GLOBAL SYMPOSIUM ON
SALT-AFFECTED
SOILS

20 - 22
October, 2021
Virtual meeting

Effective Halophilic Microbes for Bio-amelioration of Coastal Saline Soils

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Introduction

- **According to FAO, if corrective measures are not taken then salinity may result in 30% land loss in next 25 years and 50% loss by 2050 (Munns 2002)**
- **In India, it is expected that if not reclaimed and managed, SAS may increase in irrigated regions from 6.7 million to 11.0 million ha by 2050.**
- **Hence it is necessary to reclaim salinity affected regions for better future and food security**
- **In this regard, useful soil microbes known as PGPRs can be very handy and provide a sustainable solution to the problem**
- **An understanding of saline soil management and amelioration practices is important for long term sustainable agriculture**
- **Microorganisms could play important role in adaptation strategies and increase of tolerance to abiotic stresses including salinity in agricultural plants (Arora et al., 2012)**

Salinity Problems in India

- **India has 8129 km long coastline.**

- **Coastal ecosystem provides very delicately balanced resources, that sustains substantial human and animal population.**

- **The resources, if properly managed, can contribute significantly to the GDP of the country.**

THE COASTAL SOILS EXHIBIT A GREAT DEAL OF DIVERSITY IN TERMS OF CLIMATE, PHYSIOGRAPHY AND PHYSICAL CHARACTERISTICS AS WELL AS RICH STOCK OF FLORA AND FAUNA.

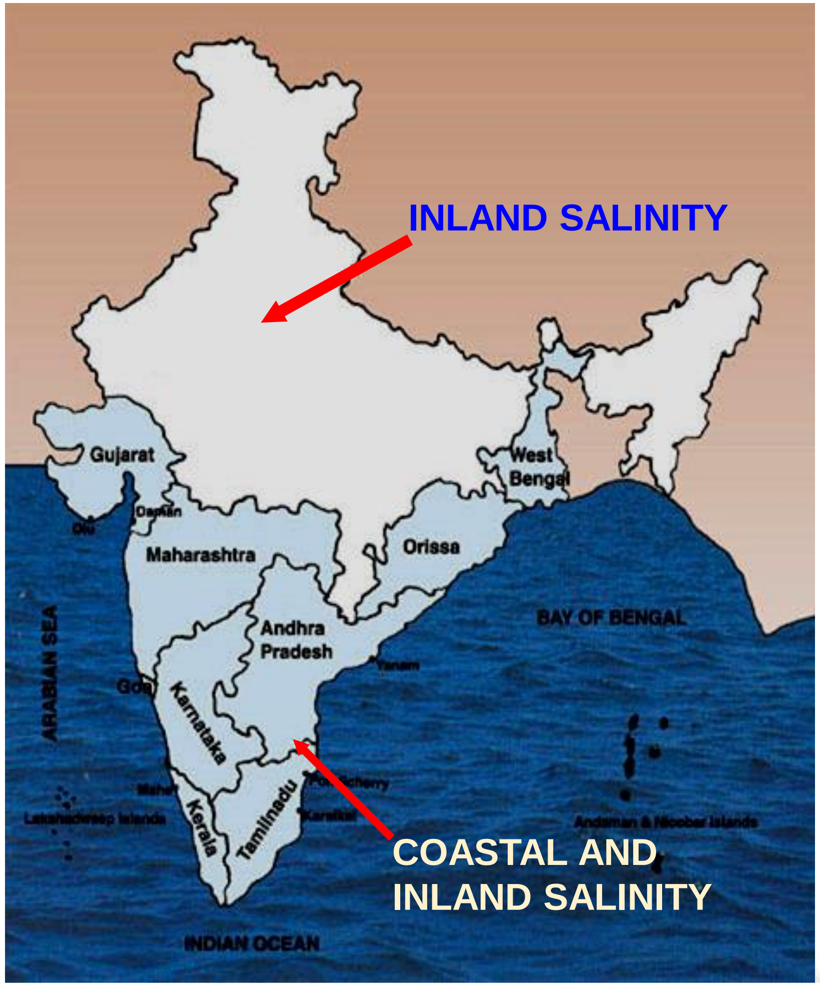


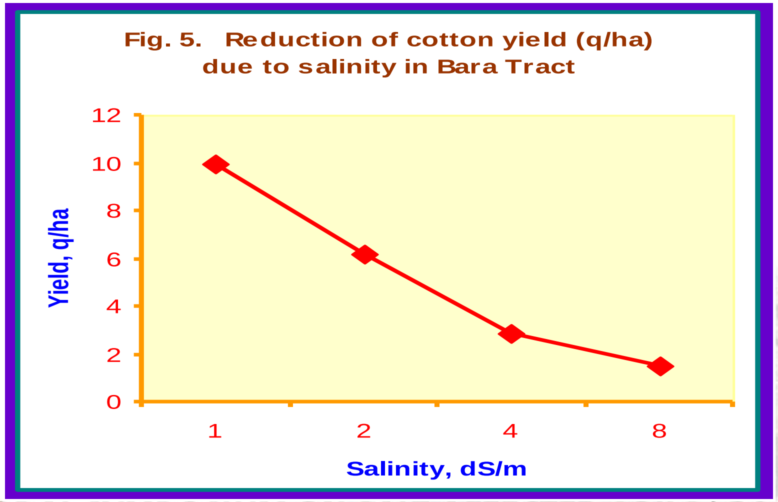
Fig.1. The Coastal States and Union Territories in India

The Severity of Coastal Salinity

Highly saline soil in coastal Gujarat

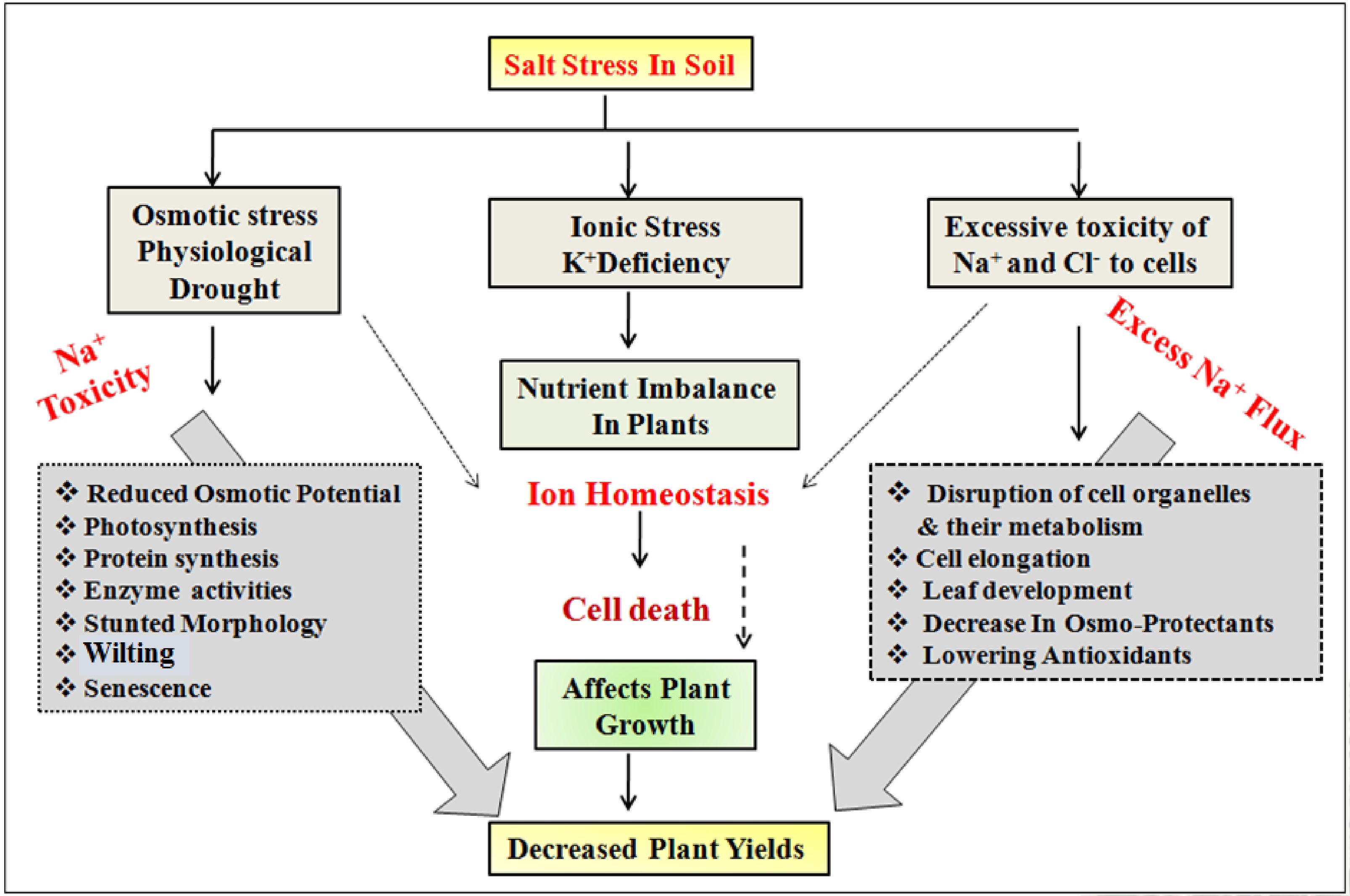
Uneven stand of cotton on saline black soil

Highly alkaline soil



Reduction in cotton yield due to salinity

Effect of salt stress on crop growth and development



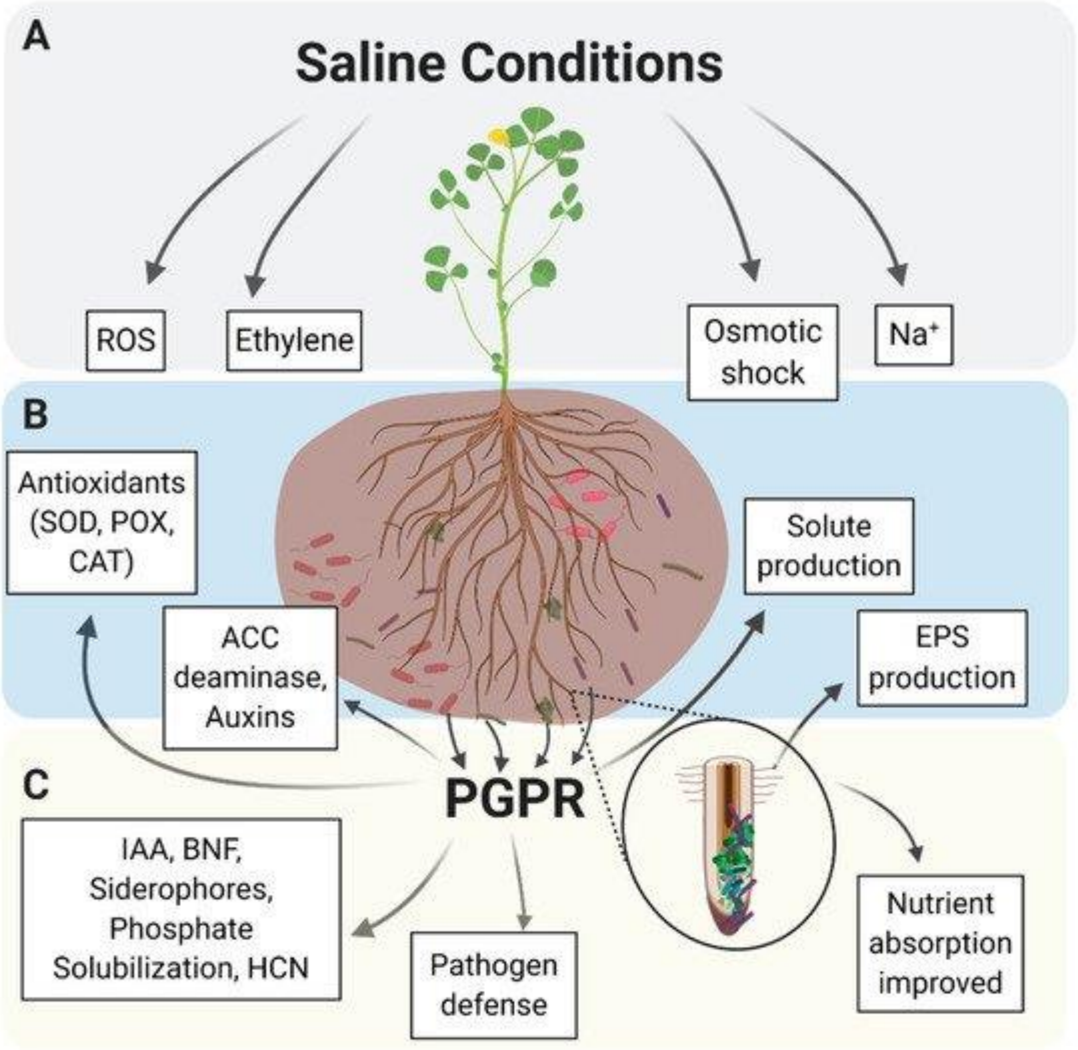
Microbial Management of salt affected soils

- Both physical and chemical methods are not cost- effective for saline/sodic soil reclamation.
- Halophilic microorganisms are organisms that grow optimally in the presence of high salt concentrations.
- The applications of halophilic bacteria include recovery of salt affected soils by directly supporting the growth of vegetation thus indirectly increasing crop production. They also enhance production of organic acids.
- Plant-microbe interaction is beneficial association and can be more efficient method used for the reclamation of salt affected soils.

Bio-remediation of SAS

- Salt tolerant useful plants
- Salt tolerant crop varieties
- Halophilic PGPR
- Mycorrhiza

Salt tolerance-related PGPR and their role in enhanced salt tolerance in plants



(A) Saline soils cause an abundance of toxic molecules such as ethylene and reactive oxygen species (ROS) to form and impede plant processes, leading to disease and death in plants without sufficient mechanisms of salt tolerance. Na+ ions disrupt the function of plant ion channels, leading to plant osmotic shock.

(B) Direct mechanisms by which ST-PGPR can enhance plant salt tolerance. Each ST-PGPR produces different antioxidants or solutes to help fight salt toxicity.

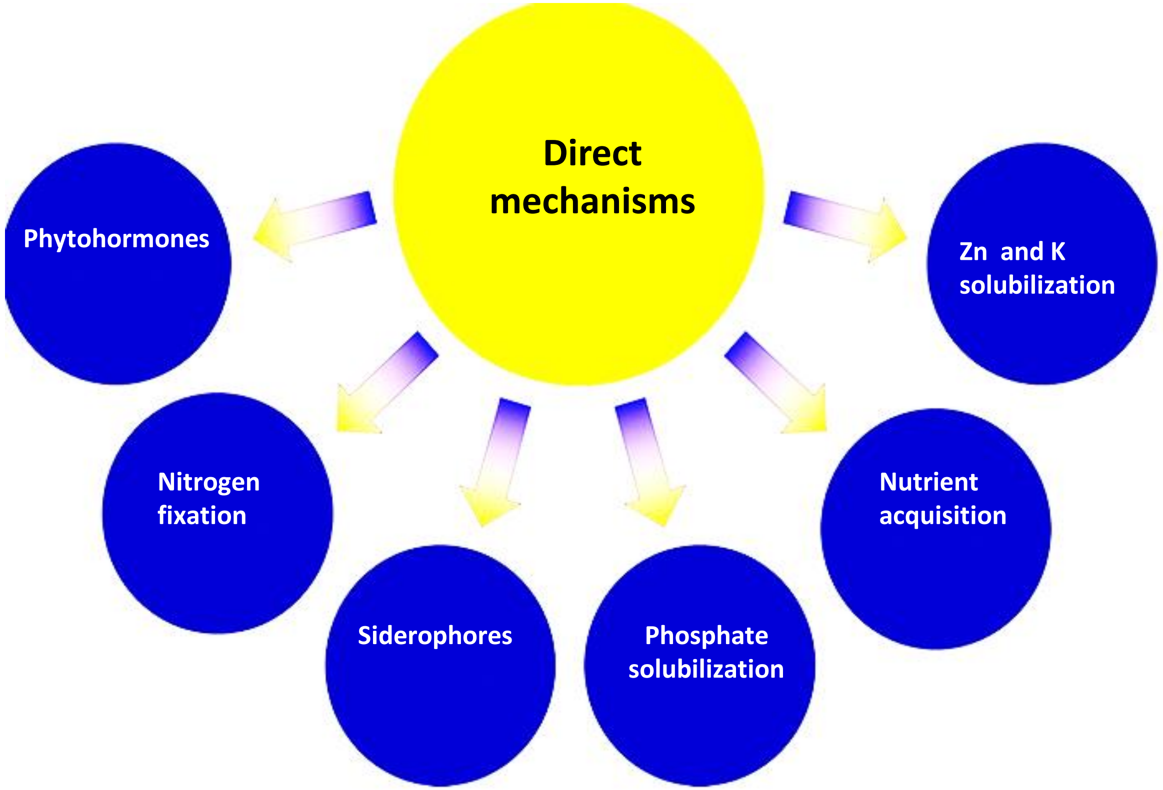
(C) Indirect methods of ST-PGPR plant salt tolerance enhancement. Not all ST-PGPR rhizobium produce all substances mentioned above.

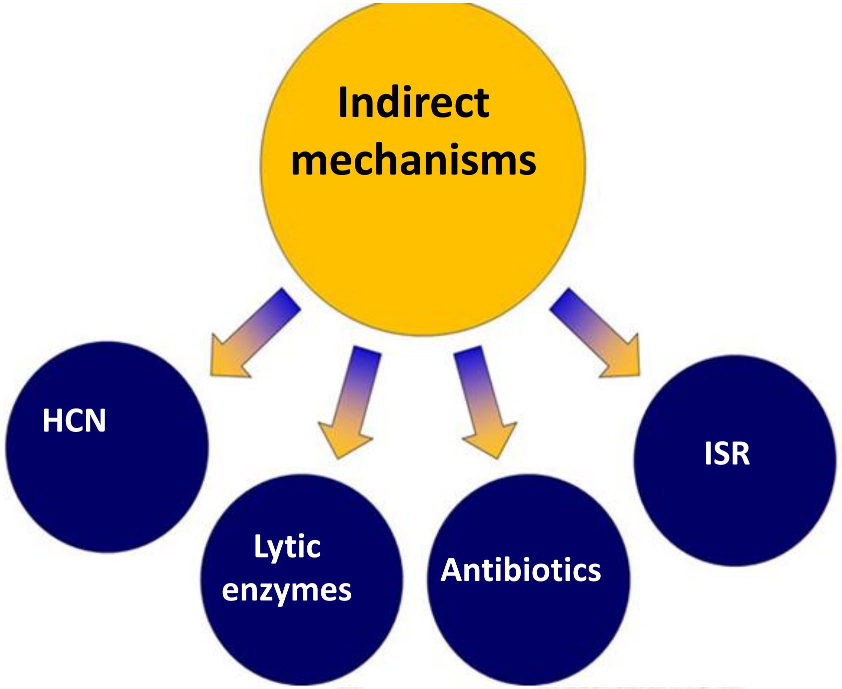
PGPR

- **The bacteria inhabiting the rhizosphere and beneficial to plants are termed plant growth promoting rhizobacteria (PGPR) (Kloepper et al. 1980)**

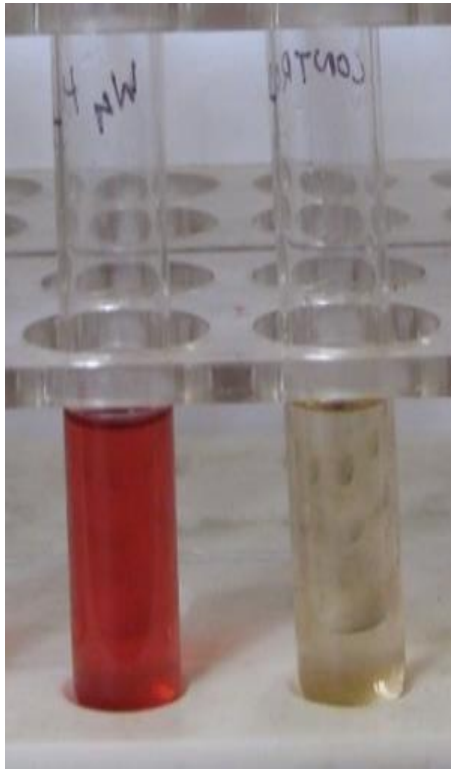
- **PGPR perform diverse roles such as plant growth promotion and disease management of phytopathogens (Arora et al. 2012)**

Direct and Indirect Mechanisms





Phytohormones



- **Indole Acetic Acid (IAA) Production**

  It is believed that approximately 80% of rhizobacteria produce IAA (Parmar and Dufresne 2011)
- **Cytokinins**

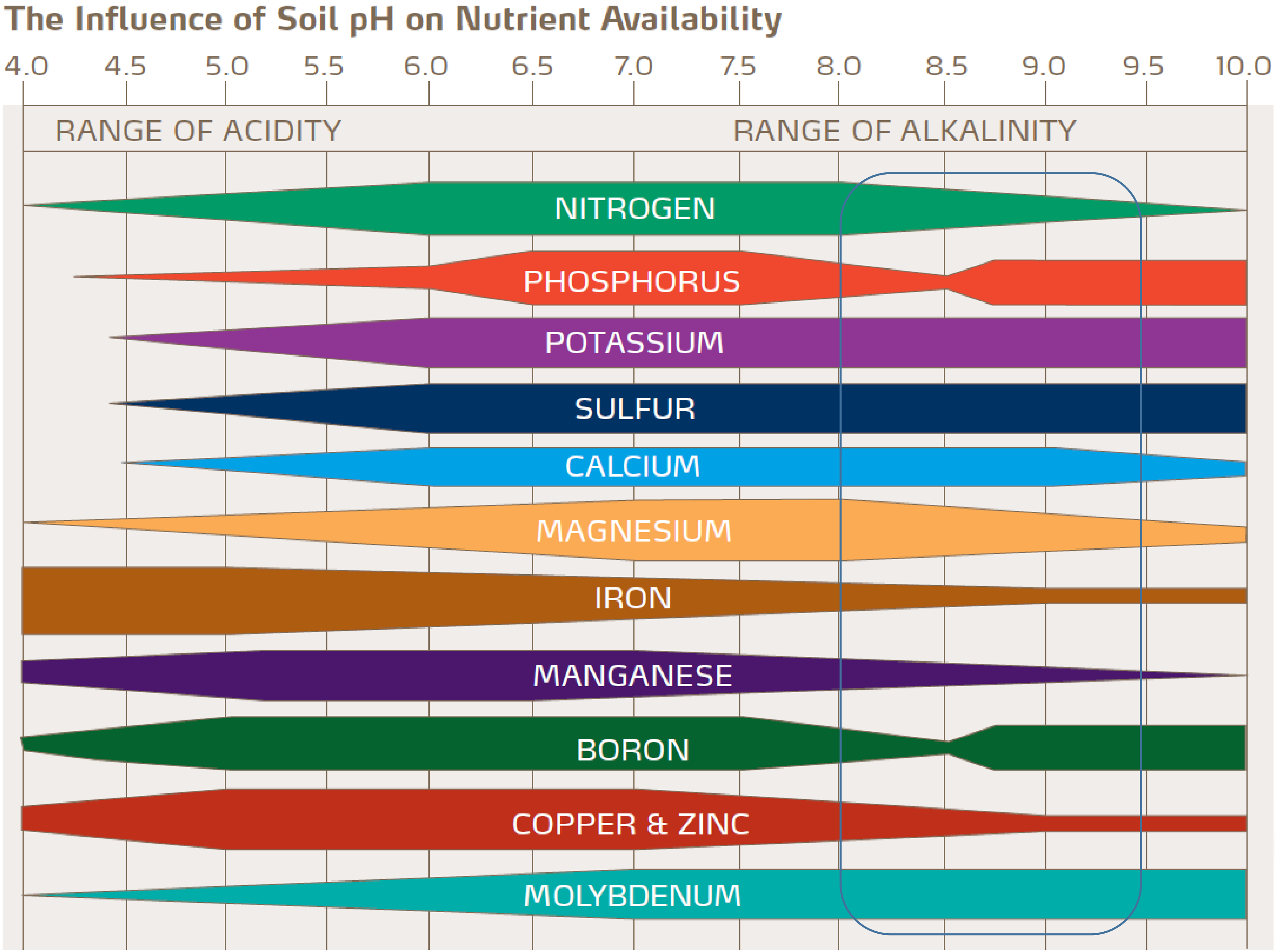
  Plants and plant-associated microorganisms have been found to contain over 30 growth-promoting compounds of the cytokinin group
- **Gibberellins**

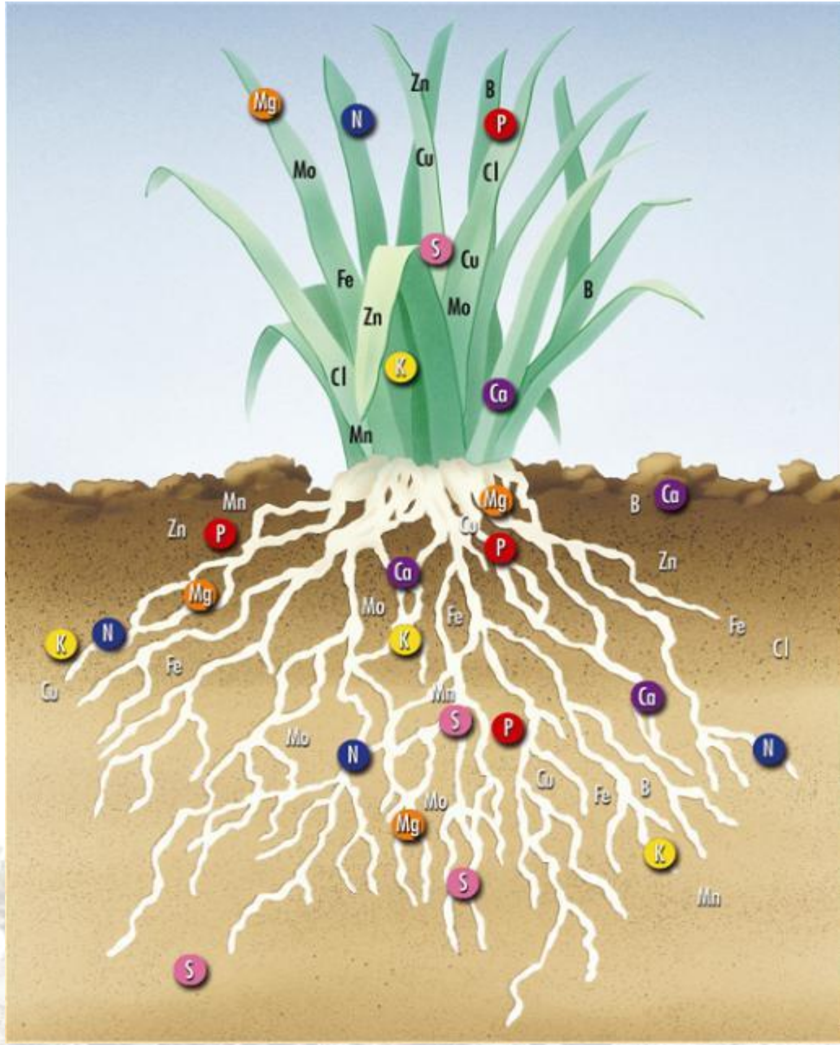
  PGPB have been reported to be associated with increased content of gibberellins in plant tissues (Kang et al. 2009)
- **Abscisic Acid (ABA)**

  PGPR synthesizing ABA which function to protect plant under stressful conditions and enhance plant growth
- **Polyamines**

  It is involved in promoting plant growth by *Azospirillum* is the polyamine cadaverine synthesized from the precursor L–lysine

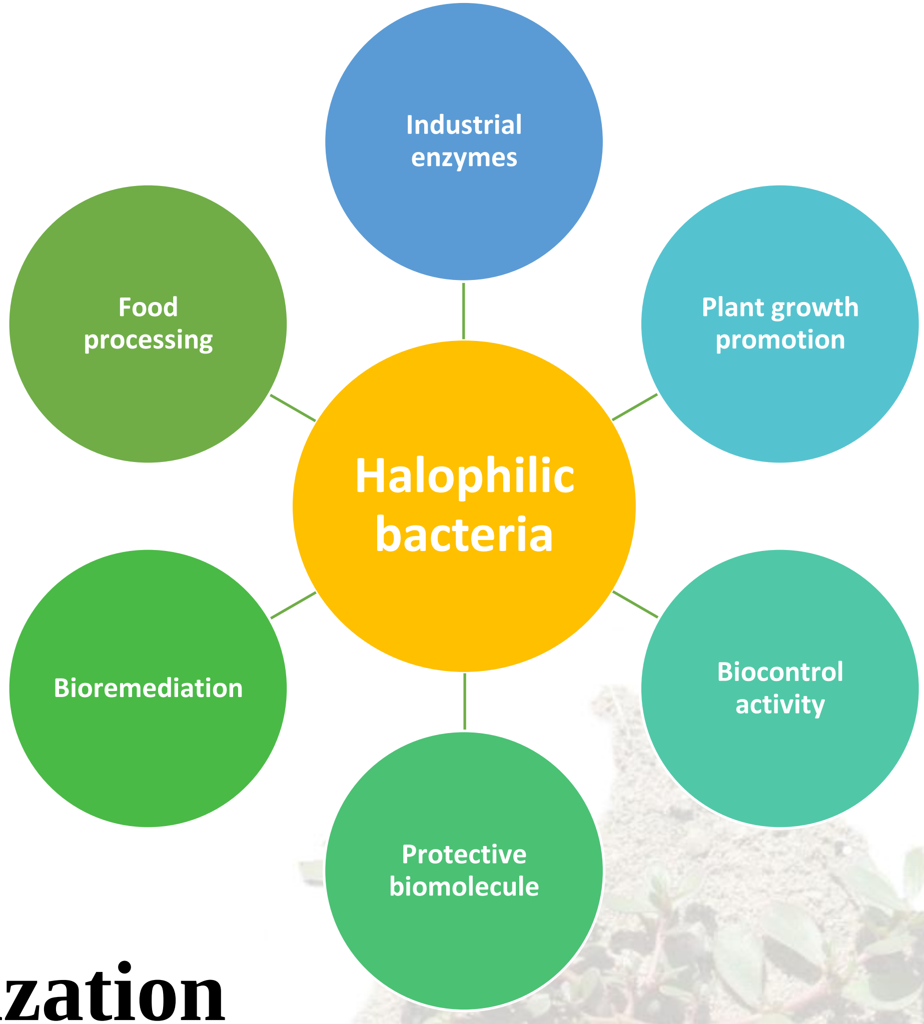
Plant nutrition - Soil





Role of microbes in mitigating salt stress

- Exo-polysaccharide
- Anti-oxydative enzymes
- IAA production
- ACC deaminase
- Nutrient mineralization/mobilization

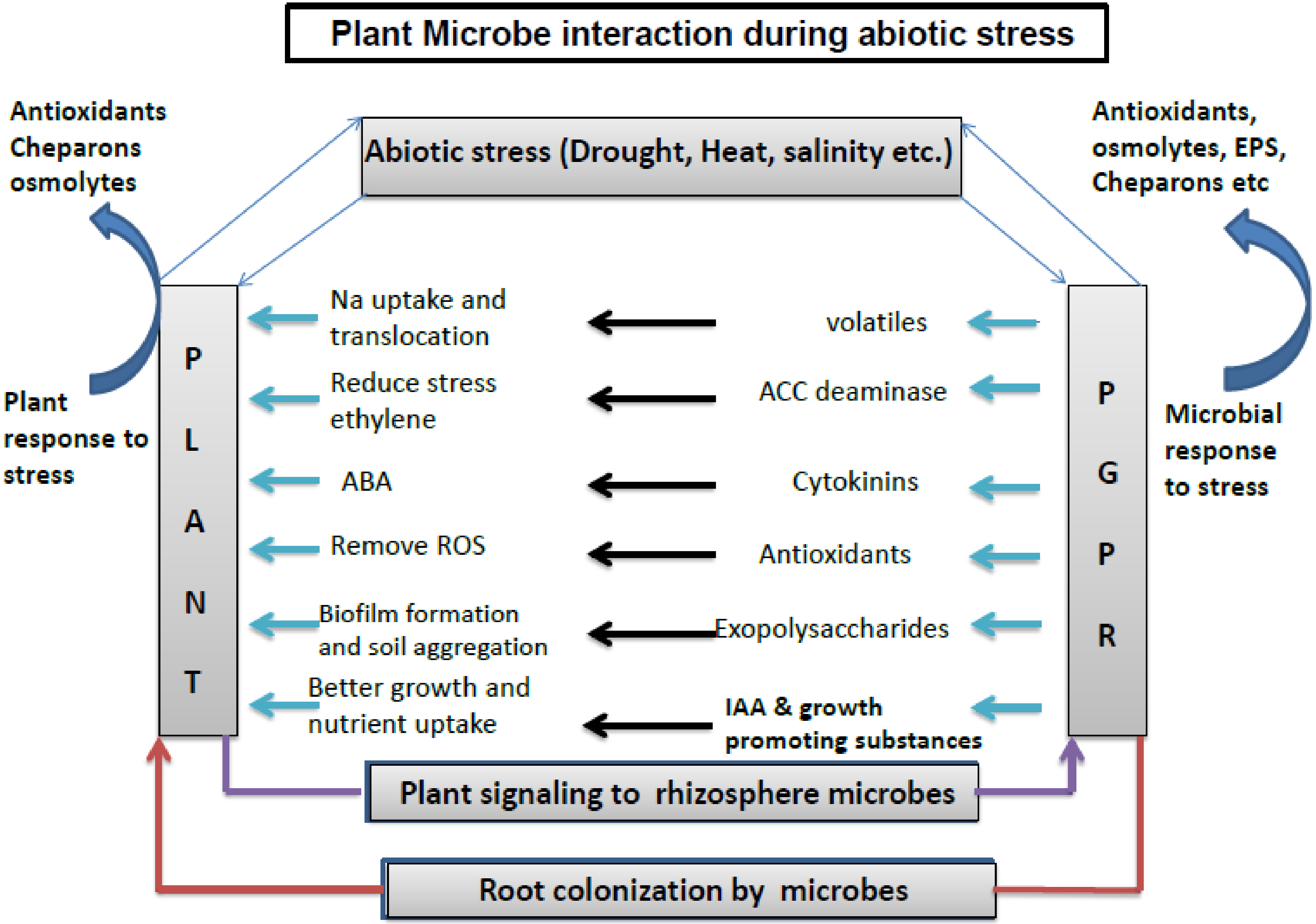


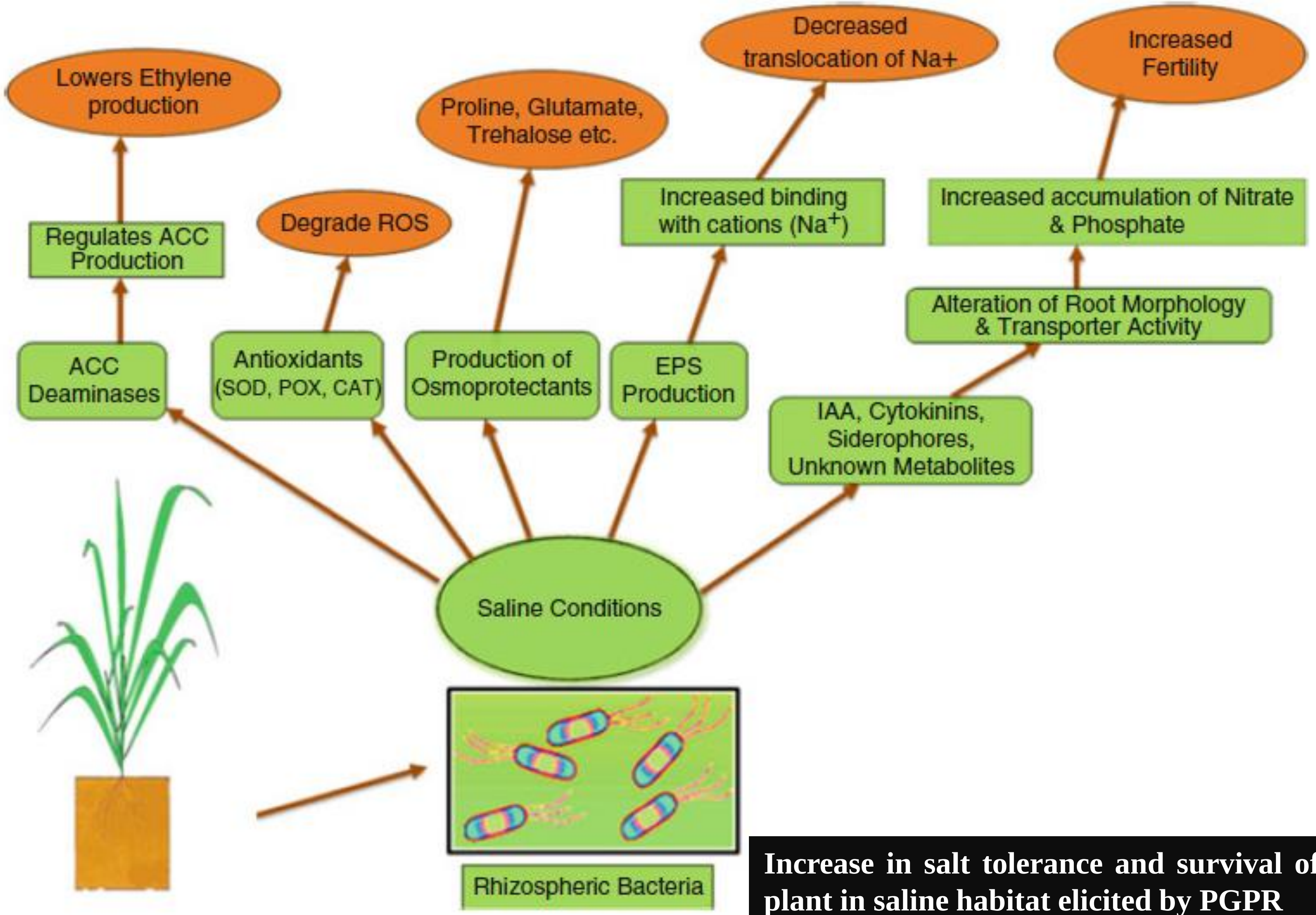
Stress management

- **Halophilic PGPR are efficient stress releasers.**
- **Most of them possess the enzyme, 1-aminocyclopropane-1-carboxylate (ACC) deaminase, facilitate plant growth and development by decreasing ethylene levels, inducing salt tolerance and reducing drought stress in plants (Zahir et al., 2008)**

- **Halophilic or alkaliphilic bacterial strains exhibiting ACC deaminase activity have been identified in a wide range of genera such as**
- ***Acinetobacter***
- ***Achromobacter***
- ***Agrobacterium***
- ***Alcaligenes***
- ***Azospirillum***
- ***Bacillus***
- ***Burkholderia***
- ***Enterobacter***
- ***Pseudomonas***
- ***Ralstonia***
- ***Serratia***
- ***Rhizobium*, etc.**

(Zahir et al., 2009 and Kang et al., 2010)


Plant Microbe interaction during abiotic stress
Abiotic stress (Drought, Heat, salinity etc.)
Antioxidants
Cheparons
osmolytes
Plant response to stress
Antioxidants, osmolytes, EPS, Cheparons etc
Microbial response to stress
P L A N T
P G P R
Na uptake and translocation
Reduce stress ethylene
ABA
Remove ROS
Biofilm formation and soil aggregation
Better growth and nutrient uptake
volatiles
ACC deaminase
Cytokinins
Antioxidants
Exopolysaccharides
IAA & growth promoting substances
Plant signaling to rhizosphere microbes
Root colonization by microbes



Increase in salt tolerance and survival of plant in saline habitat elicited by PGPR

Coastal saline belt of India


Suadea nudiflora


Cressa cretica


Suadea marina


Salvadora persica


Aleuropus lagopoides


Avicennia marina

Dominant halophytes

Details and locations of the halophyte and salt tolerant plant samples collected from halophyte and salt tolerant plant species

	Plant species	Common name	Family	Type	Location	Site
1	*Cressa cretica*	Luni	*Convolvulacea*	Herb	Inland	Occhan, Pahaj
2	*Salicornia brachiata*	Marchar	*Chenopodiaceae*	Herb	Coastal	Hatab,
3	*Suadea nudiflora*	Moras	*Chenopodiaceae*	Herb	Coastal	Aladar
4	*Sphaeranthus indicus*	Gorakh mundi	*Asteraceae*	Herb	Coastal	Gandhar

Ionic content in leaves of halophyte and salt tolerant plant species

Plant species	K (mg/g)	Na (mg/g)	Ca (mg/g)	Mg (mg/g)	S (mg/g)
Cressa cretica	5.91	50.50	20.0	16.8	3.97
Salicornia brachiata	11.92	17.76	24.0	16.8	7.33
Suadea nudiflora	10.32	21.42	12.0	4.8	0.53
Spharanthus indicus	7.66	15.30	14.0	4.8	2.42

Rhizosphere soil analysis of Halophyte species

Halophyte/ salt tolerant species	pH_2	EC_2
Pilu (*Salvadora persica*)	8.2 to 8.7	23.2 to 36.6
Khair (*Acacia catechu*)	7.6 to 8.1	2.7 to 7.5
Luni (*Cressa cretica*)	7.9 to 8.3	16.8 to 28.3
Luno (*Suaeda maritima*)	7.8 to 8.4	19.4 to 33.5
Ber (*Zizyphus nummularia*)	7.6 to 8.4	11.2 to 17.4
Babul (*Prosopis cineraria*)	7.3 to 8.2	15.0 to 38.3
Aak (*Calatropis procera*)	8.2 to 8.6	27.4 to 35.5
Tamarix ericoides	8.1 to 8.8	32.4 to 37.1
Aleuropus lagopoides	7.9 to 8.7	31.4 to 39.6

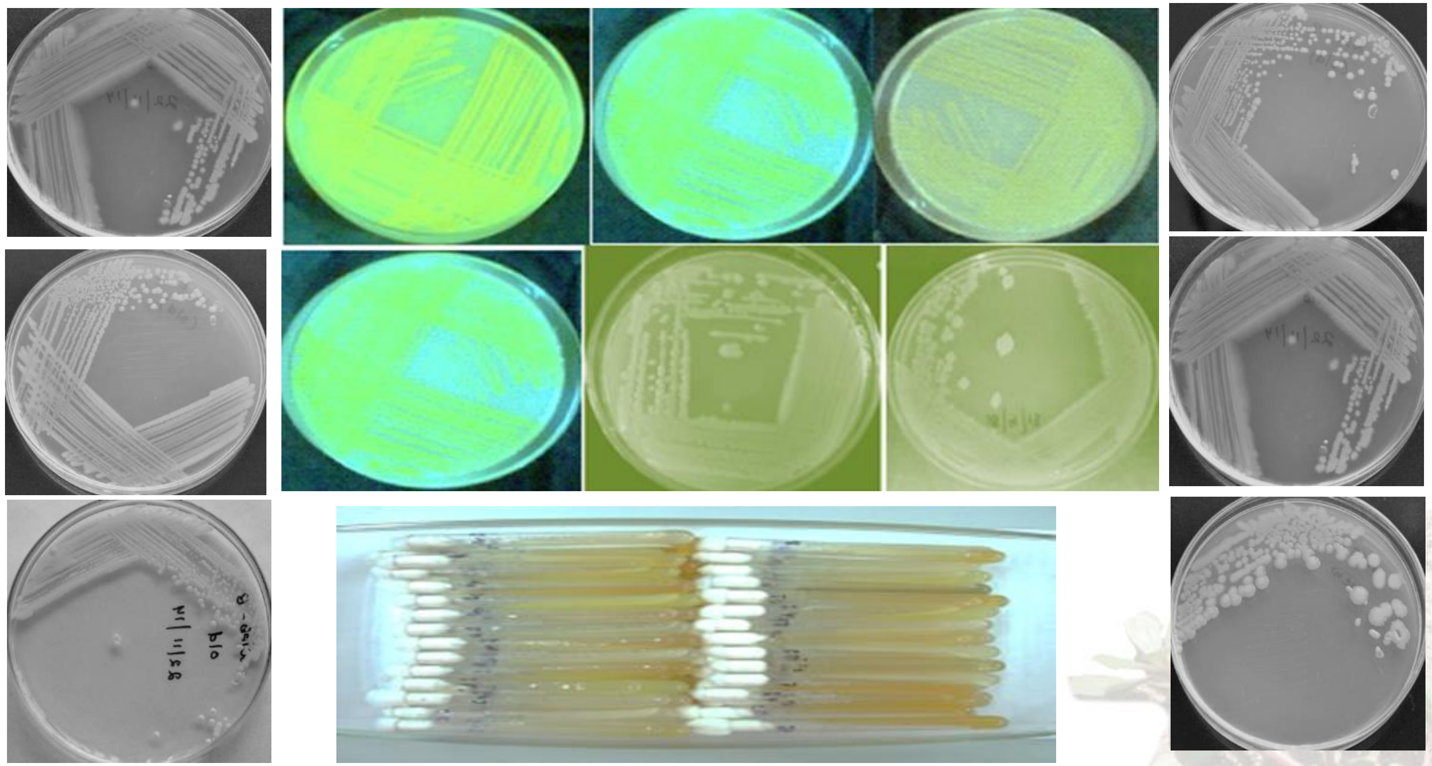
Properties of rhizosphere soil of halophyte and salt tolerant plant species

Soil properties	Range	Mean
pH (1:2 w/v)	7.85-9.25	8.40
EC (dS/m)	2.05-35.50	17.05
Org. C. (g/kg)	1.3-6.7	4.1
Available P (mg/kg)	1.41-2.62	1.98
Available S (mg/kg)	24.4-302.10	124.5
NH_4-N (mg/kg)	3.10-10.08	7.91
NO_3-N (mg/kg)	2.64-7.06	4.17
Exch. Na (mg/kg)	968.7-5171.8	2568.5
Exch. K (mg/kg)	387.5-1775.0	935.2
Exch. Ca (mg/kg)	3400-7100	5600
Exch. Mg (mg/kg)	240-2160	1080
Water holding capacity (%)	43.7-59.4	51.6

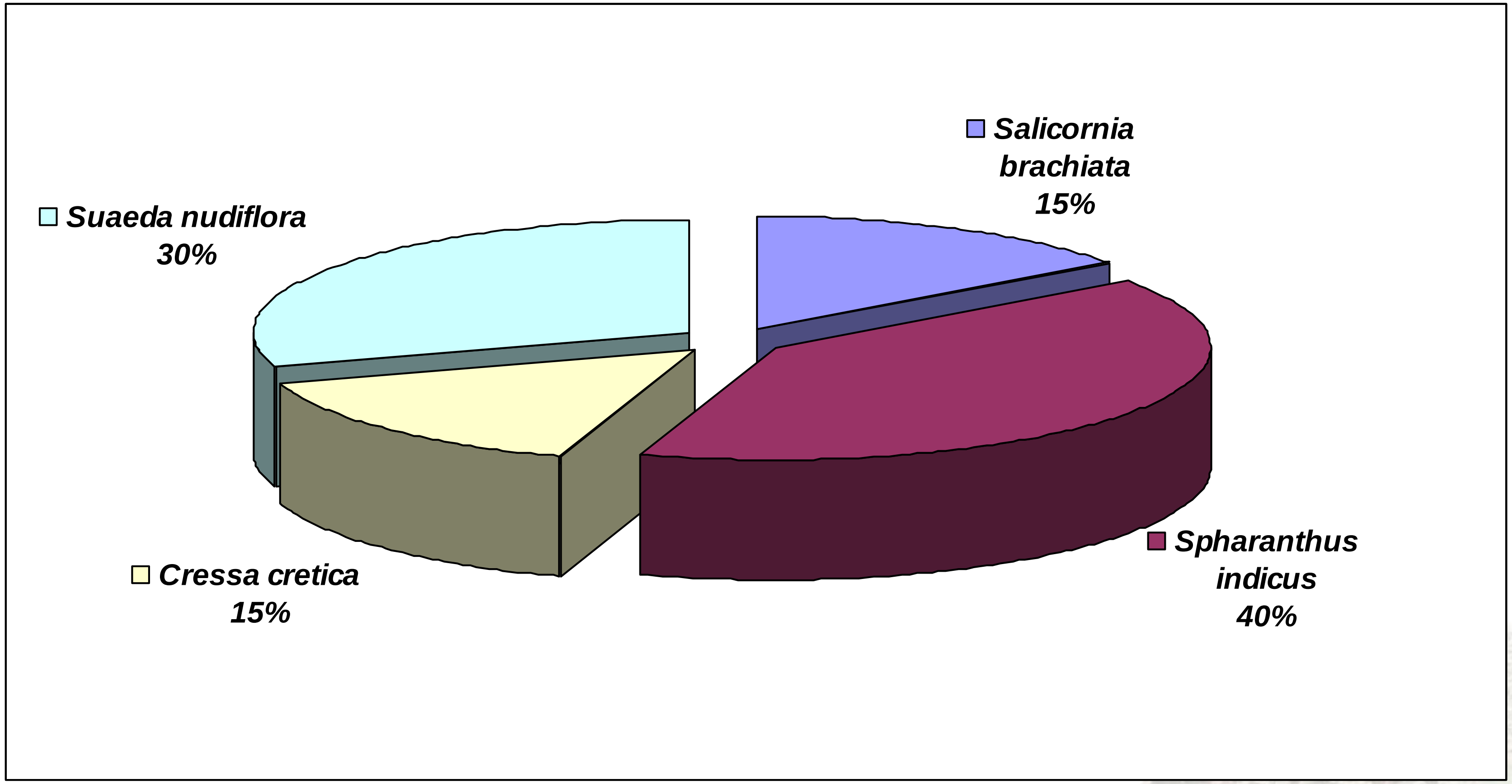
Halophilic Bacterial isolates from rhizosphere soil of different halophytes

Plant species	Total isolates on NA	Grams' reaction		Salt tolerance (NaCl)			Amylase producing
		+ve	-ve	2.5%	5.0%	10%	
Cressa cretica	7	3	4	6	4	-	2
Suadea nudiflora	3	2	1	3	2	-	1
Atriplex nummularia	7	7	-	7	6	-	-
Salvadora persica	3	2	1	3	3	-	-
Sphaeranthus indicus	12	10	2	12	9	1	2
Aleuropus lagopoides	5	3	2	5	5	3	2
Suadea maritima	7	2	5	7	7	3	2

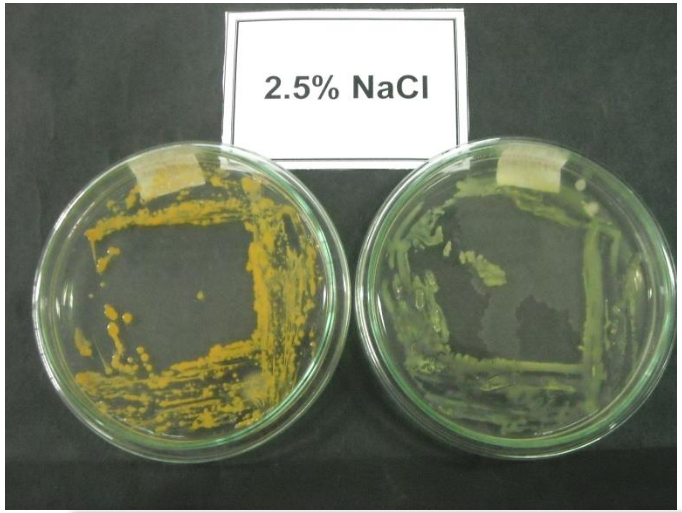
Fluorescent Pseudomonads

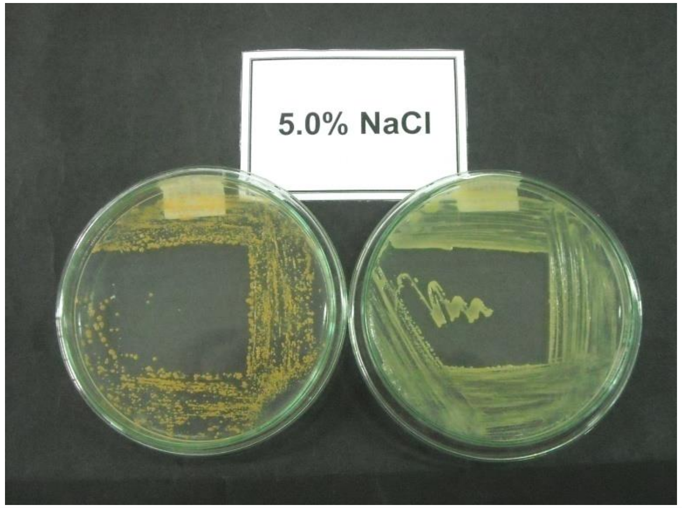


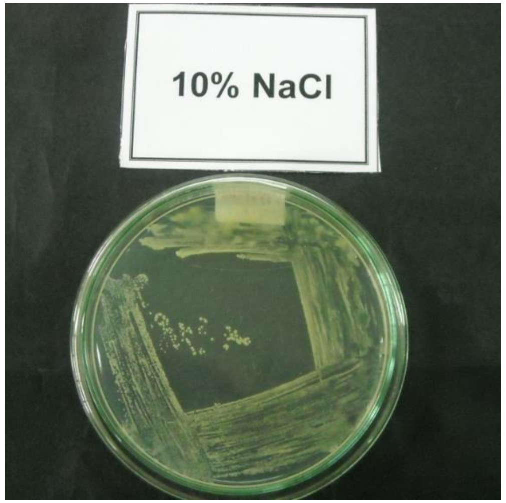
Distribution of endophytic bacteria in leaves of halophytes and salt tolerant plant species from Coastal Gujarat

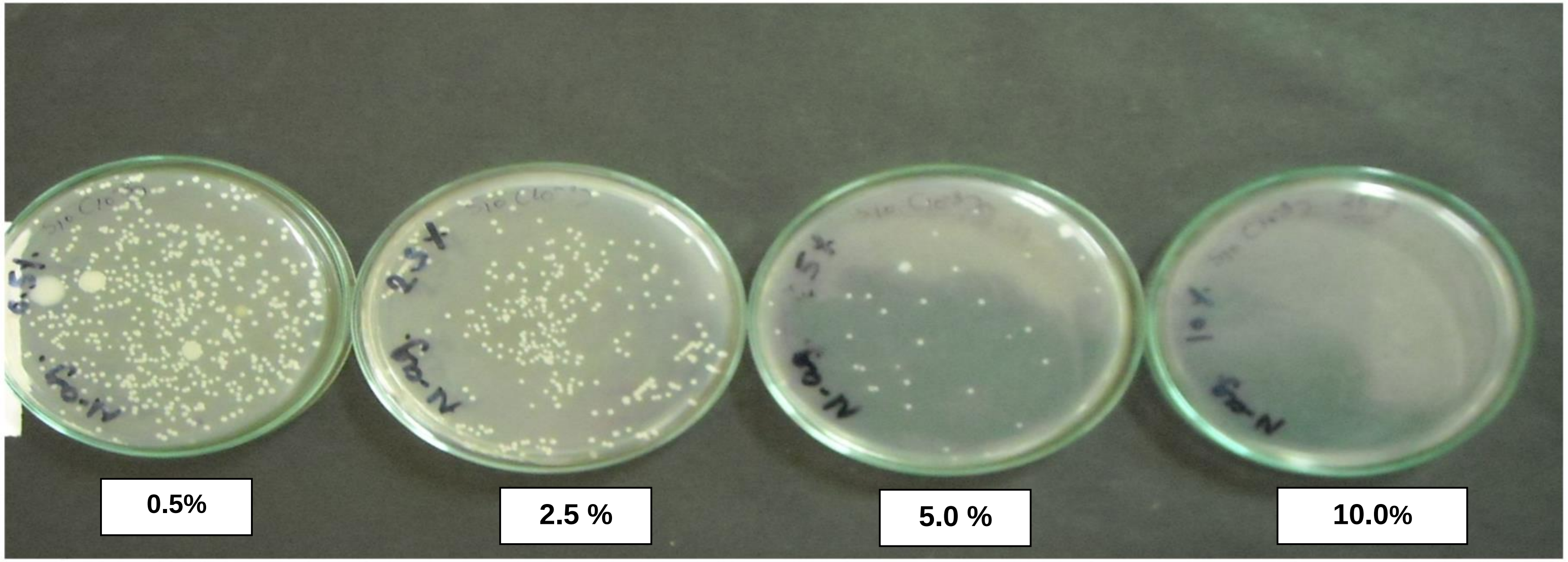


Halophilic bacteria isolates

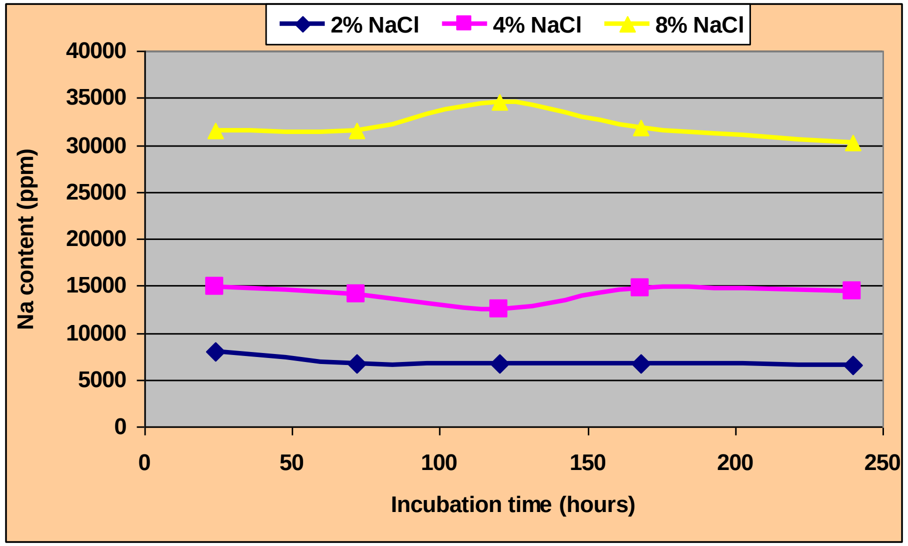




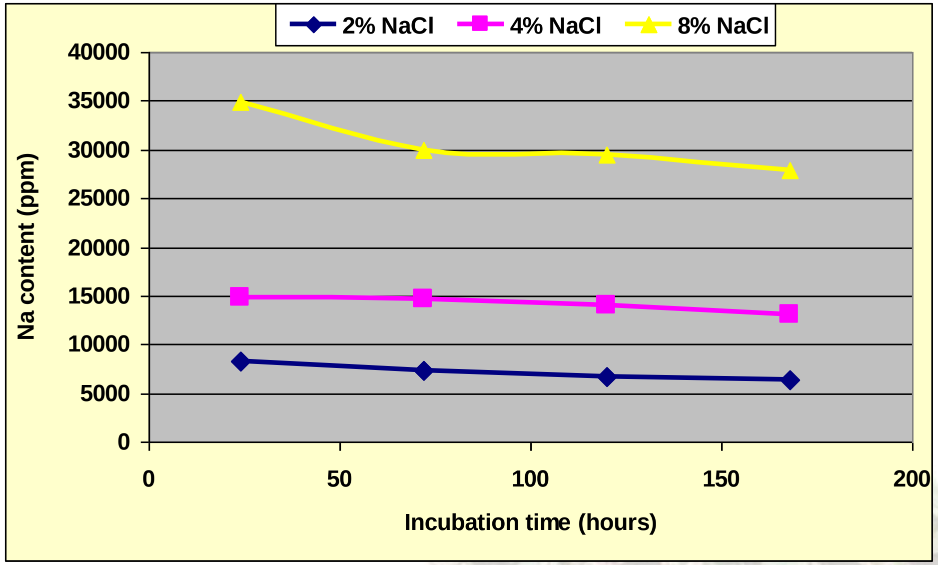




Efficacy of halophilic bacteria in salt removal from media (NA broth)



HB1 isolate (Orange pigmented)



HB2 isolate (Yellow pigmented)

Salt tolerance of endophytic bacteria isolated from leaves of halophytes and salt tolerant plant species

Isolate no	Salt tolerance (NaCl %)			
	2.5%	5.0%	7.5%	10%
1	+	-	-	-
2	+	+	+	+
3	+	+	+	+
4	+	+	+	+
5	+	+	+	+
6	+	-	-	-
7	+	+	+	+
8	+	+	+	+
9	+	+	+	+
10	+	+	+	-
11	+	+	+	+
12	+	+	+	+
13	+	+	+	+
14	+	+	+	+
15	+	+	-	-
16	+	+	+	+
17	+	+	+	+
18	+	+	+	+
19	+	+	+	-
20	+	+	+	+

Plant growth promotion properties of endophytic bacteria isolated from leaves of halophytes and salt tolerant plant species

Isolate no	MR test	VP test	Ammonia production	Indole production	Phosphate solubilization
1	-	-	+	-	+
2	+	-	-	-	-
3	+	+	+	-	-
4	-	-	+	-	-
5	+	+	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	+	+	-	-	-
9	-	+	-	-	-
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	+	+	-	-
15	-	-	+	-	+
16	-	-	+	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	-	-	-	-

+ positive; - negative

PSB isolated from rhizosphere soil of halophyte plants in coastal Gujarat

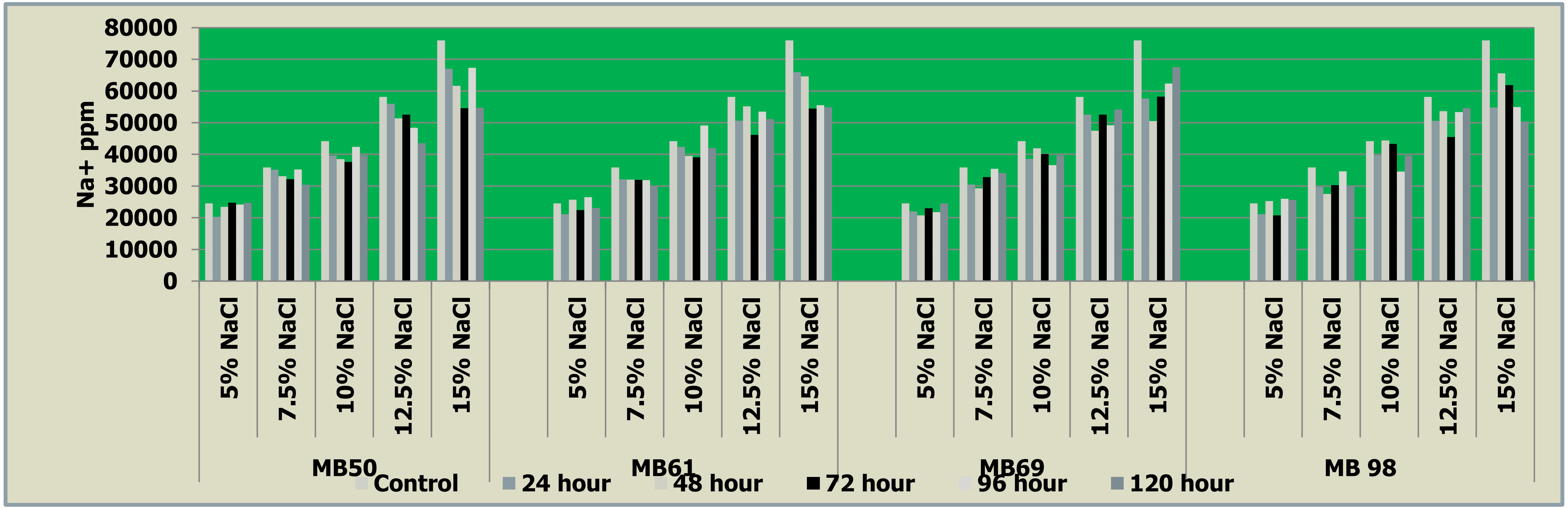
Soil	Total number of colonies (CFU/g)*	No of PSB selected
S-1	12	7
S-2	4	1
S-3	6	4
S-4	7	2
S-5	3	1
S-6	5	1
S-7	4	1
S-12	5	1
S-13	4	1
R-4	6	2
R-10	7	2
R-15	4	1

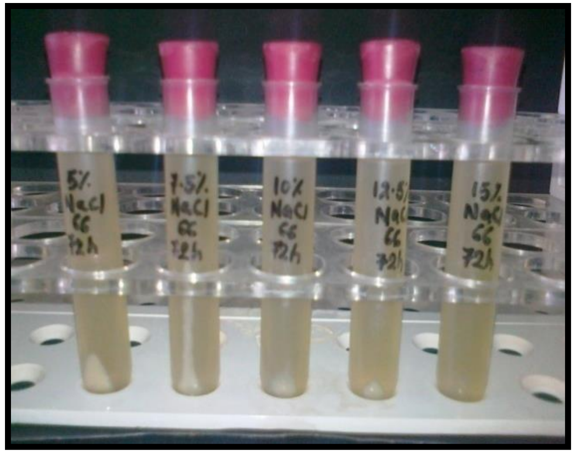
* PSB on Pikovaskay’s agar medium

P Solubilization Efficiency of halophilic PSB

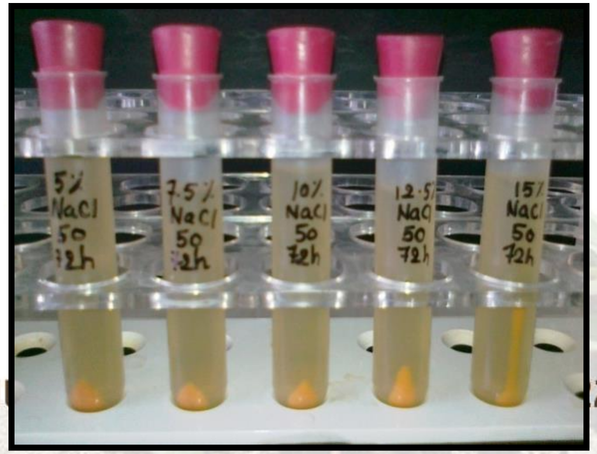
PSB isolate	Phosphate Solubilization index (PSI)	Phosphate Solubilization efficiency (PSE)
CPS 1	75	175
CPS 2	200	300
CPS 3	40	140
CPS 4	100	200
CPS 5	67	167
CPS 6	25	125
CPS 7	50	150
CPS 8	100	200
CPS 9	133	233
CPS 10	71	171
CPS 11	100	200
CPS 12	37	137
CPS 13	33	133
CPS 14	33	133
CPS 15	17	117
CPS 16	167	267
CPS 17	150	250
CPS 18	50	150
CPS 19	33	133
CPS 20	60	160
CPS 21	50	150
CPS 22	75	175
CPS 23	88	187
CPS 24	50	150

Sodium from media upon culturing of isolates (MB50, MB61, MB69, MB98) at different time interval in presence of different salt concentrations

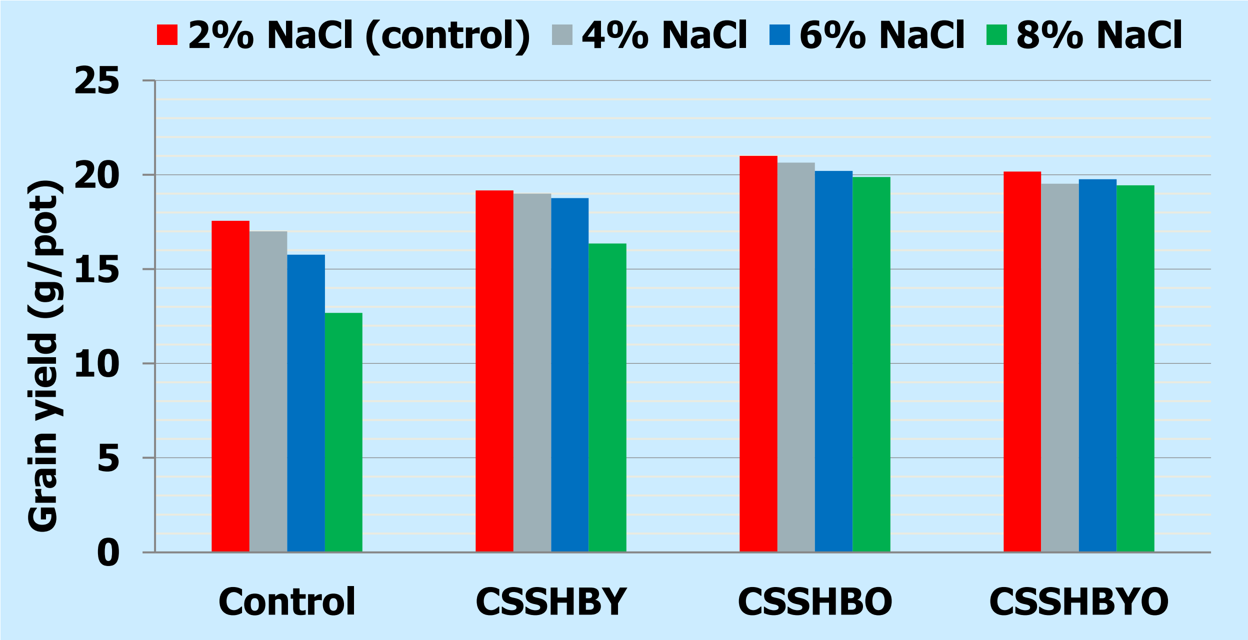


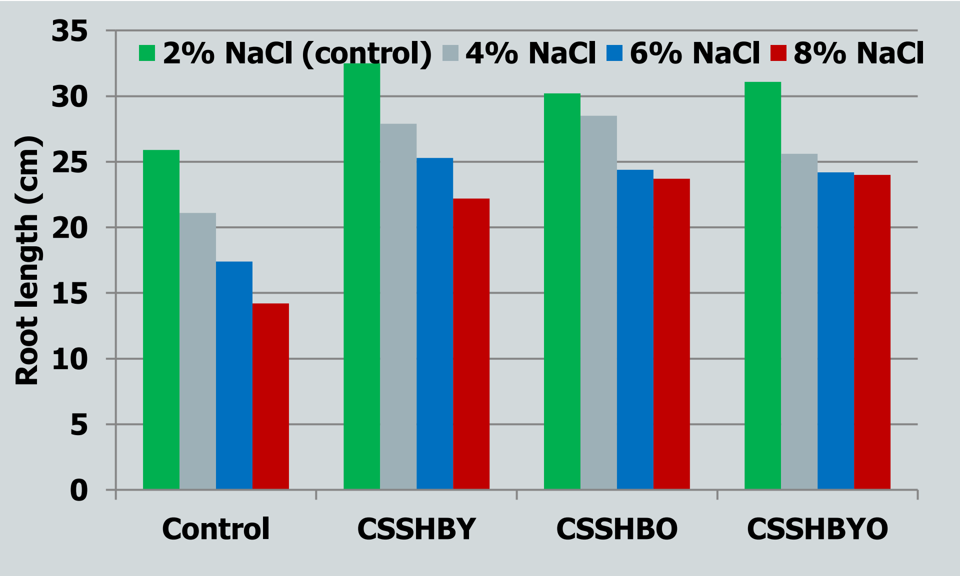


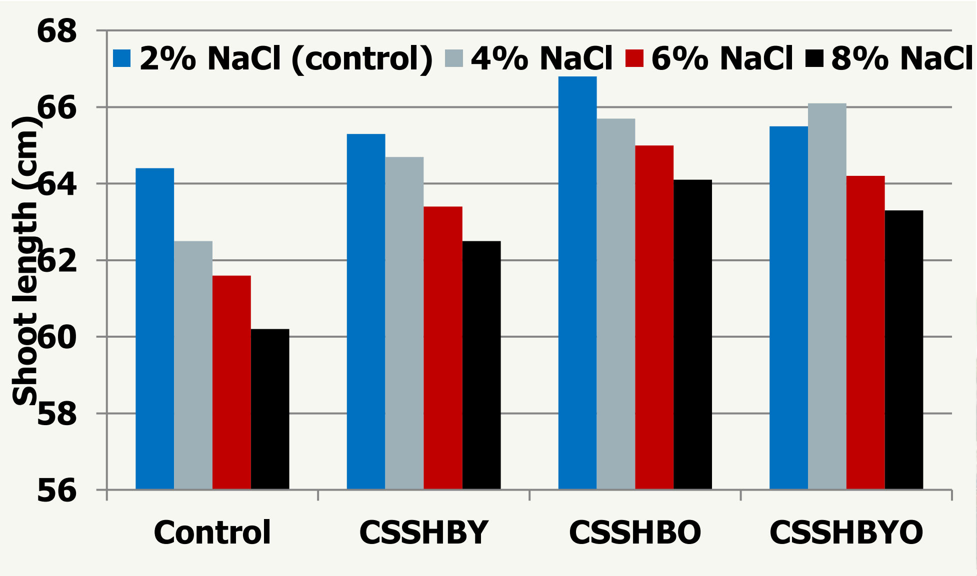
Pellets obtained upon centrifugation after culturing at different time



Wheat performance with halophilic bacteria inoculation







October, 2021

Plant Growth Promotion of halophilic bacteria on inoculation with maize

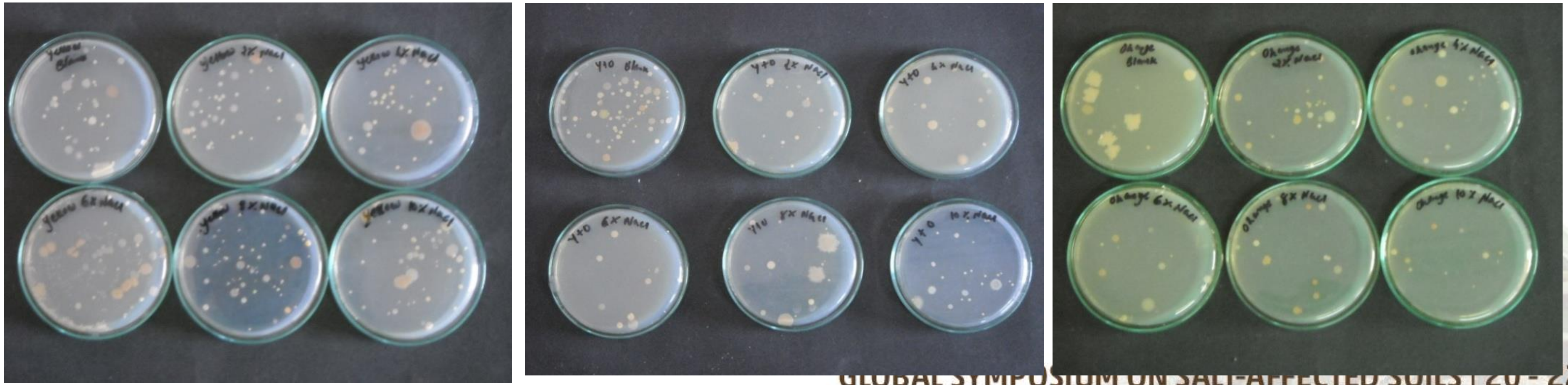
Culture	Treatment (Conc. of NaCl)	Fresh weight (g/pot)	Dry weight (g/pot)	Shoot length(cm)	Root length (cm)
MB55	5%	1.945	0.660	14.50	12.00
MB66	5%	2.920	0.505	25.00	16.80
MB90	5%	2.900	0.665	18.36	17.16
MB94	5%	2.825	0.855	11.15	13.80
Consortium	5%	5.595	0.975	27.07	17.80
Consortium	10%	2.075	0.700	8.90	11.26
Control	5%	1.900	0.490	11.7	10.40

Promising halophiles isolated from saline soils

- *Bacillus subtilis*
- *Bacillus aerius*
- *Bacillus cereus*
- *Virgibacillus salarius*
- *Nesterenkonia flava*
- *Brevibacterium halotolerans*
- *Planococcus maritimus*
- *Pseudomonas indica*
- *Paenibacillus mucilaginosus*
- *Agrobacterium larrymoorei*

CSSRHBY1 and CSSRHBO2 were inoculated in sterile soil to test their efficacy for Na removal from the soil containing different concentrations of NaCl (0% to 10% NaCl).

Na^{+} (mg/kg)				
Treatment	Control	CSSRHBY1	CSSRHBO2	CSSRHBY1+CSSRHBO2
T1=0% NaCl	5011	3389	4096	4028
T2=2% NaCl	6539	4575	4830	6391
T3=4% NaCl	7683	5235	7100	7094
T4=6% NaCl	8534	7591	7952	8425
T5=8% NaCl	9596	8665	9443	9414
T6=10% NaCl	10620	8563	10068	10547



Plates Showing CFU/ml in halophilic bacteria (a) CSSRHBY1 (b) CSSRHBO2 and (c) CSSRHBY1+CSSRHBO2

Effect bacterial inoculation on the growth parameters of wheat variety KRL 219 and 238 with 6% NaCl irrigation (35 days)* at Surat

Bacterial Strain	Root length (cm)	Shoot length (cm)
Control	6.8	19.5
Rh1	8.7	21.3
Rh2	14.0	23.4
Rh5	12.8	26.0
Rh8	13.7	27.3
Rh11	9.0	23.3
Rh12	12.0	22.7
Rh18	13.8	27.2

Bacterial Strain	Root length (cm)	Shoot length (cm)
Control	7.2	20.6
Rh1	9.0	22.9
Rh2	15.0	26.7
Rh5	8.7	26.0
Rh8	15.4	29.0
Rh11	11.8	22.5
Rh12	18.6	26.8
Rh18	15.8	29.4

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Consortium	10%	2.075	0.700	8.90	11.26
Control	5%	1.900	0.490	11.7	10.40

Bio-inoculation of HB on wheat yield

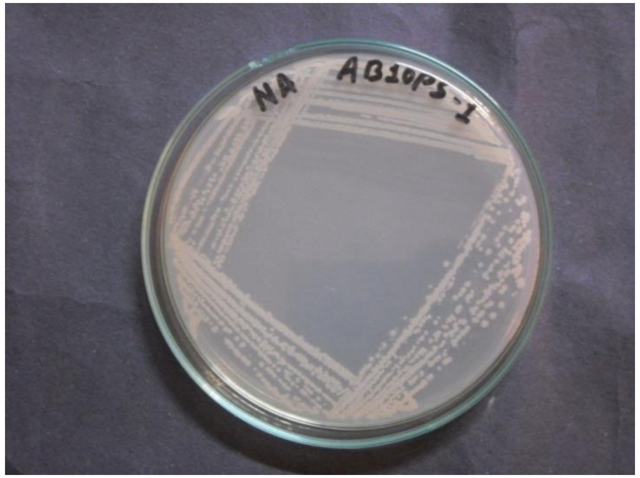
Treatment	Grain yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
Control (FYM)	3127	5028
FYM+HB1	3742	5645
FYM+HB2	4011	6112
FYM+HB3	3996	5872
FYM+Consortia	4129	6245
CD(5%)	112.7	169.1

Initial soil pH = 9.4; Org. C= 0.21%; Plot size: $30m^2$

Effect on soil after harvest of wheat

Treatment	Soil depth(cm)	Na (mg/kg)	K (mg/kg)	Av. P (mg/kg)	MBC (µg/g)	DHA (µg TPF/g/h)
Control (FYM)	0-15	323.8	28.70	9.9	82	12.45
	15-30	855.75	26.50	5.5	68	10.24
	30-60	205.7	25.80	4.9	41	7.48
FYM+HB1	0-15	269.7	29.95	14.6	116	19.65
	15-30	533.2	29.50	7.4	75	11.22
	30-60	551.1	23.20	4.1	52	10.02
FYM+HB2	0-15	226.4	24.00	11.8	137	15.88
	15-30	413.8	23.65	5.0	94	12.24
	30-60	735.1	21.50	4.3	61	7.15
FYM+HB3	0-15	240	25.95	15.6	104	13.16
	15-30	731.3	21.65	12.9	66	8.15
	30-60	904.2	22.80	6.2	52	6.11
FYM+Consortia	0-15	197.4	20.40	12.9	129	16.80
	15-30	326.3	15.75	6.6	91	9.62
	30-60	466.4	18.65	4.8	64	8.54

Mass culturing for preparation of bio-formulations




Bioremediation of Salt Affected Soils of Uttar Pradesh through Halophilic Microbes to Promote Organic Farming
(UPCAR Funded)
TREATMENTS
T1 : FYM
T2 : FYM + HB1
T3 : FYM + HB2
T4 : FYM + HB3
T5 : FYM + Consortia
Crops : Rice-Wheat
Design : RBD
Replication : Three
Year of start of experiment : 2015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Halo-PSB
ICAR-CSSRI, RRS, Lucknow (U.P.)


Halo-Azo
ICAR-CSSRI, RRS, Lucknow (U.P.)

Efficacy of liquid bio-formulations of halophilic PGP strains on wheat-rice on sodic soil (initial soil pH 9.42; Org C: 0.16%) 3 years (2014-17)

Treatment	Wheat	Paddy
	Grain yield (q/ha)	Grain yield (q/ha)
FYM (Uninoculated)	37.2	42.11
FYM+Halo-Azo	41.1	46.14
FYM+Halo-Azsp	42.8	49.54
FYM+Halo-PSB	42.4	47.72
FYM+Consortia	43.9 (18.01%)	50.39 (19.66%)
CD (0.05)	2.70	3.06

Influence of bioformulations use on sodic soil properties after harvest (Initial pH=9.42)

Treatment	pH (1:2)	EC (dS/m)	Org C (%)	Na (mg/kg)	ESP	Av N (kg/ha)	Av P (kg/ha)	MBC (µg/g)	DHA (µgTPF/g/d)
Control (FYM)	9.24	0.432	0.28	338	44	103	10.8	44	10
FYM+Halo Azo	8.94	0.318	0.35	266	42	119	11.4	55	13.9
FYM+Halo PSB	9.12	0.364	0.33	272	43	113	15.1	52	12.2
FYM+Halo Azosp	9.18	0.385	0.31	282	43	121	14.4	58	13.2
FYM+Consortia	8.91	0.322	0.38	238	41	123	15.6	61	14.8

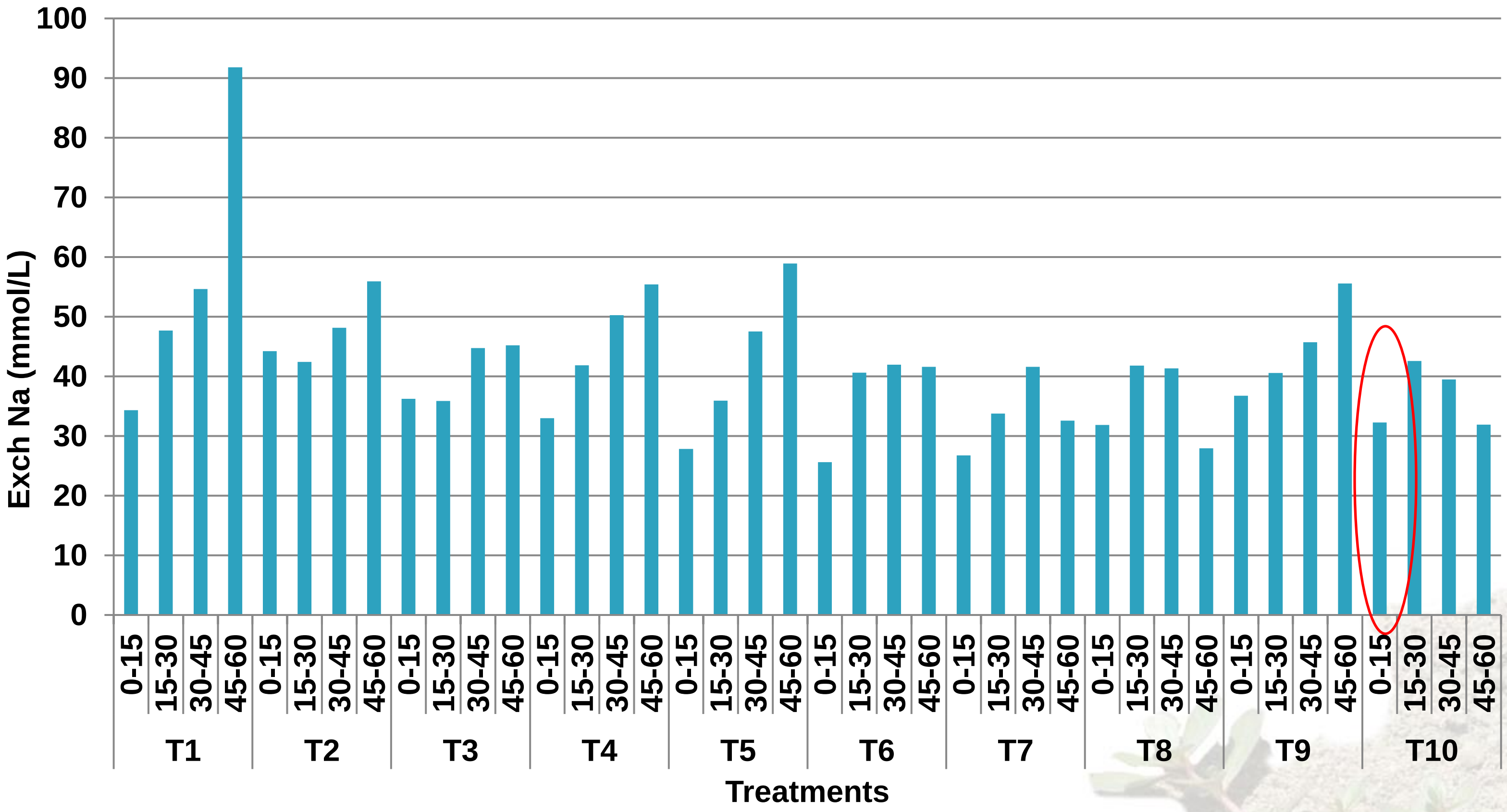
Initial soil pH (after wheat): 9.42

Rationalizing chemical amendments

Treatments

T1: Gypsum@50GR;
T2: Gypsum@25GR;
T3: Gypsum @12.5GR;
T4: Phosphogypsum@25GR;
T5: Gypsum@ 25GR+pressmud;
T6: Phospho-gypsum@25GR+pressmud;
T7: Gypsum@ 25GR+ pressmud +bio-inoculant;
T8: Gypsum@ 12.5GR+pressmud;
T9: Phosphogypsum @12.5GR +pressmud;
T10: Gypsum @12.5GR +pressmud+bio-inoculant

Exchangeable Na as influenced by treatments



Soil bio-chemical properties as influenced by amendments

Treatments	DHA (ug TPF/g/h)	Bacteria population (cfu/g)
G@50GR	12.85	$2.8*10^4$
G@25GR	11.51	$2.3*10^4$
G@12.5GR	9.23	$2.6*10^4$
PG@25GR	14.34	$2.4*10^4$
G@25GR+PM	16.94	$3.0*10^4$
PG@25GR+PM	20.10	$4.5*10^4$
G@25GR+PM+BI	22.08	$5.5*10^4$
G@12.5GR+PM	17.60	$3.1*10^4$
PG@12.5GR+PM	19.15	$4.2*10^4$
G@12.5GR+PM+BI	18.43	$4.4*10^4$

Effect of halophilic PGP strains on paddy yields (q/ha) grown on sodic soils

Location	Un-inoculated	Inoculated with Halo-Azo & Halo-PSB
Shivri Farm 2014	41.75	48.25
Lucknow 2015	42.19	50.08
Lucknow 2016	44.32	48.55
Sitapur KVK (n=10), 2015	42.43	44.36
Sitapur KVK (n=10), 2016	48.33	53.57
Ulrapur, Unnao (n=12) 2015	40.54	46.08
Ulrapur, Unnao (n=19) 2016	42.47	47.14
Maljha, Unnao (n=17) 2015	39.75	45.26
Maljha, Unnao (n=22) 2016	41.52	48.33
Koni, Raebareli (n=7)	36.82	40.45
Ramnagar, Barabanki (n=9)	38.65	44.37
Etawah (n=6)	45.54	50.10
Mau (n=10)	38.71	41.45
Sultanpur (n=8)	39.67	43.54
Kausambi (n=10)	41.68	44.15
Ambedkar Nagar	21.90	24.60

Effect of halophilic PGP strains on wheat yields (q/ha) grown on sodic soils

Location /District	Un-inoculated	Inoculated with Halo-Azo & Halo-PSB
Shivri Farm 2014	29.40	36.45
Shivri Farm 2015	31.20	35.60
Shivri Farm 2016	33.52	37.18
Sitapur KVK (n=10), 2015	36.20	40.20
Parsendi Sitapur (n=10), 2016	32.40	37.30
Dhaura, Unnao (n=10)	37.00	42.80
Raebareli (n=15)	36.10	39.60
Hardoi (n=5)	31.50	35.70
	267.32	304.83 (14.03%)

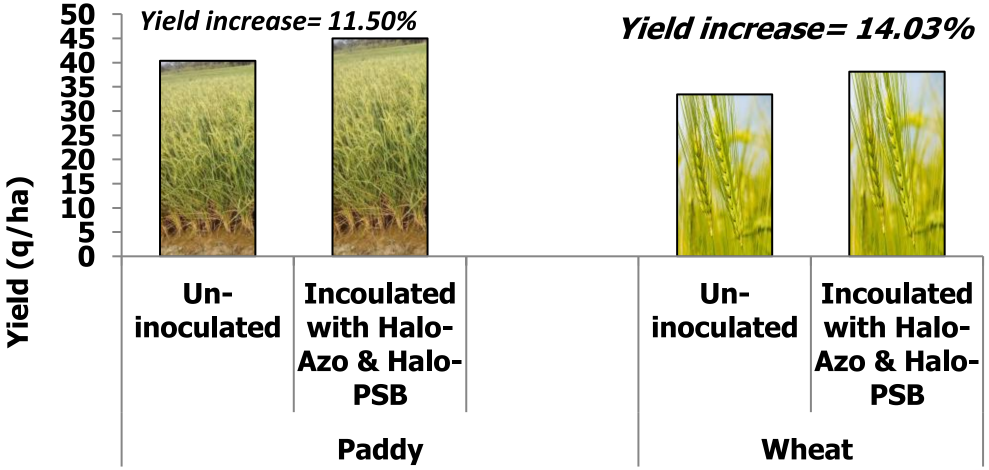
Bio-amelioration of salt affected soils
Liquid Bio-formulations of halophilic strains of PGP microbes

These liquid bioformulations have potential to bio-ameliorate salt affected soils through

***Halo-Azo* can fix atmospheric N upto 10-15 kg/ha and *Halo-PSB* has P solublization of 12-15 kg/ha.**
Active upto soil pH 9.8.
Also produces certain stress alleviation enzymes and organic acids.

Impact

-Average increase in paddy yield by 11.50% and wheat yield by 14.03% in sodic soils
- Benefit:Cost enhanced to 2.31 in paddy and 2.59 in wheat
- Soil health and fertility improved



Liquid bioformulations of halophilic PGPR developed

Mass production

Promoting bio-remediation of salt affected soils

(3) Pheromone traps (/upload/file/Pheromone traps.pdf)

(4) Medicated Wine (/upload/file/Medicated Wine.pdf)

(5) Chilli-Arka Meghana (/upload/file/Chilli-Arka Meghana.pdf)

(6) Arka Microbial Consortium (/upload/file/Arka Microbial Consortium.pdf)

(7) Arka Actino plus (/upload/file/Arka Actino plus.pdf)

(8) Tomato-Arka Samrat (/upload/file/Tomato-Arka Samrat.pdf)

9. ICAR - Central Soil Salinity Research Institute (CSSRI) Express your Interest (/register)

(1) HALO-PSB (/upload/file/HALO.pdf)

(2) HALO-AZO (/upload/file/HALO-AZO.pdf)

(3) GYP Kit (/upload/file/GYP%20Kit.pdf)

10. ICAR - Directorate of Groundnut Research (DGR) Express your Interest (/register)

(1) Nut Boost (/upload/file/Nut%20Boost.pdf)

(2) NutMagic (/upload/file/NutMagic.pdf)

11. ICAR - Central Institute of Brackishwater Aquaculture (CIBA) Express your Interest (/register)

Agrinnovate India Government of India Enterprise

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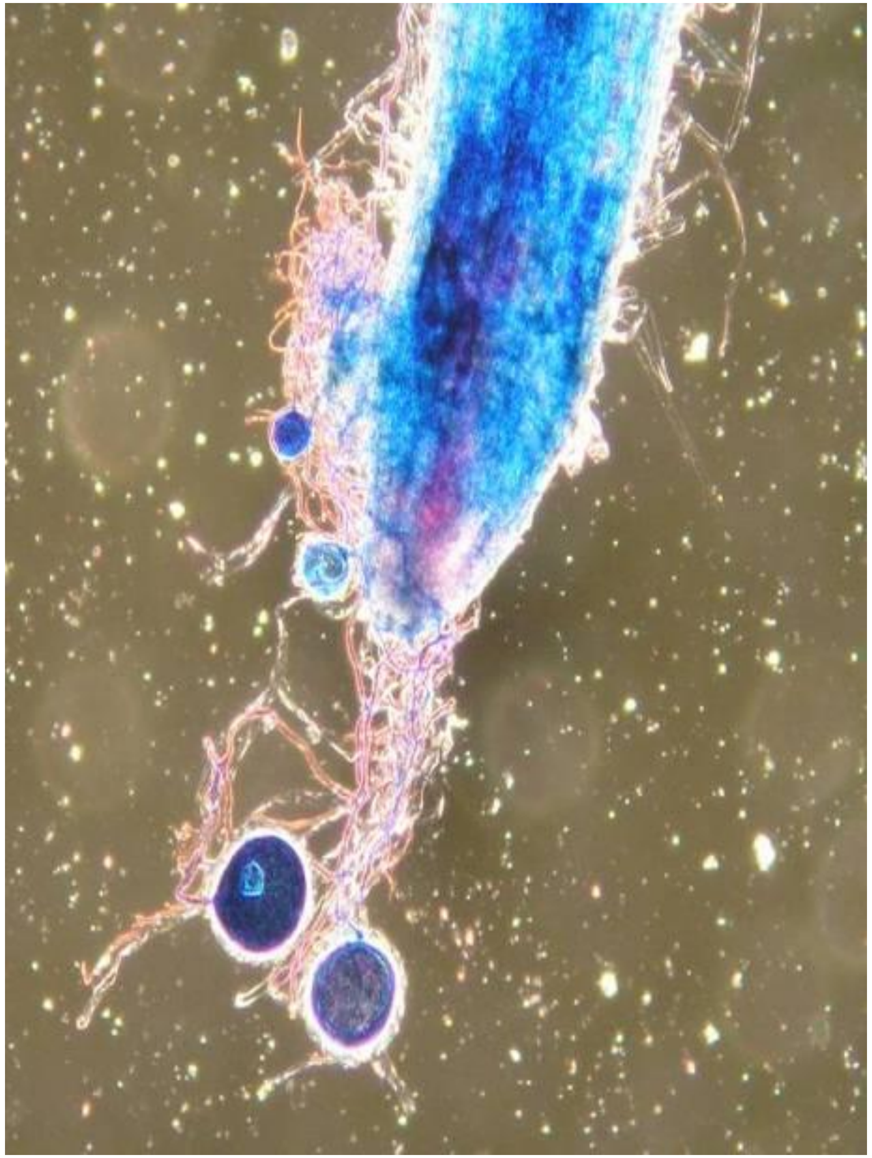
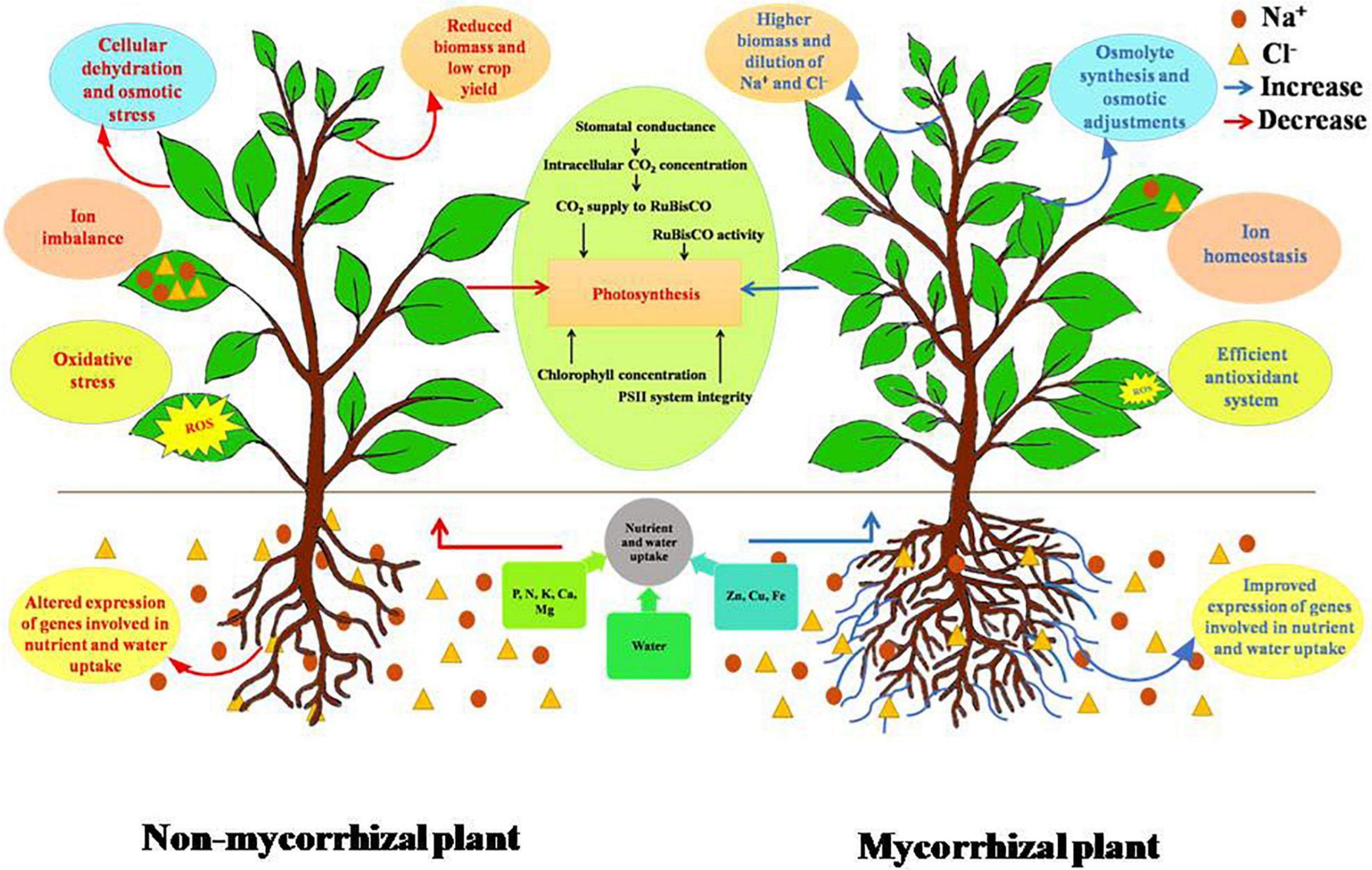
Mycorrhizal Fungi



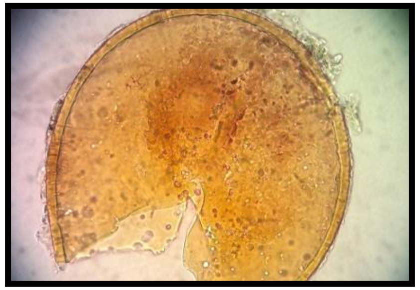
- Extends plant root systems
- Produces erosion-resistant, carbon enriched soil
- Provides mechanisms for soil biological carbon fixation Glomalin
- Slows decay of organic matter


Cellular dehydration and osmotic stress
Reduced biomass and low crop yield
Higher biomass and dilution of Na+ and Cl-
Osmolyte synthesis and osmotic adjustments
Na+
Cl-
Increase
Decrease
Ion imbalance
Stomatal conductance
Intracellular CO2 concentration
CO2 supply to RuBisCO
RuBisCO activity
Photosynthesis
Chlorophyll concentration
PSII system integrity
Ion homeostasis
Oxidative stress
ROS
Efficient antioxidant system
Nutrient and water uptake
P, N, K, Ca, Mg
Zn, Cu, Fe
Water
Altered expression of genes involved in nutrient and water uptake
Improved expression of genes involved in nutrient and water uptake
Non-mycorrhizal plant
Mycorrhizal plant

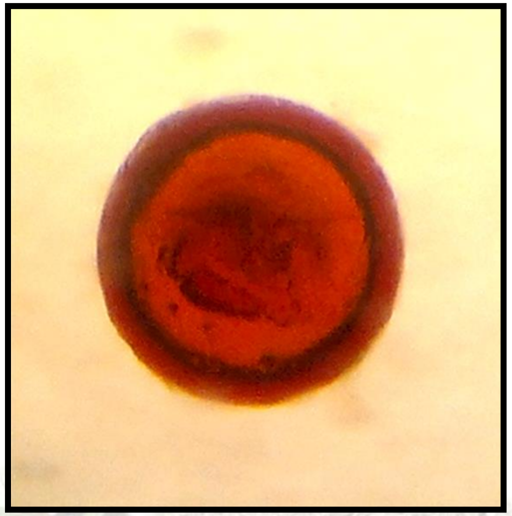
Mycorrhiza – potential C sequester

- Symbiotic relationship between **fungi** and **roots** of higher plants. This fungus-plant alliance stimulates **plant growth** and accelerates **root development**
- Fungi derives its **carbon** source from the host plant; whereas plants get better **nutrient** and **water absorption**

VAM spores from rhizosphere soil of halophytes

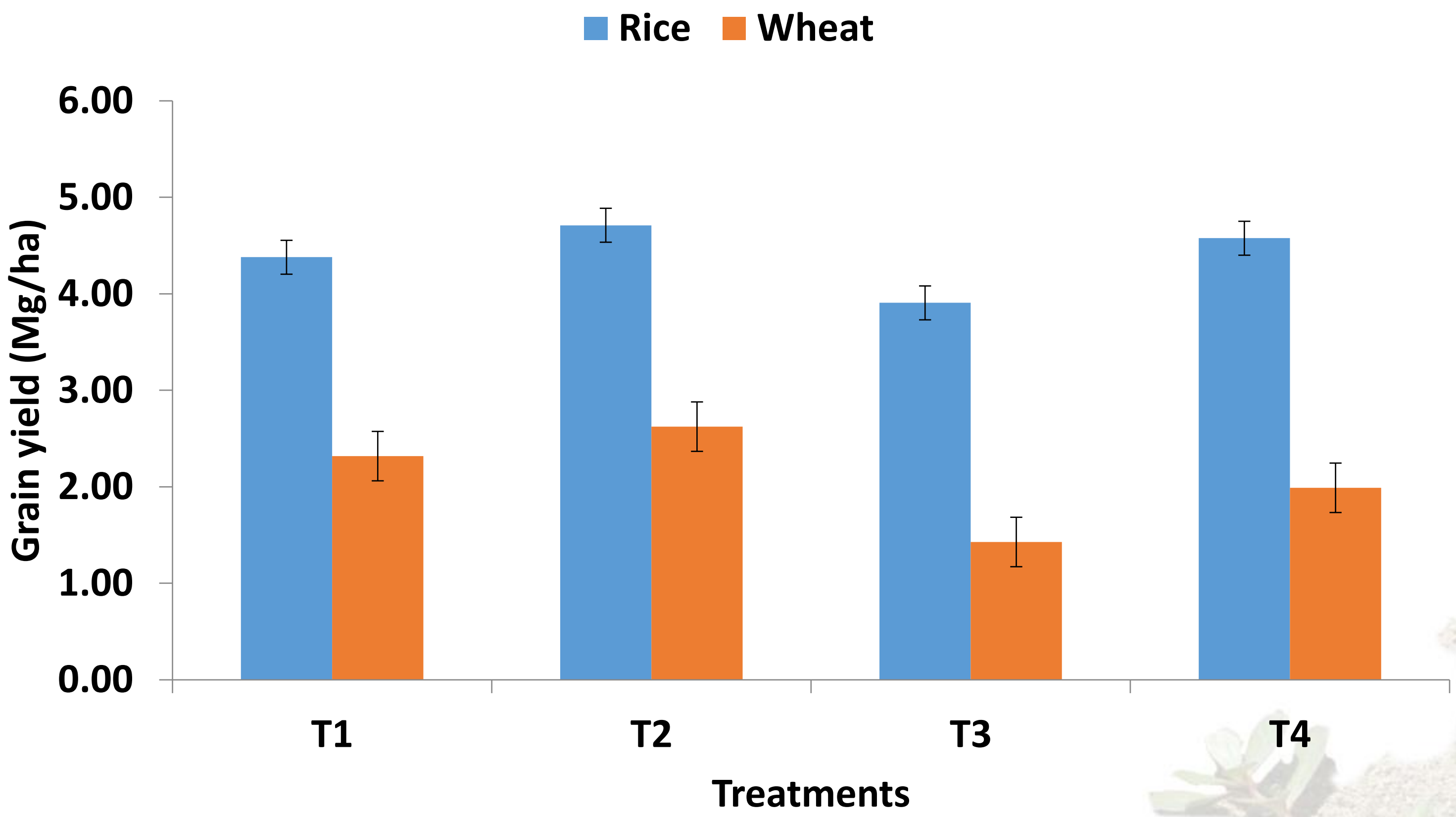


Soil Sample	Spore population	
	<u>106µm</u>	<u>37µm</u>
M1	29	38
M2	3	0
M4	48	23
M6	67	40
M7	47	23
M8	68	33
M9	56	34
M10	68	47
M12	48	23
M14	10	14
M15	68	38
M16	48	36
M17	132	87
M18	10	14



Microbial Enriched City Waste Compost

Impact of Enriched MSWC on crops in sodic soils



Effect on soil properties of sodic soils (3 years)

Treatments	Initial	T_1 (Control)	T_2 (Enriched MSWC)	T_3 (Un-enriched MSWC)	T_4 (Gyp+Pressmud)	$LSD_{0.05}$
Bulk density (Mg m^{-3})	1.60	1.57 (-1.87)	1.41 (-11.87)	1.48 (-8.10)	1.48 (-8.10)	0.03
Infiltration rate (mm day^{-1})	2.1	11.15 (+431)	17.21 (+719.5)	15.65 (+645.2)	15.42 (+634.3)	1.32
Porosity (%)	42.4	52.30 (+23.34)	68.72 (+62.07)	65.23 (+53.84)	63.204 (+49.05)	3.12
pH_2	9.8	9.15 (-6.63)	8.84 (-9.79)	8.99 (-8.26)	9.29 (-5.20)	0.26
EC_2 (µSm^{-1})	147.0	46.00 (-68.70)	45.00 (-69.38)	56.00 (-61.90)	52.00 (-64.62)	ns
ESP	78	32.00 (-58.97)	28.00 (-64.10)	30 (-61.5)	36.00 (-53.84)	2.31
SOC (g kg^{-1})	1.30	3.10 (+138.46)	3.40 (+161.53)	3.00 (+130.76)	2.60 (+100.00)	0.30
Available N (mg kg^{-1})	30.7	65.33 (+112.80)	71.42 (+132.63)	67.24 (+119.02)	67.19 (+118.85)	3.12
Olsen's P (mg kg^{-1})	8.3	11.2 (+34.93)	16.4 (+61.44)	14.3 (+72.28)	13.5 (+62.65)	0.83
Available K (mg kg^{-1})	173.0	201.4 (+16.41)	242.2 (+40.0)	181.53 (+4.93)	183.2 (+5.89)	6.32
Na^+ (mg kg^{-1})	342.0	283.75 (-17.03)	229.81 (-32.80)	288.66 (-15.60)	279.56 (-18.25)	23.20

GLOBAL SYMPOSIUM ON
SALT-AFFECTED
SOILS

20 - 22
October, 2021
Virtual meeting

Thanks

Live with the salt……