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RESEARCH ARTICLE

THE OCCURRENCE OF PESTICIDES IN ENVIRONMENT AND CURRENT TECHNOLOGIES FOR THEIR REMEDIATION AND MANAGEMENT

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Abstract

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Agriculture is facing major challenges affected by erosion, salinity and soil degradation. Chemical pesticides and fungicides are more used the agricultural lands. Chemical pesticides and fungicides are more used environment and human diseases causes. The better approaches in agriculture, biocontrol microorganisms, and Plant Growth Promoting (PGP) have emerged as safe for the environment, and also safe alternatives to chemical pesticides. Plant associated microorganisms have helped in soil nutrients enhancement, nitrogen fixation, phosphate solubilization, siderophore production, β-1,3glucanase, cellulase, protease, and lipases. These microbes have tolerances to the biotic and abiotic stress, pH, salinity drought, extremes temperature, heavy metals, and pesticide pollution. This summarized and discussed in this review evaluated actinomycetes related research and its benefits. These bacteria are biocontrol of plant pathogens and enhance the plant growth in agriculture.

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Introduction:-

In earth's ecosystem plants are play major role in humans and animals Elnahal et al., 2022; De Rosa et al., 1996; Glick 2010. In sustainable agriculture; plants growth-promoting bacteria and transgenic plants are use Lucy et al., 2004. Chemical pesticides, fungicides, and other toxic chemicals used in agriculture; they effected environmental contamination and humans diseases occurecs Nakas & Hagedorn (1990); Canaday 1995; Hokkanen et al., 1995. The replacement of chemical pesticides, the better approaches to controlling plant pathogens and insecticides to used plant growth-promoting bacteria they helps plant growth Kloepper (1994); Davison (1988).

Non-pathogenic Actinomycetes can suppress diseases as well as to promote plant growth. The plant diseases can suppression by the process of microbial antagonism or antagonistic activity, accumulation of nutrient and hormonal stimulation Van Loon 2007. Plant growth promoter Actinomycetes to binding with various parts plant such as roots and leaves: root binding bacteria are call it has a rhizosphere bacteria, leaves binding bacteria are bacterial endophytes Lynch & Whipps 1990.

Soil is packing of numorus microorganisms Viz., Bacteria, Fungi, Algae, and Protozoa. In those scenario bacteria have covered with (i.e~95%) soil Schoenborn et al., 2004. Rhizobacteria help growth of various crop plants such as

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Rice, Wheat, Barley, Oats, Cereals, and Sorghum. These bacteria are helpful for plant growth and control of plant pathogens Gopalakrishan et al., 2017: Santoyo et al., 2016.

The various strategies are used for high yield quality- quantity, and control of plant pathogens. In that way, extensively used chemical fertilizers and pesticides are more costly than normal PGP pesticides, with the slightest negative effect on the environment. These problems are rectified by to use and regeneration of environmental eco-friendly pesticides, organic farming, human health concern methods in crop production, and protection Esitken et al., 2002. The eco-friendly option includes the use of Plant Growth Promoting (PGP) microbes, synthetic pesticides, bio-fertilizers, biocontrol potential microbes, and vermicompost Rupela et al., 2005. Digramatic repesentination in image 01.

Plant growth-promoting bacteria

Soil is an excellent niche: the growth of number of microorganisms such as Bacteria, Fungi, and Protozoa. PGP bacteria have positive impact on plant pathogens, plant growth, and synthesis of secondary metabolites. PGP bacteria are beneficial to root colonizers and live within the plant tissues Mitra et al., 2022; Santoyo et al., 2016: Pérez-Montaño et al., 2014; Klopper et al., 1981.

PGP bacteria is beneficial effect on plant health, antagonized phytopathogens, reduce the consequential loss of plant, formation of root colonization, synthesis of anti-microbial compounds, assimilation nutrients, phosphate solubilization, synthesis of secondary metabolites and synthesis of active compounds Viz., siderophore production, Indole Acetic Acid (IAA), 1-Aminocyclopropane-1-Carboxylate (ACC) and also releases the hydrolytic enzymes such as., hydrogen cyanide (HCN), protease, lipase, cellulase, and ammonia Andreolli et al., 2018; Mantelin & Touraine 2004; Yang et al., 2009; López-Bucioetal 2007; Mantelin & Touraine 2004.

Plant Growth Promoting bacteria has commercialization is still under process, they limited understanding of plant interaction some bacteria are used commercially as adjuncts to agriculture practices such as Agrobacterium species, Bacillus species, Pseudomonas species, Streptomyces species, and Rhizobia species. PGP bacteria has inoculation are use in small number of crops in world-wide agricultural practices. PGP are effects directly or indirectly. Plant growth promoter bacteriais has directly by facilitating resource acquisition nitrogen, phosphorus, and other essential nutrients. Indirectly PGP bacteria have decreasing the inhibitory effects of various pathogens on plant growth and development in the forms of biocontrol agents Glick 2012. The data was representing by figure 02 and table 01.

Actinomycetes diversity

Rhizosphere micro-organism help plants in plant growth promotion and yield. Actinomycetes are one of the major components of rhizosphere microbial populations Sreevidya et al., 2015. Actinomycetes are gram-positive, aerobic, mycelia formation bacteria, with high G+C content and phylum actinobacteria Mevs et al., 2000. They can flourish in bulk soil, rhizospheric soil, stay in entophytic or epiphyte in plant tissue. The Actinomycetes population can be distributed with average 10^{-4}-10^{6} g^{-1}soil in various crop fields Shaharokhi et al., 2005; Ul-Hassan & Wellington 2000.

Actinomycetes are originated in different habitats Viz., freshwater, seawater, soil, marsh area; however they are dominant in the dry, humic, and calcareous types of soils. Actinomycetes are synthesis antimicrobial compounds thus are preventing for growth of common root pathogens Jog et al., 2016. Some researches work down by to reports regarding their ability of phosphate solubilization, organic acid, and siderophore production. Actinomycetes to produces the large number of enzymes, these enzymes are helps directly or indirectly for the plant growth Doumbou et al., 2001; Al-Aksar & Rashad 2010; Sadeghi et al., 2012. Enzymes such as Cellulase, Chitinase, Phytase, Phosphatase, and Protease play major role in maintaining soil ecology, soil fertility and soil health, inhabitant macro, micro-organisms of soil Sinsabaugh et al., 1991.

Actinobacteria are free-living microorganisms in soils and other ecosystem, and also found in endophytic (or) epiphyte. Actinomycetes are control a wide range of host pathogens viz., Barley, Wheat, Rice, Soybean, Cowpea, Chickpea, Banana, Tomato, and Chinese cabbage Martinez-Hidalgo et al., 2014; Vijayabharathi et al., 2016. The date was representing table-03. Actinomycetes are one of the major rhizosphere microbial communities and exhibit the extraordinary plant growth beneficial, such as Micromonospora sp., Streptomyces sp., Streptosporangium sp., and Thermobifida species. Those spices are shown as a biocontrol agent against the root fungal pathogens, plant growth, and shoot-root elongation Merzaeva & Shirokikh 2006; Franco-Correa et al., 2010.

They are classified into different genera based on their physiology and morphology. Based on actinomycetes are some of the known as Actinomyces, Nocardia, Streptomyces, Thermoactinomyces, Waksmania, Thermopolyspora, Micromonospora, Thermomonospora, Actinoplanes, and Streptosporangium Babalola et al., 2009.

Among streptomyces genus happens to be the most regarded and well known due to its numerous identified importances. Its importance has been established in health, agriculture, and other important sectors. In this review, emphasis will be on this genus in relation to its plant growth promotion abilities as a biocontrol agent and biofertilizers. We will also consider the strategies common to their actions as plant growth promoters Olanrewaju & Babalola 2019.

Many years' researchers assumed Actinomycetes are one of the major rhizosphere microbial communities and their exhibit extraordinary plant growth and it's beneficial. More over Micromonospora and Streptomyces spices are shown as a biocontrol agent against fungal pathogens and plant growth Merzaeva & Shirokikh 2006; Franco-Correa et al.,2010.

Overview of the Streptomyces genus and biocontrol agent

Streptomyces are important group of soil bacteria from the Actinomycetes family Vurukonda SSKP et al., 2018; Van Dissel et al., 2014. Streptomyces is the predominant genus followed by Actinomycetes, Actinomadura, Actinoplanes, Frankia, and Verrucosispora Martinez-Hidalgo et al., 2014; Vijayabharathi et al., 2016. Streptomyces has been considered as a biocontrol agent in modern agriculture, and also produces antibiotics. Streptomyces species are useful for biocontrol of plant pathogens.This bacteria are produces a wide range of secondary metabolites that can suppress the pathogenic microorganisms from their various crop plants Valencia-Cantero et al., 2007. The data was represent by the table 02.

Streptomyces species are large part of the Rhizosphere soil microbes. They are living both natural and agricultural environments soils. Streptomyces are best alternative improving the nutrients availability to crop plants, and plant growth promoting activity in agricultural systems. Plant growth promoting streptomyces (PGPS) are enhancing the plants growth in direct and indirect biosynthetic pathway in plants Figueiredo et al., 2010. Streptomyces have direct mechanisms essential factors involve some are crop growth, growth hormones, and iron acquisition El-Tarabily & Sivasithamparam 2006; Glick 2012; Bouizgarne 2013.

Directly stimulation

In direct mechanism streptomyces species are involving, like Nitrogen fixation, Phosphate solubilization, accumulation and distribution of minerals El-Tarabily et al., 2008; El-Tarabily & Sivasithamparam 2006, and also produces the PGP enzymes, Viz., Auxins, Gibberellins, Cytokines, (AAC) 1-aminocyclopropane-1-carboxylate. To obviate this problem and obtain higher yields, farmers become increasingly dependent on chemical nitrogen and phosphorus sources. Many agricultural lands are lack one or more of these compounds Glick 2012.

Nitrogen fixation

Nitrogen is an essential nutrient for all crop plants, and in atmosphere 78% of nitrogen is available. The atmospheric N_2 is converted into a plant utilizes by the process of nitrogen fixation Kim & Rees 1994. Biological nitrogen fixation is estimated between 200 and 300 million tons each year globally of both terrestrial and marine ecosystem Pedraza 2008. Rhizosphere bacteria have a huge amount of 15 to 70% of nitrogen Neumann & Rohmeld 2001. Biological nitrogen fixation in the atmosphere N_2 converts ammonium by symbiotic process. This process is found in eukaryotes, prokaryote's kingdom e.g Bacteria Dixon & Kahn 2004; Kim & Rees 1994. In symbiotic nitrogen fixation genes are broadest dived into fix genes, nif, and Nod. The nod early steps of root formation, nif is structurally homologous to the 20 K, fix genes are encoding 20 different proteins with seven operons Glick 2012. Nif genes are essential for nitrogen fixation, these genes around by both symbiotic and free-living systems Fischer 1994; Dixon & Kahn 2004.

In non-symbiotic bacteria are producing a small amount of nitrogen, this are bacterial endophytes Viz., Azospirillum, Azotobacter Azocarus Cyanobacteria, and Glucono acetobacter diazotrophicus Glick 2012: Bhattacharya PN & Jha DK 2012. Actinomycetes are nitrogen fixation in both symbiotic and non-symbiotic conditions eg., Arthrobacter, Agromces, Corynebacterium, Micromonospora, Mycobacterium, Propionibacteria, and Streptomyces Benson DR & Silvester WB 1993; Sellstedt & Richau KH 2013 the diagrammatic represention figure 03 and table-04.

Phosphate solubilization

Phosphate (P) is one of the essential macronutrients for biological plant growth, and development. It is available in organic and inorganic forms Zaidi A et al., 2009. The low availability of P is found in insoluble forms, while be plants absorb it only two soluble forms one is monobasic and another one is dibasic. It is a unique characteristic feature of the phosphor is low availability to plants because of slow diffusion and high fixation soil. In many soils have soluble phosphors are typically found in 1PPM Yin Z et al., 2015; Bhattacharyya & Jha 2012; Ahemad & Khan 2012.

A high concentration of phosphate solubilising bacteria is commonly found in rhizosphere when compare to non-rhizosphere soil. The rhizosphere bacteria are found in both aerobic and anaerobic strains. Some bacteria are like to Streptomyces, Achromobacter, Agrobacterium, Bacillus, Burkholderia, Erwinia, Micrococcus, Pseudomonas Hilda Rodríguez & Reynaldo Fraga 1999. Phosphates anions are using plant them extraordinary performances. Like re-active and also interact with Al3+, Ca2+, Fe3+, Mg2+. Phosphate cat ions are insoluble phosphate some are respectively; Aluminium phosphate, Tricalcium phosphate, ferric phosphate, magnesium phosphate complexes Hagin & Hadas1962.

The present day's phosphate is shifting through agriculture fields; phosphate-solubilising bacteria were increasing the soil fertility, these bacteria are converting insoluble P to soluble P by releasing organic acids, chelation, and also ion exchange Narula et al. 2000; White. w 2000. Most of the considerable numbers of bacterial species are, they are mostly associated with the rhizosphere plant, beneficial effect on plant growth, therefore they use of development of plant growth and also useful in biofertilizers and biocontrol agents in agriculture Rodríguez & Fraga 1999 the diagrammatic represention is image 04 and 05.

Phytohormones

Hormones are chemicals, it is the trigger of the plant’s it is a response to the under these critical situations. Most of the microorganisms are producing phytohormones such as Auxins, Cytokinin, and Gibberellins. Microorganisms are effectively growth on the shoots proliferation and enhance the uptake of nutrients, minerals, and water. Enterobacter sp., Streptomyces rochei, and Streptomyces sundarbansensis this are produces various enzymes ACC, siderophore, IAA, HCN, and phosphate solubilization nitric oxide (NO) and strigolactone for the growth and development of plants Gray & Smith 2005; Sarkar et al., 2018: Han et al., 2018: Numan et al., 2018.

Siderophore production

Siderophore are chelating agents, it secreting many microorganisms, helps to mobilizing iron transport the ions. Active oxygen and the ideal redox chemistry for the electron transport in all the above consideration iron is an indispensable cofactor for different cellular processes in eukaryotes and most prokaryotes Andrews et al., 2003 ; Halliwell & Gutteridge 1984. Iron is rich in sources in soil Hantke 2001. Fur and fe2+ binding sequences are GATAATGAAATCATTATC, known as Fur box Escolar et al., 1999. Siderophore are produced iron and secreted into the surrounding environmental condition, its play solubilization iron and minerals Schalk et al., 2011.

Cytokinins

Cytokinins help to develope root callus, shoot formation, totipotent stem cells in root and shoot meristem Numan et al., 2018: Howell 2003. Cytokinins promote cell proliferation, regulating leaf phyllotaxy, gynoecium development, and female gametophyte development, promoting phloem and auxin xylem Kieber & Schaller 2018. Cytokinins are signalling to the plants; the signalling receptors are (AHK2), (AHK3), (AHK4), (CRE1), (WOL) and also useful in plant growth Kakimoto 2003. In rhizobacteria Bacillus megaterium, Azotobacterial, Bacillus subtills, Pantoea agglomerans, paenibacillus polymyxa, Phodospirillum rubrum, Pseudomonas fluorescens, and Rhizobium spp using the cytokinins receptor they increasing plant growth-promoting López-Bucio et al., 2007; Atzorn et al., 1988; Lorteau et al., 2001.

Gibberellin Production by bacteria

Gibberellin is plant hormone, it is essential for plant development processes like flowering, leaf expansion, seed germination, elongation, pollen maturation, and trichome development Davière et al., 2003. Gibberellin one of the most important compounds is found in nodules of the plant in Leguminosae species, they play crucial role in hormonal balancing in plants, cell metabolism, and modified by microorganisms Cassán et al., 2003. In Phaseolus lunatus plants Bardyhizobium were enhancing and elongation of the internode, plant growth. In this condition the bacterial strain have enhanced the plant growth, and produce GA1, GA19, GA20, and GA44. The Rhizobium sp is producing a pure form of auxins and gibberellin.

Few reports are reported in microorganisms species like., Azospirillum sp, and Bacillus sp. are inoculate in wheat roots they produce in gibberellin, its increase nitrogen uptake. GA 3 is produced by microorganisms to increase the growth of maize roots, also increase the plant growth in cereal but other food crops Kucey 1988: Fulchieri et al., 1993: Bottini et al., 1989.

Volatile organic compounds (VOC)
Volatile organic compounds (VOC) which help the attracting pollinators in crops, pollinator interactions, seed disperse, and antagonistic activity of pathogens. Dudareva et al., 2013 reported the production of VOC in bacteria its helps antagonistic activity in fusarium oxysporum Tomato plants, and also for developing bio-pesticides in tomato. VOC producing bacteria are PGPR interaction with plants, biocontrol of phytopathogens, and antibiosis mechanism in plants Vespermann et al., 2007. Numan et al., 2018 studied on Bacillus subtilis can stimulate hormonal singles in arabidopsis thaliana, and it contains plant hormones. In this conclusion, the VOCs are increasing the plant immunity and productivity, biocontrol of phytopathogens, production of biopesticides, attraction pollination in many agricultural plants, and production of secondary metabolites.

Abscisic Acid
Abscisic Acid were identify in 1960s, develop and enhances the plant growth, stress responses, reproduction of plant metabolites, participates in morphological, physiological, biochemical, molecular processes, vegetative growth, modulation of root architecture, leaf senescence, and central regulator of abiotic stress in plants Dhakal et al., 2015. Abscisic Acid is found in higher plants, bacteria, fungi and algae are producing in recently Carmen CA et al., 2016;Takezawa et al., 2011. In plants that have under stressful environmental conditions such as water shortage, high salinity, and extreme temperature, the ABA helps plants adapt and survive under these adverse conditions Ullah et al., 2019; Shahzad et al., 2017; Forchetti et al., 2007. Clinical investigation on Bacillus amyloliquefaciens are isolate in rice seed, Bacillus licheniformis and Pseudomonas flouroescenste isolated in helianthus annuus root, these bacteria are produce abscisic acid in normal and salt-stressed condition**.**

ACC 1-aminocyclopropane-1-carboxylate
In the presence of enzyme ACC 1-aminocyclopropane-1-carboxylate PGP bacteria have facilitating root and shoot growth in plants Glick 2012 & Glick et al., 1998 was proposed, ACC deaminase-producing bacteria binding to plant surface, internal tissue of the plants, leaves, and flowers Glick 2014.

Ethylene
Ethylene one the simplest unsaturated hydrocarbon, derived from amino acid of methionine. Ethylene is responsible for plant growth & development, and fruit ripening. Plants have produces phytohormones to react specifically and quickly, plants produce ethylene to response many stresses. In recent study's Arabidopsis and some other crop species ethylene is key role, regulation of organ growth and yield increases under the abiotic stress Dubois et al., 2018. Ethylene synthesis occurs in all higher plants through methionine-dependent pathway Nascimento et al., 2018 the semantically digram was repesnted by image 07.

Abiotic stress resistance of rhizobia
Agricultural productivity can be modulated by various environmental factors Viz., biotic and abiotic stress. Abiotic stress resistance rhizobacteria are; they may not be able to full nitrogen fixation, under the stress condition (salinity, acidity, nutrients deficiency, and extreme temperature). The abiotic stress is negative impact on the legume nodulation, growth of plants and even increasing the strength of legume host. In rhizobium strains are utilization in many agricultural applications, rhizobium inoculants must be competitive for nodule occupancy, nitrogen fixation, and growth of physiological conditions Sharma et al., 2017. Therefore, the characterization of the indigenous rhizobium population may be beneficial towards legume plants Agrawal et al., 2012. The data was represented by the table-05

Salinity stress
Around 25 to 50% of lands are affected by soil salinity. Salinity is negative impact effects on the plant development and fertile land, more over economy loss for world wide. Soil has soluble different salts in water Viz., Bicarbonate ($HCO3^-$), Calcium (ca), Carbonate (CO_3), Magnesium (Mg), Potassium (K), and Sulphate (SO_4^{-2}) is called

salinization Numan et al., 2018. Most of the plants have facing two types stress under the high salinity, Osmotic & Ionic stress. Osmotic stress leads to the dehydration and accumulation of salts surround plant root. Ionic stress leads to dehydration influx of sodium ions, efflux of potassium ions Del Carmen Orozco-Mosqueda et al., 2020.

Most of the fertility soils may be salinized by neutral salts (NaCl and Na_2So_4) alkaline salts such ($NaHCO_3$ and Na_2CO_3), these salts are which is particularly detrimental to plants. Neutral and alkaline salt are caused by demage to plants, uptake of low water potential ions, toxicity ions, and high-pH stress Song et al., 2017. Nacl is an important source for soil, in plants have high-level of chloride ions be toxic, these ions are cells inhibit plant growth Numan M et al., 2018. Some stress response genes are identified in plants e.g aquaporin, free radical scavengers, embryogenesis abundant proteins, heat shock proteins, and ion transport. Arabidopsis thaliana, Lotus corniculatus, and Oryza sativa L this plants are involving to control the salt tolerances in both the molecular and cellular level Katiyar-Agarwal et al., 2006. The data were repesnted by Table 11

Soil acidification

Soil acidification is a major problem for agricultural sustainability lands; they are affecting approximately 10 to 30% of land area in world-wide Kumawat et al., 2022; Sumner & Noble 2003. Soil acidification is defined as a low level of ph; when the soil pH <4.5 fungal and bacterial growth is inhibited in roots, due to the decrease the plant productivity. In soil, acidic conditions wood ash and lime are improved the soil pH and reduces bacterial wilt. Soil acidification its effects on the different parameters in plants e.g Plant growth, uptake of nutrients, root growth, and resistances in plant diseases Rout et al., 2001. When the soil pH is >6.0 soluble content increase the soil and plant are more effective for the growth of plants by the physiologically and morphologically. In acidic soil pH <5.5 plant essential nutrients cannot directly uptake by plants such as, Ca, K, Mo, and Mg Läuchli & Grattan, 2017. In acidic conditions Ralstonia solanacearum bacteria is resistant to tobacco plants Smiley, 1975. The data were repesnted by the table-06.

Heavy metals resistance

Heavy metals pollinated soils; significant environmental problem, it hurts agriculture and human health Nocelli et al., 2016. Rhizobia bacteria are important drives of environmental and agricultural services. Heavy metals concentration are affects the growth of microorganisms, influences microbial populations, and also losing the antimicrobial properties. However, some meals have long-term contamination in soils like Cadmium (Cd) Lead (Pb), and Zinc (Zn), these meals affect microbial diversity and composition. This contamination occurs depend upon the meal's availability and also influences some other factors such as climate, soil type, soil structure, presences of organic matter, pH, and plant roots Mohamad et al., 2016. Maynaud et al., 2014 reported by the Mesorhizobium metalliduransis are effective control of Anthyllis, the meta tolerance bacteria have a wide range of applications, genes encoding metals efflux resistance to Zn and Cd some few are reports are represented by table 07.

Growth hormones in indole acetic acid (IAA)

IAA is a plant growth hormone which comes under the auxins group. They are regulating plant growth & development, photosynthesis, responses to stressful condition, seed germination, plant cell division & elongation Ullah et al., 2019. Auxin in plants are Indole-3-acetic acid (IAA) (strong auxins), phenylacetic acid (PAA), Indole-3-butyric acid week acid Jayasinghege et al., 2019. In IAA cellular process such as cell division, enlargement, and differentiation, in plants vascular tissue formation, adventitious root initiation, apical dominance, developing and fruit flowering. Ullah et al., 2019 studies on pea plants IAA genes were isolated PS-IAA4/5 and PS-IAA6 genes. Arabidopsis Luo, J et al 2018 reported by 14Aux / IAA genes are isolated from pea plant. In quantitatively 80% IAA is produces by rhizospheric bacteria. Most of IAA producing bacteria is Macrobacterium, Mycobacterium, and Rhizobium Ullah et al., 2019. The represented data was table -08.

Plant production in Hydrogen cyanide (HCN)

Hydrogen cyanide is plant base horomone, its beneficial to root-associated bacteria Viz; Rhizobacteria are produced many chemical compounds with different benefits for the plants. Among them, HCN is recognized as a bio-control agent in plants, helping for plant growth & development Rijavec & Lapanje 2016. De Coste et al., 2010 reported the PGPR production HCN has identified as a key mechanism for disease suppers and produces the antifungal metabolites. The data were represented by the table -09.

Ammonia

Ammonium hydroxide call it has ammonia, is a basic building block for ammonium nitrate which is releases nitrogen. Ammonium is the major nitrogen source plant ecosystem. Ammonification process plays important role in the transformation of dissolved organic nitrogen (DON) too dissolved nitrogen (DIN) Mohamad et al., 2016: Maynaud et al., 2014. The schematic diagram was represented in the image 06**.**

In-direct stimulation

Indirect mechanism Streptomyces species are played vital role in plant growth, antagonistic activity, interfering with bacterial Quorum Sensing (QS) systems, etc., and also controlled by the external stress such as biotic & abiotic conditions. They are produces low molecular inhibitory substances such as Ammonia, Alcohols, Aldehydes, Cyanogen's, Ketones, cell-wall degrading enzymes, and secondary metabolites Sathya et al., 2017.

Pesticide tolerance of rhizobia (PGP)

Many microorganisms have pesticide degradative genes like chromosomes, plasmids, and transposons. Microorganisms are very sensitive to environmental changes, and degradation of the microbial community. Plant Growth Promoting Rhizobacteria (PGPR) is participating in many functions e.g Recycling processes of nutrients & sustain soil fertility Ahemad M & Khan M S 2011. The data were represented in table 1.

Application of PGPR as multifunctional Agents

PGPR batter alternatives to chemical fertilizers, to hances agriculture yield, they also can produce vitamins, and phytohormones such (Auxins, Cytokinin, and Gibberellins). Sonbarse et al., 2020; Pradeep & Giridhar 2017 rewived that PGPR stimulates the plant growth by nitrogen-fixing, and phosphorous solubilizing, secondary metabolites production, acting a wide array of defense-related compounds. Some bacteria are exhibit PGPR activity like Actinomycetes, Azospirillum, Azotobacter, Bacillus spp., Pseudomonas spp., Serratia, etc. These microorganism are useful in growth-promoting activity in plants, strong survival in soil, maintain soil health, biocontrol activity, biofertilizer, minerals enhancer in soils Sonbarse et al., 2020; Priyanka et al., 2017; Rosier et al., 2018. PGPR act as an abiotic elicitor to increase the reactive oxygen species (ROS), the antioxidant activity they are using the plant stress hormones (abscisic acid, methyl jasmonate, and salicylic acid) which is hints at the stress linkage pathways. PGPR is also known to produce stress hormones, to increase the levels of anti-oxidative molecules in plants Sonbarse et al., 2020; Barickman et al., 2014.

Conclusion:-

The present review document has shown that rhizosphere microorganisms have tremendous potential as bio-fertilizers. Plant Growth promoting rhizobacteria (PGPR) having multiple activities, an adaptation of plants to stresses and conferring resistances (microbial) and have a potential role in biocontrol activities and solving future food security issues. The rizhospeher bacteria are interaction with plants, not only the plant but also changes to soil properties & soil fertility. PGPR is played a major role in nitrogen fixation, chelation, production of organic acids; siderophore production, and glomalin protein. PGP microbes are capable of enhancing nutrient bio-availability and improving soil aggregation & soil fertility. The PGPR are tolerances to heavy metals & phosphate solubilizing microorganisms have to promote sustainable agriculture, crop productivity, and improving soil fertility. In the future, they are expected to replace chemical fertilizer with biological fertilizers. Further research and understanding of screening and characterization, formulation strategies, and understating molecular, and PGPR mechanisms, behind their action and field trials are necessary and find out more competent rhizobacterial strains that may work under diverse Agro-ecological conditions.

Image 01:- Plant and microbial interaction in plants.

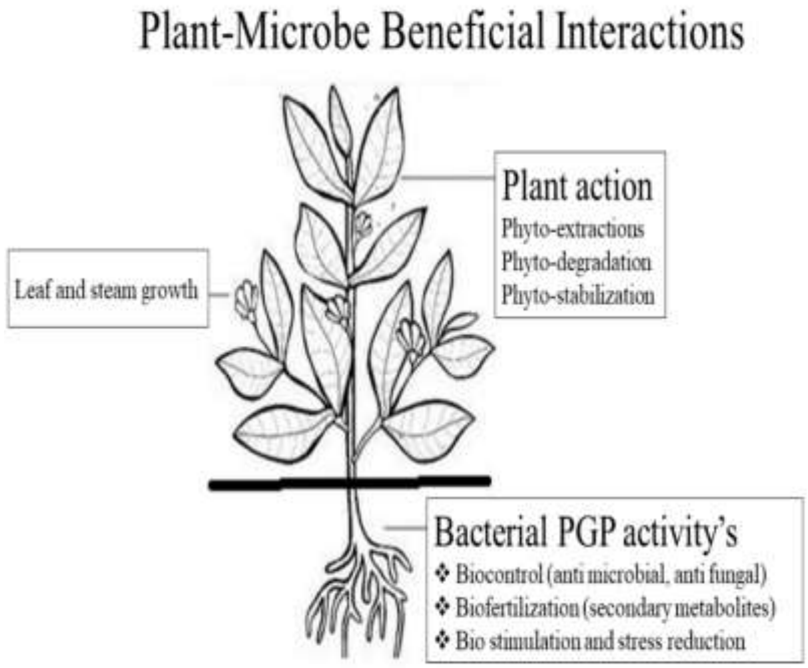
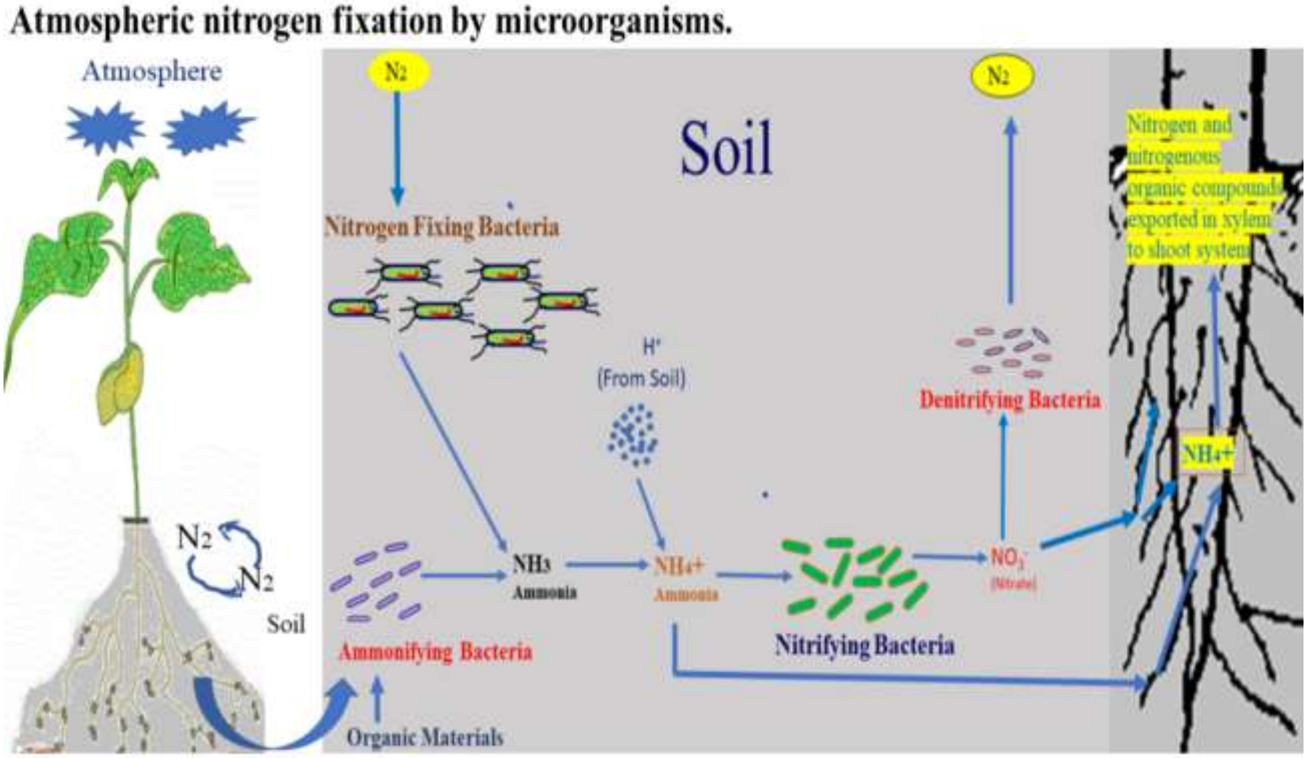


Image 02:- Mechanisms of plant growth promoting activity.

Mechanisms of plant growth promoting rhizobacteria.1. Biofertiliaztion is free living and symbiotic atmosphere is diatomic nitrogen N_2-fixing bacteria are able to convert by means of nitrogenase enzyme N_2- into ammonia. Antifungal activity is inhibits the fungal pathogens and producing antibiotics. 2. Rhizoremediation and stress control, plant expose the stress condition and pollutants shows an increase the ethylene levels that leads to metabolisms disturbances and plant damage. 3. Growth augmentation and phytostimulation , they production phytohormone like Indole acetic acid, cytokines, gibberellins, proliferation and enhance plant mineral uptake and root exudation. The PGPR that contain the enzyme ACC-deaminase is plant growth and development by decrisease the plant ethylene levels. 4. The PGPR is solubilization of Phosphate and metal solubilization Ca,K,Fe,Cu,Mn, and Zn.

Image 03:- Mechanisms of nitrogen fixation



Plants absorb in atmosphere mainly nitrate, the nitrate their produced from ammonium by nitrifying bacteria. Ammonium is made available to plants by two types of (1) soil bacteria, (2) Nitrogen-fixing bacteria convert nitrogen gas into ammonium. Ammonifying bacteria decompose organic material.

Figure 04:- Mechanism of plant growth promoting activity in rhizosphere soils.

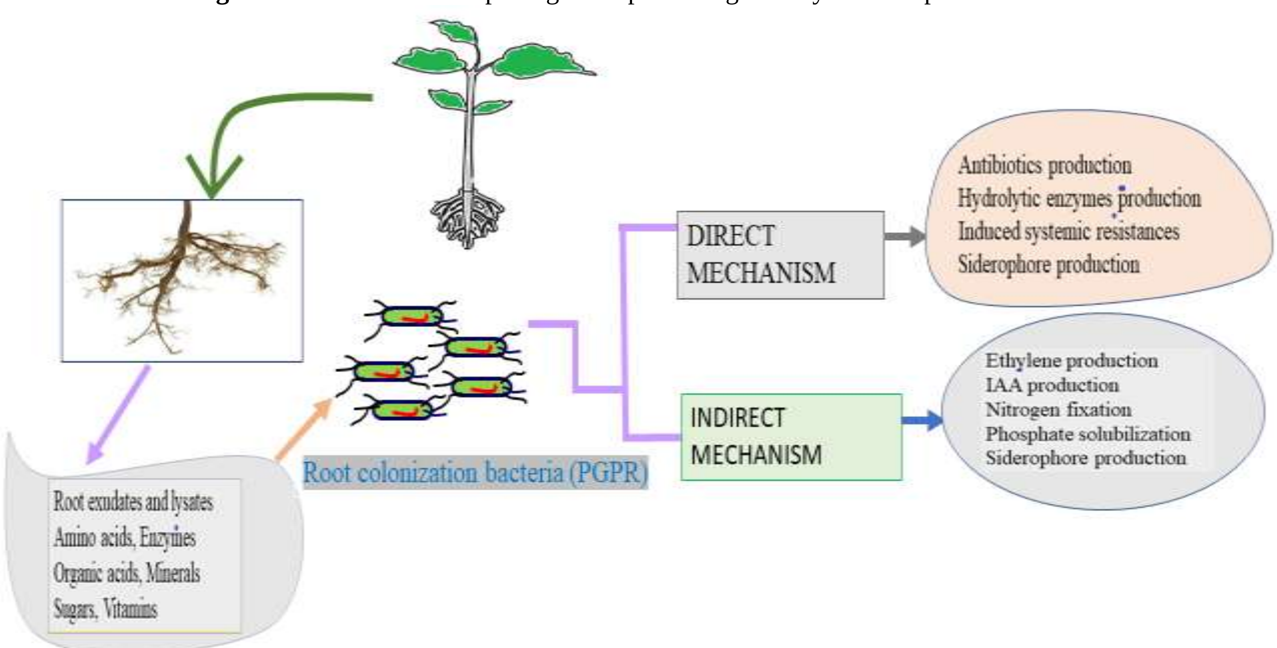


Image 05:- Beneficiates of phosphate solubilization.

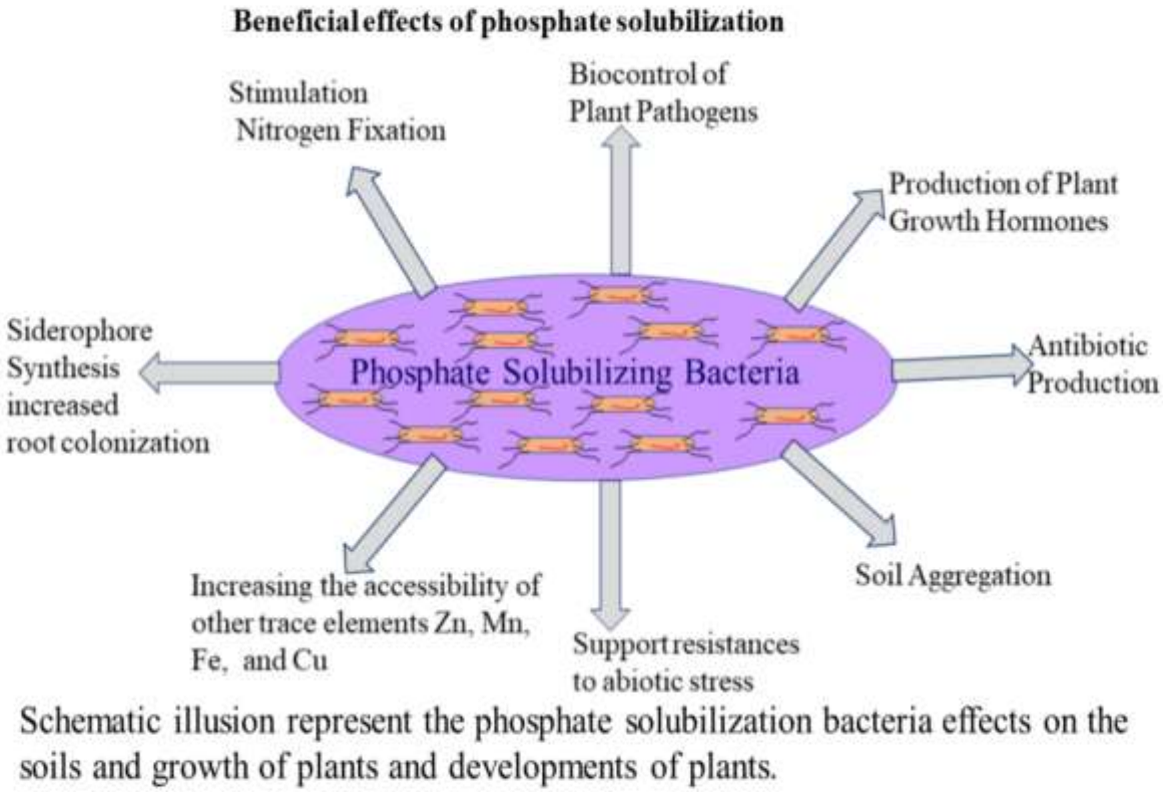


Image 06:- Mechanism of biological Ammonification.

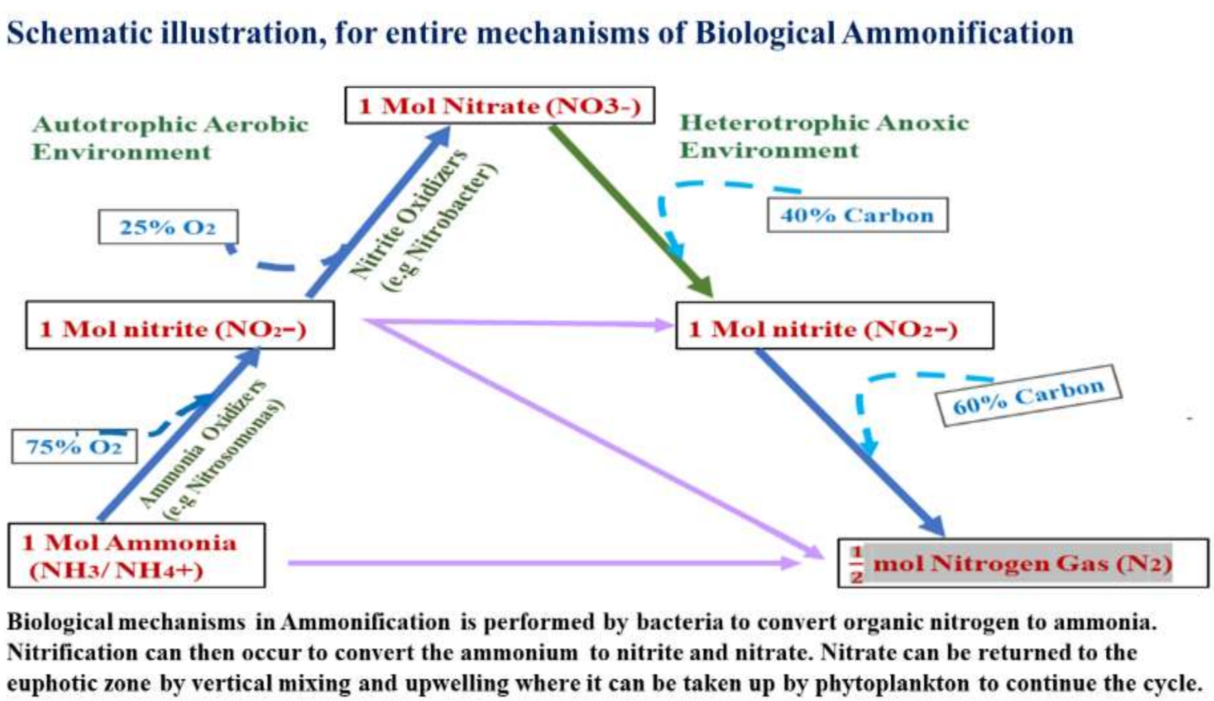


Image 07:- Ethylene biosynthesis pathway.

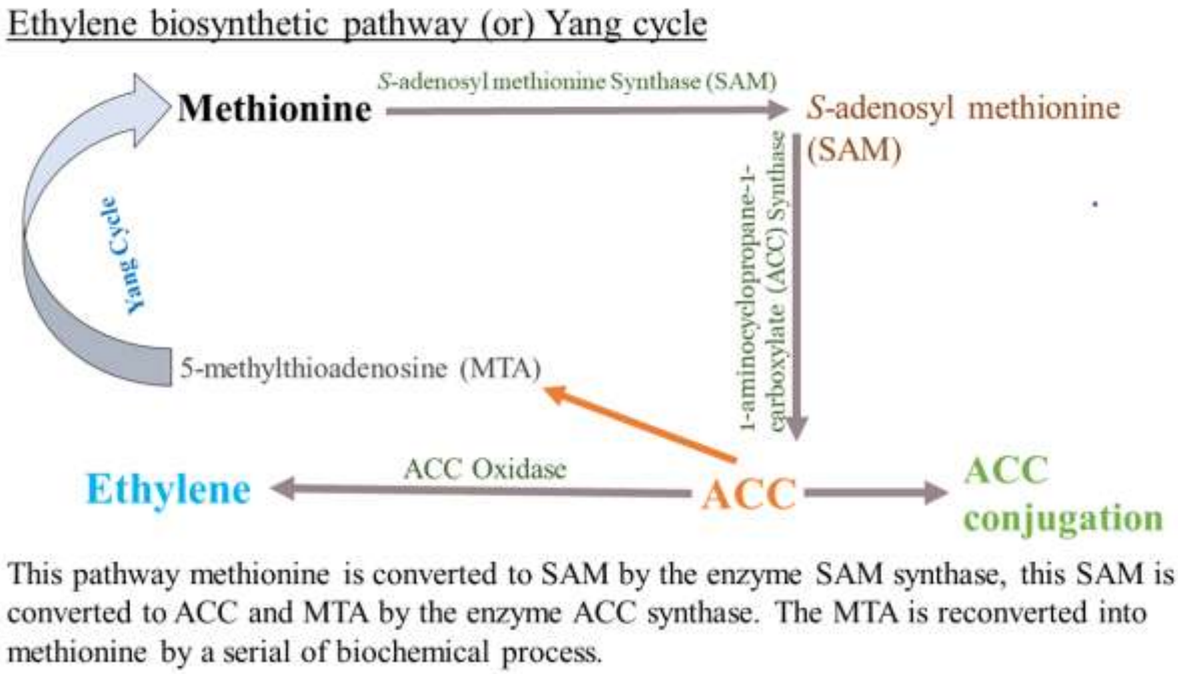


Table 01:- Effects on the plants (or) plant growth promoting activities Streptomyces species plant host.

S.no	Streptomyces species	Plant host	Effects on the plants (or) Plant Growth Promoting Activities.	References
1.	Streptomyces atrovirens	Tomato Rhizosphere plants,	Plant growth promotion (PGP)/ Auxin/IAA production.	Abd-Alla M.H et al (2013), El-Tarabily, K.A. (2008).
2	Streptomyces aurantiogriseus	Rice,	IAA production	(Harikrishnan, H et al., 2014(a), (b).
3	Streptomyces carpinensis, Streptomyces thermolilacinus	Wheat rhizosphere	Production of siderophore, IAA synthesis, and phosphate solubilization	Jog, R et al., 2012.
4	Streptomyces filipinensis,	Tomato	PGP activity	El-Tarabily, K.A. (2008).
5	Streptomyces griseoviridis, Streptomyces lydicus, Streptomyces olivaceoviridis, Streptomyces rimosus,	Rhizosphere plants,	Auxin/IAA production	El-Tarabily, K.A. (2008), Lin, L; Xu, X (2013).
7	Streptomyces igroscopicus	----------------	ACC deaminase	Nascimento, F.X et al., (2014).
8	Streptomyces lydicus	Pea	Nodulation	Tokala, R et al., (2002).
9	Streptomyces	Wheat	Auxin, gibberellin, and	Aldesuquy, H.S et

	olivaceoviridis		cytokinin synthesis.	al., (1998).
10	Streptomyces rochei,	Wheat rhizosphere, Wheat	Production of siderophore, IAA synthesis, and phosphate solubilization. Auxin, gibberellin, and cytokinin synthesis	Aldesuquy, H.S et al., (1998), Jog, R et al., (2012).
11	Streptomyces spiralis	Cucumber	Plant growth promotion	El-Tarabily, K.A et al., (2009).
12	Streptomyces species.	Alnus glutinosa, Casuarina glauca, Eleagnus angustifolia	Production of zeatin, gibberellic acid, & IAA	Ghodhbane-Gtari, F et al., (2010).
13	Streptomyces species.	Clover	Nutrient uptake and plant growth	Franco-Correa et al., (2010).
14	Streptomyces species.	Chickpea, Rice	Nutrient uptake	Gopalakrishnan, S et al., (2014), (2015).
15	Streptomyces species.	Mung bean	Enhanced plant growth	Rungin, S et al., (2012).
16	Streptomyces species.	Rice	Enhanced stover yield, grain yield, total dry matter, and root biomass	Gopalakrishnan, S et al., (2013).
17	Streptomyces species.	Sorghum	Enhanced agronomic traits of sorghum	Gopalakrishnan, S et al., (2013).
18	Streptomyces species	Pea	Nodulation	Tokala, R et al., (2002).
19	Streptomyces species.	Marine environments	Gibberellic acid, IAA, abscisic acid, kinetin, and benzyladenine	Rashad, F.M et al., (2015).
21	Streptomyces species	soil	Synthesis of IAA and siderophore production	Rafik, E et al., (2014).
22	Streptomyces species	Rhododendron	Accelerated emergence and elongation of adventitious roots in tissue-cultured seedlings	Hasegawa, S et al., (2006).
23	Streptomyces species	-----------	Gibberellin biosynthesis	Tsavkelova, E.A et al., (2006).
24	Streptomyces species	------------	B-1,3-Glucanase, IAA, and HCN synthesis	Gopalakrishnan, S et al., (2014), Gopalakrishnan, S et al., (2013).
25	Streptomyces species	--------	Siderophore production	Lee, J et al., (2012).

Table 02:- Target pathogen in plants in streptomyces spices.

S. No	**Name of the Plant (or) crop**	**Name of the Diseases**	**Target Pathogen**	**Streptomyces Spices (or) Strain**	**References**
	Banana	Wilt	Fusarium oxysporum f. sp. cubense race 4	S. violaceusniger G10	Getha, K and Vikineswary, S 2002

	Banana	Wilt	Fusarium oxysporum f. sp. cubense	Streptomyces G10	Getha, K et al., 2005
	cherry tomato and Pepper	Anthracnose	Colletotrichum gloeosporioides	Streptomyces sp. A1022	Kim,H.J et al., 2014
	chili	Root rot, blight, and fruit rot	Alternaria brassicae, Colletotrichum gloeosporioides, Rhizoctonia solani, Phytophthora capsica	Streptomyces sp.	Srividya, et al., 2012
	chili	Wilt	Wilt Fusarium oxysporum f. sp. capsici	Streptomyces sp.	Saengnak, V et al., 2013
	Chickpea	Fusarium wilt	Fusarium oxysporum f. sp. ciceri	Streptomyces sp.	Gopalakrishnan, S et al., 2011
	Chickpea	Basal rot	Macrophomina phaseolina	Streptomyces sp.	Gopalakrishnan, S et al., 2014
	Chickpea	-----------	Phytophthora medicaginis	Streptomyces sp. BSA25 and WRAI	Misk, A and Franco, C 2011
	Cotton	Soilborne diseases	Soilborne plant pathogens	Streptomyces sp. 5406	Yin, S.Y et al., 1965
	Cucumber	Fusarium wilt	Fusarium oxysporum	Streptomyces sp.	Singh, P.P et al., 1999
	Ginger	Rhizome rot	Fusarium oxysporum f. sp. zingiberi	Streptomyces sp.	Manasa, M et al., 2013
	Groundnut	Stem rot	Sclerotium rolfsii	Streptomyces sp. CBE	Adhilakshmi, M et al., 2014
	Lettuce	Basal drop disease	Sclerotinia minor	Streptomyces viridodiasticus	El–Tarabily, K.A et al., 2000
	Many	Anthracnose and leaf blight	Colletotrichum gloeosporioides and Sclerotium rolfsii	S. hygroscopicus	El–Tarabily, K.A et al., 2000
	Many	Collar or root rot, stalk rot, leaf spots, and gray mold rot or botrytis blight	Rhizoctonia solani, Fusarium solani, Fusarium verticillioides, Alternaria alternata, Botrytis cinerea	S. spororaveus RDS28	Prapagdee et al., 2008
	Many	Foliar and root fungal diseases	----------	S. lydicus WYEC108	Crawford, D.L et al., 1993: Lahdenpera, M 1987
	Many	Root rot and wilt pathogenic fungi	----------------	S. griseoviridis K61	Crawford, D.L et al., 1993: Lahdenpera, M 1987
	Many	----------	Aspergillus fumigatus, Mucor hiemalis, Penicillium roqueforti, Paecilomyces variotii	S. halstedii K122	Frändberg, E et al., 2000
	Many	________________	Curvularia sp., Aspergillus niger, Helminthosporium sp., Fusarium sp. Alternaria sp.,	Streptomyces sp. CACIS-1.16CA	Zahaed, E.M 2014

			Phytophthora capsici, Colletotrichum sp., and Rhizoctonia sp.		
	Oilseed rape	Stem rot	Scleotinia sclerotiorum	S. felleus YJ1	Cheng, G et al., 2014
	Onion	Bacterial rot	Erwinia carotovora subsp. carotovora, Burkholderia cepacia	S. lavendulae HHFA1, S. coelicolor HHFA2	Abdallah,M.E et al., 2013
	Pepper	Root rot	Phytophthora capsica	S. rochei	Ezziyyani, M et al., 2007
	Pepper	Blight	Phytophthora capsica	Streptomyces spp. 47W08, 47W10	Papavizas, G.C and Sutherland, E.D 1991
	Red chili fruits	Anthracnose	Colletotrichum gloeosporioides	S. ambofaciens S2	Heng, J.L.S et al., 2006
	Red pepper	Blight	Phytophthora capsica	S. halstedii	Joo, G.J 2005
	Raspberry	Root rot	Phytophthora fragariae var. rubi	Streptomyces sp.	Valois, D et al., 1996
	Rice	Sheath blight	Rhizoctonia solani	S. aurantiogriseus VSMGT1014	Harikrishnan, H et al., 2014
	Rice	Blast	Curvularia oryzae, Pyricularia oryzae, Bipolaris oryzae, Fusarium oxysporum	S. vinaceusdrappus	Ningthoujam, D.S et al., 2009
	Rice	Blast	Pyricularia oryzae	Streptomyces sp. KH-614	Rhee, K.H 2003
	Sugar beet	Damping off	Sclerotium rolfsii	Streptomyces spp.	Errakhi, R et al., 2007
	Sugar beet	Root rot	Rhizoctonia solani, Phytophthora drechsleri	Streptomyces spp	Karimi, E et al., 2012
	Soybean	Bacterial blight	Xanthomonas campestris pv. glycines	Streptomyces sp.	Mingma, R et al., 2014
	Tomato	Damping off	Rhizoctonia solani	Streptomyces sp. S30	Cao, L et al., 2004
	Tomato	Root rot	Rhizoctonia solani	S. toxytricini vh6	Patil, H.J et al., 2011
	Tobacco	Brown spot	Alternaria spp.	Streptomyces sp.	Gao, F et al., 2014
	Tomato	Root rot	Rhizoctonia solani	S. vinaceusdrappus S5MW2	Yandigeri, M.S et al., 2015
	Tomato	Many	Alternaria solani, A. alternata, Colletotrichum gloeosporioides, Fusarium oxysporum, Fusarium solani, Rhizoctonia solani, Botrytis cinerea	S. albidoflavus	Haggag, W.M et al., 2014
	Turfgrass	Crown/foliar disease	Rhizoctonia solani	S. violaceusniger YCED9	Trejo-Estrada, S.R et al., 1998
	Maize	Seed fungi	Aspergillus sp.	Streptomyces sp.	Bressan,W 2003
		Wood rotting	Different fungi	Streptomyces sp. MT17	Nagpure, A et al., 2014
	Porphyra	Red rot	Pythium porphyrae	Streptomyces sp. AP77	Woo, J.H and Kamei, Y 2003
	Pepper	Blight	Phytophthora capsica	Streptomyces spp.	Liang, J.F et al.,

				47W08, 47W10	2005
	Many	Wood rot	Phanerochaete chrysosporium, Postia placenta, Coriolus versicolor, Gloeophyllum trabeum	S. violaceusniger XL-2	Shekhar, N et al., 2006
	Sweet pea	Powdery mildew	Oidium sp.	Streptomyces sp.	Sangmanee, P et al., 2009
	Lemon fruit	Green mold and sour rot	Penicillium digitatum, Geotrichum candidum	Streptomyces sp. RO3	Maldonado,M.C et al., 2010
	Tomato	Damping off	Rhizoctonia solani	Streptomyces sp.	Goudjal, Y et al., 2014
	Tomato	Wilt	Fusarium sp.	Streptomyces sp. CACIS-1.16CA	Anitha, A and Rabeeth, M 2009
	Potato	Silver scurf	Helminthosporium solani	S. rochei	Elson, M.K 1997
	Cucurbit	Anthracnose	Colletotrichum orbiculare	Streptomyces sp.	Shimizu, M et al., 2009

Table 03:- Plant growth promoting activity in bacterial strains.

S.no	Bacterial strains	Plant Growth Promoting activities (enzymes production)	References
1	Actinomycetes	Antagonistic activity of fungal pathogens, IAA, siderophore, HCN, enzymes production.	S. Gopalakrishnan et al., 2014
2	streptomyces spp Rice	β-1,3-glucanase-production	S. Gopalakrishnan et al.,2014
3	Acinetobacter spp.	IAA, phosphate solubilization, siderophores	Rokhbakhsh-Zamin et al. (2011)
4	Acinetobacter sp., Pseudomonas sp.	ACC deaminase, IAA, antifungal activity, N2- fixation, phosphate solubilization	Indiragandhi et al. (2008)
5	Rhizobium sp. (pea)	IAA, siderophores, HCN, ammonia, exo-polysaccharides	Ahemad and Khan (2012b)
6	Mesorhizobium sp.	IAA, siderophores, HCN, ammonia, exo-polysaccharides	Ahemad and Khan (2009a)
7	Rhizobium sp.(lentil)	IAA, phosphate solubilization, siderophores Rhizobium sp.(lentil) IAA, siderophores, HCN, ammonia, exo-polysaccharides	Rokhbakhsh-Zamin et al. (2011)
8	Bradyrhizobium sp.	IAA, siderophores, HCN, ammonia, exo-polysaccharides	Ahemad and Khan (2012 f)
9	Bradyrhizobium sp. 750,	Heavy metal mobilization	Dary et al. (2010)
10	Rhizobium phaseoli	IAA	Zahir et al. (2010)
12	Mesorhizobium sp.	IAA, siderophores, HCN, ammonia	Wani et al. (2008)

Table 04:- Compounds present in root exudates in different plant species.

Amino acids	α-Alanine, β- Alanine, α-Aminoadipic acid, γ-Aminobutyric acid, essential and non-essential amino acids.
Enzymes	Amylase, protease, acid and alkaline-phosphatase, invertase.

Inorganic ions and gaseous molecules	HCO_3, OH-, H+CO2.H2
Organic acids	Acetic acid, aconitic acid, aldonic acid, butyric acid, Citric acid, erythronic acid, fumaric acid, glycolic acid, malic acid, malonic acid, oxalic acid, piscidic acid, pyruvic acid, succinic acid, valeric acid.
Nucleosides/purines	Adenine, thiamine, cytidine, uridine.
sugars	Mono saccharides, (Glucose), Disaccharides (fructose), oligosaccharides, raffinose, maltose.
Vitamins	Biotin, thiamine, niacin, riboflavin.

This acquired from (Dakora and Phillips 2002: Ahemad, M and Mulugeta K 2014)

Table 06:- Acidic condition in antagonistic activity.

Bacteria	**Fungal pathogens**	**Growth of bacteria between pH Range (1-14)**	**References**
B. cereus	R. solanacearum	Normal growth was 5.0. Optimal growth of pH 7.0.	Li, S et al., 2016
P. fluorescens	R. solanacearum	Normal growth 5.5 Optimal growth ~7.0	Li, S et al., 2016

Table 05:- Rhizobacteria screening medium.

Crop species	**Rhizobia**	**Screening medium**	**Growth condition**	**Remarks**	**References**
Chickpea	Mesorhizobium spp (pH stress)	pH 5,7, and 9	In-vitro	Large range of isolate variation in growth at pH 7, and 9 and other at pH 5, and 7.	Rodrigues et al. (2006)
	Mesorhizobium spp **(Temperature stress)**	20, 28 and 37 ^{O}C Heat shock at 60 ^{O}C for 15 min; 46 ^{O}C for 3 h	In vitro	Overproduction of 60 k Da protein by all the isolates All the isolates revealed more tolerance to 20 ^{O}C than 37 ^{O}C Variations in the expression of protein profile	Rodrigues et al. (2006)
	Rhizobium sp. DDSS69	5 ^{O}C	In vitro	Induction of 135 and 119 k Da Proteins. Variation in the protein profile of stressed and non-stressed cells	Sardesai and Babu (2001)
Chickpea - salt resistant and sensitive cultivars	M. ciceri ch-191 **Salt/osmotic stress**	50, 75, 100 mM	In vitro	Decreased plant dry weight, nitrogenase activity in sensitive cultivars. Less N2 fixation inhibition, higher root to shoot ratio, normalized nodule weight and shoot K/Na ratio and reduced	Tejera et al. (2006)

	M. ciceri ch-191	100–400 mmol NaCl/L	In vitro	foliar accumulation of Na, in resistant cultivars. Higher tolerance was noticed on 200 mmol/L. Altered protein and LPS levels Higher proline accumulation than glutamate.	Soussi et al. (2001)
	Acacia rhizobia. (40 strains)	0.4-1.4 M NaCl	In vitro	Presence of small and large plasmids Intracellular accumulation of free glutamate. Three rhizobia strains has tolerated 1.4 M NaCl.	Gal and Choi (2003)

Crop species	**Rhizobia/ bacteria**	**Heavy metals stress**	**In vitro/ In vivo/ Pot experiments/ filed conditions**	**Using the plants/ remarks**	**References**
Chickpea	M. ciceri, M. mediterraneum S. medicae	25 mM NaCl	Glasshouse	M. cicero enhanced the nodulation and CAT activity. Least decrease in nodule protein and SOD activity.	Mhadhbi et al. (2004)
Kidney bean	R. tropici co-inoculated with Paenibacillus polymyxa **Drought stress**	-7, -70 and <-85 kPa	Greenhouse	Enhanced plant height, shoot dry weight and nodule number	Figueiredo et al. (2008)
	Bradyrhizobium sp.	PEG 6000 induced	In vitro and pot culture	Enhanced drought tolerance, IAA and EPS production; nodulation, nodule ARA, nodule N	Uma et al. (2013)
Chickpea	M. mediterraneum LILM10		Field study	Increased nodule number, shoot dry weight and grain yield. Water deficient tolerant strains were also NaCl tolerant.	Romdhane et al. (2009)
Kidney bean	R. elti (engineered for enhanced trehalose-6-phosphate synthase		Pot studies	Enhanced nodules, nitrogenase activity and biomass production Higher tolerance than wild type strains	Sua´rez et al. (2008)

Table 07:- Heavy metals stress in verious crop species In vitro/ In vivo/ Pot experiments/ filed conditions.

Green gram	Bradyrhizobium RM8	Ni, Zn	Pot experiments	Enhanced growth performance	Wani et al. (2007c)
Chickpea	Mesorhizobium RC3	Cr	Pot experiments	Enhanced growth, nodulation, chlorophyll, Leghaemoglobin, nitrogen content, seed protein and seed yield	Wani et al. (2008b)
Black medic	S. meliloti	Cu	Pot experiments	Enhanced biomass production	Fan et al. (2011)
Hyacinth bean	Rhizobium sp.	Co,Cu, Zn, Cd	Pot experiments and field conditions	Greater HM accumulation in nodules than in roots and shoots	Younis (2007)
Lentil	Rhizobium RL9	Pb, Ni	Pot experiments	Increased growth, nodulation, chlorophyll, leghaemoglobin, nitrogen, seed protein and seed yield	Wani and Khan (2012, 2013)

Table 08:- IAA function and using plant growth.

S. No	Production of bacteria in HCN	Effects on the diseases	References
1.	Pseudomonas spp	Fusarium oxysporum, Thielaviopsis basicola	Laville et al., 1998.
2.	Pseudomonas fluorescens, Pseudomonas putida	Verticillium dahliae	Mercado-Blanco et al 2004
3.	Streptomyces	Pythium sp	Lachance and Perrault., 1953
4.	Burkholderia, Rahnella, Pseudomonas, Curtobacterium.	Rhizoctonia solani, Fusarium culmorum, Gaeumannomyces graminis var. tritici, Pythium ultimum.	Kandel, S. L et., 2017.
5.	Burkholderia contaminans	R. solaniAG 1(IA), S.botryosum,A. alternate,P. graminicola,F. moniliforme,F. graminearum,C. dematium,S. lyco-persici,A. solani,F. oxysporumf.sp.melonis,S. rolfsii,M. cannonballus	Tagele, S. B et al., 2018.
6.	Trichoderma erinaceum	Rhizoctonia solani, Sclerotium rolfsii and Sclerotium oryzae	Swain, H et al.,2018.

Anthyllis plants	Mesorhizobium metallidurans	Zn, Cd, Pu	In vitro	metal-tolerant	Mohamad, R et al., (2016)

Table 09:- Production of HCN and effects of diseases.

S.no	**Functions of Aux / IAA**	**Aux / IAA genes in growth and development**
1.	Apical dominance	IAA8, IAA16, IAA17, IAA28
2.	Embryo axis formation	IAA24
3.	Embryonic root	IAA12, IAA13, IAA20.
4.	Embryonic patterning	IAA12, IAA18, IAA24.
5.	Flower organ	IAA8, IAA16
6.	Gravitropism	IAA1, IAA8, IAA17, IAA19, IAA20, IAA30, IAA31.
7.	Hypocotyl elongation	IAA2, IAA3, IAA6, IAA8, IAA7, IAA17, IAA18, IAA19.
8.	Lateral root formation	IAA3, IAA8, IAA12, IAA14, IAA16, IAA18, IAA19, IAA28.
9.	Leaf morphology	IAA2, IAA3, IAA6, IAA7, IAA8, IAA17, IAA18.
10.	Lateral branch	IAA8, IAA17
11.	Plant size	IAA8, IAA17
12.	Primary root	IAA16, IAA20
13.	Responses to light	IAA7
14.	Root hair	IAA3, IAA7, IAA16, IAA17.
15.	Vasculature	IAA20, IAA24, IAA30, IAA31.

Table 10:- Crop pest management with rhizospheres soils.

S.no	**Crop's species**	**Pesticides management**	**Bactria/ rhizobium**	**conditions**	**Concentrations**	**Remarks**	**References**
		Herbicides					
1.	Pea Lentil	Quizalafop -pethyl	Rhizobium MRP1 Rhizobium MRL3	Pot experiments	40, 80 and 120 µg/kg soil	Enhanced biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and seed protein	Ahemad and Khan (2009a, 2010b, d)
2.	Chick pea	Clodinafop	Mesorhizobium MRC4	Pot experiments	400, 800 and 1,200 µg/kg soil	Enhanced biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and seed protein	Ahemad and Khan (2009a, 2010b, d)
3.	Chick pea	Metribuzin	Rhizobium MRP1	In vitro	850, 1,700 and	Concentration-dependent	Ahemad and Khan

			Rhizobium MRL3		2,550 µg/L	progressive decline in PGP substances except exo-polysacchari des	(2011a, b, 2012a, c)
4.	Chick pea	Glyphosate	Mesorhizobium MRC4, Bradyrhizobiu m MRM6.		1,444, 2,888 And 4,332 µg/L	----------	Ahemad and Khan (2011a, b, 2012a, c)
5.	Chick pea	Terbuthyla zine Simazine and Prometryn Bentazon	R.leguminosaru m RCR 1045	In vitro	4, 8, 16, 32 and 64 mg/L. 4.3, 8.6, 17.2, 34.4 and 68.8 mg/L. 4, 8, 16, 32 and 64 mg 4.1, 8.2, 16.4, 32.8, 65.6 mg/L	Growth decline was in the order of Terbuthylazi ne> Prometryn > Simazine No adverse effects on growth	Singh and Wright (2002)
6.	soybe an	chlorimuro n-ethyl	Bradyrhizobiu m japonicum	Filed conditio ns		leguminous plants living in symbiosis with rhizobia, nodules may contribute to an enhanced tolerance to ALS inhibitors.	Zawoznik, M. S and Tomaro, M. L., 2005
		Insecticide s					
7.	Chick pea, Pea, Lentil	Fipronil Pyriproxyf en	Rhizobium MRL3 R. Leguminosaru m MRP1 Mesorhizobium	Pot experim ents	200, 400, and 600 mg/kg soil 1,300, 2,600, and 3,900	Enhanced the biomass, nodulation, leghaemoglo bin content, root and shoot N, root and shoot P,	Ahemad and Khan (2009b, 2010a, 2011f)

			MRC4		mg/kg soil	seed yield and seed protein	
8.		Imidacloprid Thiamethoxam	Rhizobium MRP1 Rhizobium MRL3 Mesorhizobium MRC4 Bradyrhizobium MRM6	In vitro	100, 200 and 300 µg/L	Concentration-dependent progressive decline in PGP substances except exopolysaccharides	Ahemad and Khan (2011a, b, 2012a, c)
9.		**Fungicides** Hexaconazole Metalaxyl Kitazin	Rhizobium MRP1 Rhizobium MRL3 Mesorhizobium MRC4 Bradyrhizobium MRM6 Rhizobium MRP1	In vitro	40, 80 and 120 µg/L 1,500, 3,000 And 4,500 µg/L 96, 192 and 288 µg/L	Concentration-dependent progressive decline in PGP substances except exopolysaccharides	Ahemad and Khan (2011a, b, 2012 a,c)
10.	Pea	Tebuconazole	Actinomycete (CAI-13, CAI-140, CAI-85, CAI-93, CAI-155 and KAI-180).	In vitro Pot experiments	100, 200 and 300 µg/L 00, 200 and 300 lg/kg soil	Concentration-dependent progressive decline in PGP substances except exopolysaccharides, HCN and ammonia. Enhanced the biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and	Ahemad and Khan (2011d)

						seed protein	
11.	Rice	Bavistin Captan Radonil Thiram Benemyl Benlate	Actinomycetes CAI-24, CAI-121, CAI-127, KAI-32 and KAI-90	antagonistic field conditions	2500 (ppm) 3000 (ppm) 3000 (ppm) 3000 (ppm) 3000 (ppm) 4000 (ppm)	Agronomic performance and yield potential of rice, Enhanced the biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and seed protein	S.Gopalakrishna et al., (2014)
12.	sorghum	Fusarium oxysporum f. sp. ciceri (FOC) Rhizoctonia bataticola.	Actinomycetes VAI-7, VAI-40, SAI-13 and SAI-29	Antagonistic activity Greenhouse and wilt-sick field conditions	45-76% and 4-19% reduction	Potential for biological control of Fusarium wilt disease in chickpea. Enhanced the biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and seed protein	S.Gopalakrishnaet al., 2011
13.	chickpea	Bavistin,Thiram, Captan Benlate , Ridomil. Macrophomina phaseolina, Fusarium oxysporum f. sp. cicero Sclerotium	Streptomyces (CAI-21, CAI-26 and MMA-32)	In vitro and in vivo conditions, filled conditions. Antagonistic activity.		Increase in nodule number, pod number, leaf weight, leaf area, plant height, stem weight, grain yield, seed weight, total dry matter, and seed number. Potential for	M. Sreevidya et al., 2016

		rolfsii				biological control of Macrophomina phaseolina, Fusarium oxysporum f. sp. cicero Sclerotium rolfsii disease in chickpea.Enhanced the biomass, nodulation, leghaemoglobin content, root and shoot N, root and shoot P, seed yield and seed protein	
14.	Rice	Macrophomina phaseolina (Tassi)				Enhanced the panicle length, filled grain numbers and weight, panicle weight, seed weight, tiller numbers, total dry matter, root length, root dry weight, grain yield, Stover yield, and root dry weight. Concentration-dependent progressive decline in PGP substances exopolysaccharides, HCN,	S.Gopalakrishnan et al., 2012

						IAA, cellulase, lipase, and ammonia.	

Table 11:- Function of gene in plants.

Plants	Function of gene	Gene	References
Alfalfa	Water and salt stress tolerances	MnSOD	Mckersie et al. (1996)
Arabidopsis thaliana	Transcription factor	JcDREB HKT1	Tang et al. (2011) Munns (2005)
Brassica	Plasma membrane Na+/K+ antiporter Vecuolar Na+/K+ antiporter.	SOS1	Chakraborty et al. (2012), Zhang et al. (2001)
Campestris and Brassica Juncea	Mannitol may be involved in Hexose sensing (or) mopping up hydroxyl radicals	SOS2 SOS3 S6PDH	Gao et al. (2001)
carrot	Cell viability and membrane stability under heat stress	DcHsp17.7	Song and Ahn (2011)
Wheat Oryza sativa	1. Turgor maintenance, particularly in the cytosol 2. Signalling, possibly through hexose sensing 3. Cell-wall protection. 4. Heat-shock proteins, molecules, Chaperones, and folding.	Mt1D OsHSP80.2 OsHSP71.1 Coda, otsA, otsB, PRP	Abebe et al. (2003) Sakamoto and Murata (1998), Zhou et al. (2015)
Tobacco	Turgor maintenance	P5Cs mod	Hong et al. (2000)
Tomato	Salt tolerances	BADH1(Betaine aldehyde dehydrogenase)	Zhang et al. (2001)

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