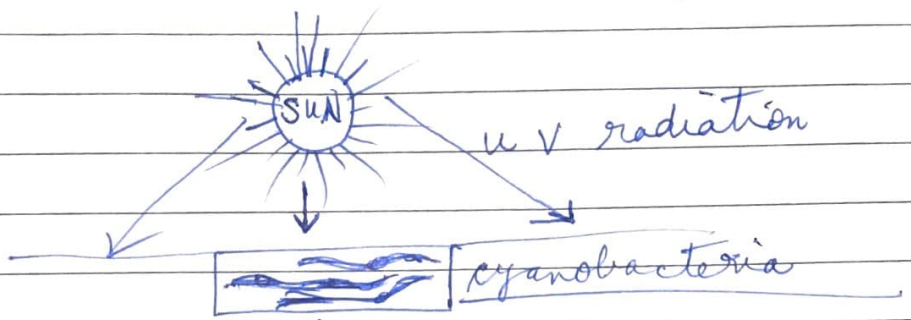
Gene product	UV Source	Organism →
Rec A-like protein	UV-C	Anabaena viralibis
UV shock protein	UV-C	Phormidium laminosum
UV shock protein	UV-B + UV-A	Synechococcus PCC 7942
D1:2 protein	UV-B	"
psbA mRNA	UV-B	Synechocystis PCC 6803
ClpP$_1$ protein	UV-B	Synechococcus PCC 7942.

Page No.

DATE _____

Under normal conditions, psbAII is expressed.

In response to UV-B stress psbAII gene is switched on & the pool of psbA mRNA for production of new D1 protein increases.



1st line

Avoidance

- Mat formation
- Migration
- Change in morphology
- Synthesis of extracellular Polysaccharide
- Enclosure of filaments in amorphous silica matrices.

2nd line

Scavenging

- Enzymatic
  - → SOD
  - → Catalase
  - → Apx
  - → GR
  - → etc.
- Non-Enzymatic
  - → Carotenoids
  - → Ascorbate
  - → Phycobiliproteins
  - → α-tocopherol

3rd line

Screening

- MAAs
- Scytonemin
- Bioprotein glucoside

4th line

Repair & Resynthesis

- De novo Synthesis of proteins
- DNA repair
- PCD (programmed cell death)

Page No. _____