Chapter 2

Review of Literature

From ancient times, pathogen attack on plants is the biggest challenge in the agriculture sector. Viruses, bacteria, fungi and nematodes are the major causes of plant diseases. These pathogens are responsible for approximately 10 to 30% of global yield loss. The other factors contributing to yield loss include climate change, threat management and evolving strains of pathogens (Kumar *et al.*,2014). Disease symptoms usually appear when plants launch their immune response against pathogen attack. Pathogen-associated molecular patterns-triggered immunity [PTI] and effectors-triggered immunity [ETI]) provide the necessary help to control the infection but do not sustain for long. These immunities act as primary and secondary layers of defense to lower down the impact of infection in plant (Xue Jia-Yu*et al.*, 2020).

Besides suppressing plant immune response, pathogens need to cross barriers like cell wall, plant metabolites and environmental conditions to colonize within the host plant successfully (Andersen EJ*et al.*, p. 2018). Plant exposure to various stress conditions also induces disease resistance in many plants which could be segregated into the next filial generation. Such resistances may include polygenic resistance, durable resistance and pathogen resistance. (Piquerez Sophie J. M. *et al.*, 2014). Biffen (1905) has reported one of the first disease resistance plant mechanism and its segregation to off-springs through classical genetics. Subsequently, vast research has been carried out to understand the physiological, biochemical and molecular responses of host plant against pathogen invasion.

From pathogen point of view, plant susceptibility to pathogen infection depends on poor or no immune response induction by host plant and strong virulence demonstrated by the pathogen. Proteins demonstrating virulence are products of one or more virulence genes present in the pathogen. According to gene theory of Flor (1942), for a single gene of disease resistance of the host plant, pathogen also has a corresponding virulence gene (Webb, P*et al.*, 1986). This can be explained by demonstrating allelic conditions of the host (R/r) and pathogen gene (V/v) and their combinations. It can be further explained in details by performing the genetic and molecular studies on host and their pathogens. The mechanisms for the same is hypothesized differently by Van der Plant (1960) and explained through vertical disease resistance, where one or more genes are transferred under monogenic and oligogenic resistance.

On the other side under polygene condition non-specific disease resistance is observed against multiple strains of a single pathogen or against range of pathogen which is known as horizontal resistance. Under this spread of the pathogen is decreased due to reduction in pathogen number or its spore interacted with host. There are different cons and pros of these host plant response against pathogen in both of these mechanisms. One the one side vertical resistance of host plant is often qualitative where response is pathogen specific and oligogenic horizontal resistance is observed as quantitative, usually nonspecific and mainly demonstrated by polygenic genes. Moreover, to this vertical disease resistance of host plant is more effective against mobile pathogens compared to horizontal disease resistance, demonstrated through host-pathogen active interaction. (Mayank Anand Gururani, 2012)

These responses are widely studies for agriculturally important crops and horticulture species to develop the diseases resistant variety as well as to develop the economic strategies to control various plant infections and disease spread. Current strategies i.e., application of pesticide has several adverse effects for environment and human health moreover it is expensive and practically difficult for range of pathogens as well as host plants. Considering the agriculture sector as one of the major boosters for GDP research on plant disease resistant response is one of the prominent needs. Further susceptibility of host plant may dramatically vary for different pathogens, its strains and among cultivars of the crop plants. (Sharma A *et al.*, 2019)

To overcome this issue various practices are introduced in agriculture sector like crop rotation, spreading of pesticides, plant breeding and genetic modification in plants. (H. Peter van Esse *et al.*, 2019) (Zaidi *et al.*, 2020). The use of the genetic engineering tools in plants raised many ethical and environmental issues. The technique is useful show an impact over increase in yield but now a days the pathogens also adopted a resistance strategy against it (Venezia Matthew *et al.*, 2021)**.**

Another approach to resolve the resistance issue is to use natural remedies. A group of bacteria called Plant Growth Promoting Rhizobacteria (PGPR),diverse group of microorganisms, increase the plant growth by 3 main mechanism includes, Direct mechanism, Indirect mechanism and Induced Systematic Resistance (ISR). The direct interaction between plant pathogen and PGPR shows an alteration in physiological metabolism and virulence gene expression in plant pathogens. (Meena M *et al.*, 2020) (Jiao Xiurong *et al.*, 2021)

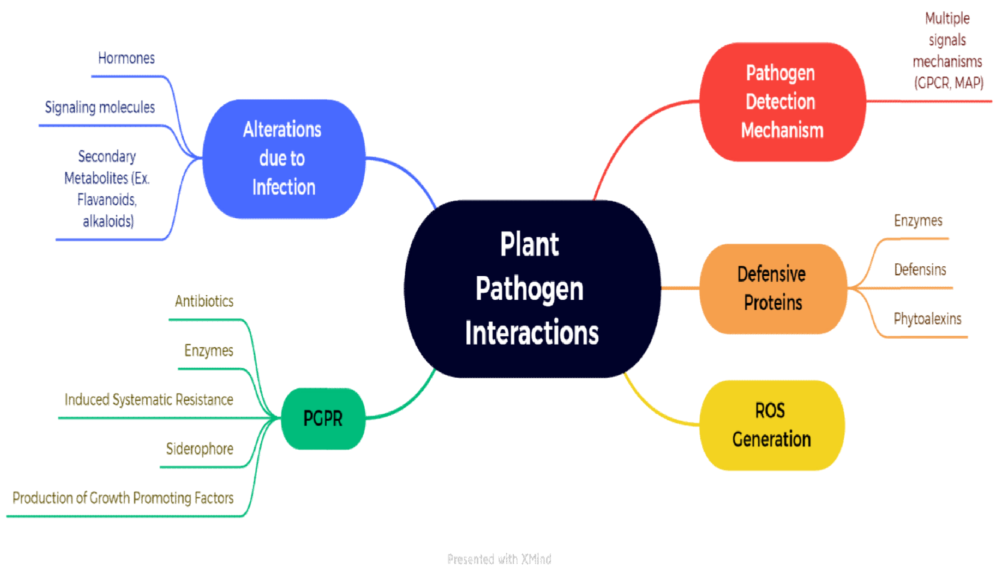

Fig 1. A schematic representation of interactions of plant pathogens by Saraf (2015)

These PGPR performs multitude role with plants that includes recycling of nutrients, mineral solubilization, competition with plant pathogens for space and nutrition, production of antibiotics, enzymes, plant hormones and signalling to plants. Some know PGPR are *Pseudomonas, Azotobacter, Klebsiella, Enterobacter, Arthrobacter, Bacillus, and Serratia*. (Mohanty Pratikhya *et al.*, 2021)(Backer Rachel *et al.*, 2018) (Basu *et al.*, 2021).

India is second largest country known for the cultivation of various agricultural crops and exported to all over the world. While as per the report of Union Agriculture Ministry in agricultural sector of India's shared total Gross Value Added (GAV) economy has decline15% in 2022-23 due to the high growth rates of the industrialization and overwhelming utilization of chemical fertilizers and pesticides. Due to these effects pathogens get resistant into the soil and cause various diseases in economically important crop plants. Some of selected economically significant plants are highlighting in this research which are majorly important crops in saurashtra region of Gujarat and susceptible for plant pathogens such as cumin, groundnut, chickpea, rice and mung bean.

Gujarat is the largest producer and exporter of cumin seeds. Cumin (*Cuminum cyminum* L.), generally called as jeera and it is oldest seed in worldwide. It belongs to and annual therapeutic plant and spices of the umbelliferae family .Gujarat's production reaches 420000 tons per year, assembly is the greatest India's leading producers. India generally exports about 8000 to 9000 tons of cumin per yearly. Cumin is a tropical plant and grown only in rabbi season at the low humidity flowering and seeding arises. Unfortunately, some of the diseases such as *Fusarium* wilt, powdery mildew, and blight are significant pathogenic effects for lower production and nutritional deficiency (Dange *et al.,* 1992).Amongst all the diseases, the extreme damage caused by *Fusarium* wilt.

Vishwadhar and gurha (1998), has reported that the chickpea has been and is being consumed by people since ancient times showing to its good nutritional properties. Chickpea (cicer arietinum L.) is the world third most important pulse crop. In India, it is commonly known as ‘Chana’, contributes largest producer with 75% of world. Chickpea was grown on 9.92 million hectares with the production of 9.80 million tones and productivity 945 kg. In India, Madhya Pradesh stood first as far as acreage and production were concerned.

Pulses play a crucial role as primary protein sources for vegetarians in India, and complementing staple cereals in the diets with proteins, essential amino acids, vitamins and minerals. The protein content of 22%, pulses offer nearly twice the protein found in wheat and thrice that of rice. Pulses provide significant nutritional and health benefits, and are known to reduce several diseases such as colon cancer and cardio-vascular (Laxmipathi *et al.*, 2013). Beniwal *et al.,* (1992) has reported, the chickpea production is mostly affected by soil-borne phytopathogens which can cause wilt and root rot disease in chickpea plants. However, *Fusarium* wilt, black root rot, and dry root rot which can be caused by *Fusarium oxysporum*, *R. solani*, and *F. solani*, respectively. The soil-borne plant pathogenic fungi *viz.*, *F. oxysporum* have a wide host range for disease complex symptoms which in turn lead to great worldwide economic losses every year (Rudresh *et al.*, 2005; Senthikumar *et al.*, 2009). *Fusarium oxysporum* is a soil-borne pathogen and causes wilt disease in chickpea plants. (VellaichamyMageshwaran *et al.,* 2022).

Vasumathi S and Ahila Devi, 2020 has reported groundnut (*Arachis hypogea* L.) belongs to the Fabaceae family, which has edible oil in the seeds. Groundnut is cultivated extensively in nearly all tropical and subtropical countries across the world. Including China, India, Nigeria, Sudan and USA. In India, Gujarat is the largest producer of groundnut contributing to 25 per cent of its production. The pathogen *Fusarium oxysporum* that causes wilt of groundnut was first reported in Tansania by Armstrong *et al.,* (1975). Groundnut plant is affected by several diseases, like leaf spot, collar rot,and rust and bud necrosis.

Hubiao Jiang *et al.,*(2020) has reported the rice (*Oryza sativa* L.) stands as a crucial staple food, providing sustenance for over 60% of the world's population. The threat of rice bakanae disease (RBD) caused by seed-borne *Fusarium spp*. Poses a potential risk to global food security. Manifestations of RBD include the elongation of primary leaves, induced by the production of fungal gibberellic acid. This characteristic has led to the disease bakane, a Japanese term meaning, 'foolish seedling'. Rice blast, a severe fungal disease affecting rice (*Oryza sativa* L.) that is threatening global food security. It has been extensively studied due to the importance of rice production and consumption, and because of its vast distribution and destructiveness across the world. Wilt and root rot disease in plants has been caused mainly by *Fusarium* species. Previous studies reported that members of the *Fusarium oxysporum* species complex (FOSC) was usually associated with this disease, but there has been no report of it being caused in rice by specific *Fusarium* species. However, in this study, wilt and root rot disease of rice was caused by *Fusarium commune*. This is the first report of *F. commune was* recognized as the causative agent for wilt and root rot disease in rice plant.

Mung bean (*Vigna radiata* L.) stands as an economical significant grain legume crop. Indigenous to the North-eastern India–Burma region of Asia, it is cultivated across tropical, subtropical, and temperate regions of Asia, Central Africa, South and North America, as well as Australia for its protein-rich grains. In Gujarat region mung bean cultivation is near about 3 to 4% out of the entire India. According to Dean *et al.,*(2012) *Fusarium oxysporum*, ranked 5th among the 10 plant pathogens of scientific and economic importance, poses a threat to various causing *Fusarium* wilt or root rot. Pathogenic strains of *F. oxysporum* exhibit a broad host range, affecting over 150 plant species, including crucial horticultural and agricultural crops. *Fusarium* wilt emerged as a growing concern for mung bean cultivation in China in 2019.

2.1 Problem Statement

1. Organic farming – why needed

2. Background as – industrialization

3. Natural fertility of soil reduction

4. To circumvent the problem – best alternative

5. Wilt disease a common problem in India specially Gujarat – how to deal with it? Organically

The advent of more and more likelihood towards sustainable life practices and increased consciousness of wellbeing among the human civilization has paved the way to adopt a new but cost effective, healthy agro-economic practice that is organic farming or in other words Green Revolution. The consumers both of indigenous population and globally are inclining more towards the adoption of green and clean safe hazard free life commodities and one such prime requirement is food. Minimization of external input with use of inside resources in farm makes the process more eco-friendly although the comparative evaluation of yield with respect to industrial agriculture not so attractive till now. Rather, than claiming a profound interest on product yield the more emphasize can be claimed in such technique is underneath in its process. Well talking about, the management of soil reclamation and choice of approaches for safeguarding the soil mineral and major C N P ratio maintainnece from increased side effects of industrialization and urbanization the practice of organic farming in many ways beholds a natural attribute in its methodology and use of input (Ramesh *et al.*, 2005).

Due to uncontrollable population increase and with that in parallel getting maintained the hunger management made the sudden irrational shift of traditional in-house farming (in Vedic World) to modern Agricultural practices or precisely *Synthetic agricultural practices* making broadened the over usage of the chemical in the fields. With the advent of novel insecticides and herbicides like DDT (Dichloro, diphenyltrichloro acetic acid) followed by the discovery of n BHC (Benzene hexachloride), Nitrophenols, 2, 4-D (2, 4-dichloro phenoxy acetic acid), MCPA (2-methyl, 4- chlorophenoxy acetic acid around in mid-20th century modern agricultural tools and techniques, i.e. farm machinery, chemical fertilizers and agrochemicals are more get inclined to the farmers (Aulakh and Ravishnakar, 2017). Going back to the soil science and fundamentals of agricultural practices we are all aware that, in the soil organic matter and humus happened to play an important role in stabilizing soil health and soil structure which indirectly influence strongly the plant growth and also the natural for a of the soil. According to Waksman (1983), the major source of nutritional exchange was benefitted by these soil natural flora that is microbes.

2.2 Contribution of the research work towards problem domain

- It refers to the potential contribution of a successful rhizobacterial consortium preceded by individual potent isolate screening and its validation with respect to PGPR trait identification in terms of growth promoting factors study at lab scale level.
- The pot experiment trial also further validates the real time application of the potent identified rhizobacterial consortium. This trial confers the root and shoot growth ratio, chlorophyll content, RWC etc. which is found will be quite satisfactory in this project.
- The present research work surely worth for an exploratory laboratory trial pertaining to a suitable alternative of exhaustive chemical fertilizer usage.
- The research work will be explored a potent biocontrol agent for suitable remedy against wilt disease, a very popular menace in agricultural crops like and monocot (Rice, Cumin) & dicot (Groundnut, Mung, Chickpea) plants taken as an objective of research.
- The present research work is an attempt for the solution of an unavoidable menace of wilt disease causing agent in a popular economic plant whose sustainable management in terms of crop protection and growth promotion is necessary at current context. The knowledge of the biocontrol strategies and green technology for sustainable crop protection and management is also confer here in this research.

By considering the above facts and issues the following objectives are set to find out possible remedy to control *Fusarium* wilt in monocot and dicot plants and also PGPR can be utilized as a biofertilizer to promote the plant growth and crop productivity of Saurashtra region.

2.3 Biofertilizer

Gustavo *et al.,* (2021) has found, the synthetic fertilizers are applied to crops on a large scale to meet the growing global food demand, leading to high health, economic and environmental costs. One of the most extensively researched sustainable alternatives for improving plant growth and soil fertility is the utilization of plant growth promoting rhizobacteria, which can regulate the growth, development and productivity of crops. This mechanism can effects are due to improvement of the availability and biosynthesis of several limiting macro and micro nutrients, as well as crop protection against stressful environmental conditions.

Mishra *et al.,* (2007) stated bio-fertilizers are the best modern tool for agriculture, which is the gift of our modern agricultural science. Bio-fertilizers are usedin the agricultural field as substitutes as chemical fertilizers.A biofertilizer is a product comprising living microorganisms that colonize the rhizosphere and stimulate development by enhancing the supply or accessibility of nutrients to the host plant when administrated to the soil, seed, or plant surface.

2.3.1 Application of Bio-Fertilizers

Bio-fertilizers are formulated in liquid, powder and granular forms for application to soil, compost, seed, seedling and plant leaves. When using bio-fertilizers, it is crucial to adhere to the instructions and warnings provided on the label. There are three methods for utilizing bio-fertilizers

a. Inoculation to seed,
b. Seedling root dip and
c. Field application.

2.3.2 Significance in the Agriculture of Bio-Fertilizers

a. More cost-effective than synthetic fertilizers.
b. Enhance soil fertility, improve fertilizer utilization efficiency and ultimately boost yields by approximately 20-30% on average.
c. They produce specific substances that promote plant growth.
d. Display anti-fungal properties and protect the plants from pathogenic fungi,
e. Enhance the phosphorus nutrition of plants (Nur *et al.,* 2018)

2.3.3 Bio-Fertilizers are used in Agriculture

2.3.4.1 N_2 fixing Bio-fertilizers

1. Free-living

Example : *Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc*.

2. Symbiotic

Example : *Rhizobium, Anabaena azollae*

3. Associative Symbiotic

Example : *Azospirillum*

2.3.4.2 PhosphorusSolubilizing Bio-fertilizers

1. Bacteria

Example : *Bacillus megaterium var. phosphaticum.*

2. Fungi

Example : *Penicillium sp, Aspergillus awamori.*

2.4 Nutritional Value

As per information provided by the (USDA), a 100 grams serving of raw peanuts comprises 567 Kcal, amount of micro and macro nutrients are carbohydrate 16.13 g,sugars 4.72g, protein 25.8 g and fat, minerals and vitamins, whereas white and brown rice have similar 130 calorie, 28.7 g carbohydrate, 2.36g protein, and 0.19g fat content and other nutrient also present.Chickpea in a 100g serving, nutritional value like 364 calories, fat 6 g, carbohydrate 61 g, protein 19 g, and vitamin c is also present, whereas mung per 100 g serving 347 calories, total fat 1.2g, sodium 15mg,carbohydrate 63g,protein 24g and other nutrients like vitamin c, vitamin b12 and magnesium is also present.

2.5 Occurrence of disease in crops

2.5.1 Plant Diseases

Most plant diseases – around 85% are caused by fungal or fungal-like organisms. However, other serious diseases of food and feed crops are caused by viral and bacterial organisms (Jim *et al.,* 2012)**.** Here are a few examples of common fungal, bacterial, viral and nematode plant diseases

2.5.2 Fungal diseases

- Wilt in various plants such as groundnut, cumin, chickpea etc.
- Powdery mildew
- Blight
- Corn smut
- Powdery mildew
- Leaf rust (common leaf rust in corn)

2.5.3 Bacterial Diseases

- Leaf spot with yellow halo
- Canker
- Crown gall
- Bacterial wilt in tomato

2.5.4 Viral Diseases

- Tobacco mosaic
- Cucumber mosaic
- Barely Yellow dwarf

2.5.5 Nematodal Disease

- Root –knot nematodes

Among all the disease in our research work we are majorly focusing about the fungal disease of *Fusarium* Wilt which is more susceptible to the whole Saurashtra region of Gujarat.

2.6 Pathogenicity of fungal pathogen

Fungal Plant pathogen species are primarily classified into two groups, one is Ascomycota and other is Basidiomycota. In *Ascomycetes* group, plant pathogens are in various classes such as the*Dotjidiomycetes* (e.g *Cladosporium spp*.), *Sordariomycetes* (e.g. *Magnoporthe spp*.), and the *Leiomycetes* (e.g. *Botrytis spp*.). Basidiomycetes are represented by the two largest plant pathogen groups 1. Rusts (*Pucciniomycetes*) and 2. Smuts (Spread among the subphylum of *Ustilaginomycotina*) (Gunther *et al.,* 2017).

Monteserrat *et al.,* 2023 has reported soil - borne fungus *Fusarium oxysporum* is a major causative agent of vascular wilt. In present study, well- studied activity as a plant pathogen, *Fusarium Oxysporum* is known as a serious emerging pathogen of humans due to the increasing number of severe cases reported and crop yield reduces. *Fusarium oxysporum, Fusarium solani and Fusarium fujikuroi* complexes represent significant global pathogens, particularly affecting plants, human and animal pathogen (Tulin *et al.,* 2018).

Most pathogenic fungi function as intracellular pathogens, the interaction between the host and the invading species, as these pathogens reside within host cell. The variety of intracellular fungal pathogens infecting both plant and animal cells also in unique ways, there are limited solutions to the challenge of penetrating and surviving inside host cells (Casadevall *et al.,* 2008).

Certain *Fusarium spp.,* have the capability to generate mycotoxins, contaminating grains upon infection,there by posing a threat to both animal and human health (Escriva *et al.,*2015). Segura – Mena *et al.,*(2021) has reported host responses to *Fusarium* infection could also be affected by input made by farmers during cultivation. For example, *Fusarium* wilt of banana may be exacerbated by nitrogen fertilizers that are routinely applied during banana cultivations. Plant and Health Research and Diagnostics has been reported in 2007. Presently, 80% of the plant diseases can be traced to fungal pathogens. *Fusarium* wilt is a soil borne fungal disease in which the water conducting (xylem) vessels become blocked, so that the plant wilt and often dies. *Fusarium* wilts are caused by pathogenic strains of several species of *Fusarium* including *Fusarium oxysporum, Fusarium avenaceum, Fusarium solani, Fuasarium sulphureum and Fusarium tabacinum* which are usually host specific. However, the most commonly encountered culprit is *Fusarium oxysporum*. *Fusarium* wilt is wide spread in the world, plant disease caused by many forms of the soil inhabiting fungus that is *Fusarium* oxysporum. More than hundred plant species are susceptible, including economically important food crops such as sweet potato, tomatoes, legumes, cabbage cotton, palms and banana (in which panama disease is also known as banana wilt).

2.7 Antagonistic activity

Antagonistic potential of PGPR that can be exploited as biopesticides on commercial scale for sustainable agriculture system. Since many decades the use of chemical pesticides by farmers in agriculture field to successfully control the pest and thus increasing the crop production. One of the major issues of chemical pesticides is that many of them are not able to breakdown into simple and safer constituents and remained intact over a long time period polluting soil environment and synthetic pesticides are also non - targeted in nature as they affect the broad spectrum of microbe including plant beneficial microbe. Biopesticides is one of the best alternatives to chemical pesticides. Biopesticides are safe to use as compared to synthetic pesticides and they have the targeted activity against specific pathogens. It can also be easily decomposed. Some of the biopesticides such as *Bacillus thuringiensis* have a long history to safe and effective use as bio-insecticide. *Bacillus thuringiensis* as an insecticidal bacterium has been registered in United States (US) for commercial use since 1961 (Tariq *et al.,* 2017).Tariq *et al.,* (2010) has reported rhizobacteria can stop the growth of phytopathogens in different ways;

1. Competing for space and nutrients

2. Lytic enzymes,

3. Producing bacteriocins,

4. Antibiotics and siderophore.

Plant growth-promoting rhizobacteria present a valuable alternative for farmers face the new challenges of modern agriculture as serious environmental and social problems emerged as a consequence of industrialization of agriculture provoked by necessity to increase a great amount of food to the general population.

Antagonistic bacteria including *Bacillus, Enteribacter, Pseudomonas, Serratia* and *Staphylococcus* (Jing *et al.,* 2007).Antagonistic activity of PGPR is controlled by several mechanisms including competition, parasitism, and siderophore.

2.8 Microbial Interactions

In recent years, to enhance the beneficial functions displayed by these bacteria, the design of bacterial consortia has gained interest as a suitable strategy for sustainable crop and food production. The impact of the rhizobacterial strains on plants has been well explored leading to the commercialization of numerous microbial inoculants (Reed *et al.,* 2013).

2.9 Consortia Development

Bacterial interactions within a consortium can be categorized into three groups

1. Positive or stimulatory

2. Negative or inhibitory

3. Neutral

Commensalism is a positive because of one way interaction, in which one member benefits while the other is unaffected. Mutualism, protocooperation are also the examples of positive associations. One bacterium utilizes the metabolic products produced by another consortium member, which called positive interactions. Negative interactions include amensalism, predation, parasitism and completion, which can be leads to the suppression of bacterial members in consortium. Member of the consortium do not influence or affect one another that called neutral interactions (Loccoz *et al.,* 2015).

The non rhizobacteria partners including the bacteria, which belonging to the Firmicutes (e.g., *Bacillus sp., Paenibacilus sp.*), Proteobacteria (e.g., *Pseudomonas, Azospirillum*, Pantoea) Actinobacteria (e.g. *Streptomyces*) Flavobacteria and some cyanobacteria. Moreover, the beneficial effects of co-inoculations have been observed in diverse systems (e.g., *Phaseolus vulgaris, Cicer arietinum*) and their respective compatible alpha and beta rhizobial symbionts (e.g., *Rhizobium, Neorhizobium, Bradyrhizobium*).This indicates that the co-inoculation process can be a generally beneficial practice that benefits most legume rhizobia symbiosis (Lie t *et al.,* 2017).

2.10 Disease Control Management

As per the report of Jing *et al.,* (2007). Rhizobacteria can inhibit the growth of several phytopathogens through diverse mechanism that followed by the below points including;

1. Competing for space and nutrients,

2. Producing bacteriocins,

3. Lytic enzymes,

4. Antibiotics

5.Siderophore

2.10.1 Antibiotics

Antibiotics play an important role in disease management i.e., can be used as biocontrol agents. PGPR synthesizes antibiotics such as kanosamine, butyrolactones, xanthobaccin phenazine-1-carboxylic acid, pyrrolnitrin, zwittermycinA, viscosinamide. *Pseudomonas spp*. Produces phenazine, exhibiting antagonistic activity against *Fusarium oxysporum* (Vivero *et al.,* 2010).

2.10.2 Siderophore

Siderophore are the low molecular weight substances that chelate iron. Microorganisms encounter the nutritional requirements for iron using siderophore. Low ferric ions availability in the environment results in the reduced growth of pathogens, which ultimately exclude pathogen from niche (Hibbing *et al.,* 2010).

2.10.3 Bacteriocins

Bacteriocins prove highly effective in reducing antagonistic features displayed by Plant Growth Promoting Rhizobacteria (PGPR) and inhibiting the growth of phytopathogens. Conventional antibiotics, bacteriocins have narrow killing spectrum as compared to and exert damaging effects on bacteria closely relative of bacteriocins producing bacteria. Colicins are most prominent bacteriocins produced by Escherichia coli. Similarly, magicians is synthesized by B. megaterium; marcescins from Serratia marcescens; cloacins from Enterobacter cloacae; and pyocins comes from P. pyogenes. Bacteriocins that are produced by Bacillus spp. remarkably gain importance due broad range of inhibition of fungal, yeast, gram positive and gram-negative species that may have some pathogenic effect on animals and human beings (Abriouel *et al.,* 2011).

2.10.4 Lytic Enzyme

Microbes can directly suppress the growth and activities of pathogens by the secreting lytic enzymes. Hydrolytic enzymes, such as glucanases, proteases, chitinases, lipases, play a role in breking down the fungal cell wall through lysis. These enzymes either digest the enzymes or deform components of cell wall of fungal pathogens. The important mechanisms for environment friendly control of soil-borne pathogen. Lytic enzymes produced by Myxobacteria are effective in the suppression of fungal plant pathogens. Lysobacter has ability to produce glucanase, which plays a role in controlling disease caused by Bipolaris and *Pythium sp*. Hydrolytic enzymes directly contribute in the paratalization of phyto athogens and rescue plant from biotic stresses (Tariq *et al.,* 2017).

2.11 Biopesticides

Biopesticides refer to naturally derived compounds or agents sourced from animals, plants, and microorganisms like bacteria, cyanobacteria, and microalgae. These substances play a crucial role in managing pests and pathogens in diverse agriculture settings such as forests, gardens, and farm land. Various types of biopesticides have been developed from different origins, as documented by Kumar *et al*; 2021. To reduce the side effect of chemical pesticides, biological control agents are the eco-friendly approach towards the organic farming practices. Based on their potential application and strong inhibitory activity against pests, these synthetic pesticides dominate the market and have a significant impact on the manufacture of products (Liu *et al.,* 2021).

The utilization of biopesticides offers several advantages over traditional chemical pesticides. Derived from natural sources, including animals, plants, and microorganisms like bacteria and microalgae, these agents can effectively control agricultural pests and pathogens. Gene or metabolite based products from these biocontrol agents serve as preventive measures against crop damage. Notably, the eco-friendly and host specific nature of biopesticides makes them a preferable choice over their chemical parts, as highlighted by Essiedu *et al.,* (2020).

2.11.1Types of Biopesticides

Biopesticides are categorized based on their extraction sources and the specific molecules or compounds employed in their formulation. The categories are listed below.

2.11.1.1 Microbial Pesticides

These are originated from microorganisms such as bacteria, fungi and viruses. The active molecule and compounds are extracted from these organisms target particular pest species or entomopathogenic nematodes.

2.11.1.2 Biochemical Pesticides

Biochemical pesticides are naturally derived substances employed for pest control through non- toxic mechanisms, contrasting with chemical pesticides that rely on synthetic molecules for directly killing pests. Biochemical pesticides are further categorized based on their mode of action.

1. Insect Pheromones

2. Plant-Based Extracts and Essential Oils

3. GMO Products

2.11.1.3 Mode of action of Microbial Pesticides

Biopesticides act in a many ways on microorganisms depending on their type and nature. A few mechanisms through which biopesticides attack or kill pathogens.

Microbial Biopesticides, Fungicides and bactericides. These biopesticides generally inhibit or disrupt the process of translation and thus protein synthesis in numerous ways, including through binding of 50S ribosomes in prokaryotes, to prevent the transfer of peptides and inhibit chain elongation.

2.12 Aim & Objectives

Aim Study of Effect of PGPR on Growth and Disease Resistance in Selected Economically Important Crops of Saurashtra Region- India

Objectives

- Isolation and screening of rhizobacteria from the cultivated fields of Saurashtra region.
- Study of qualitative and quantitative characterization of PGPR traits of the isolated rhizobacteria.

- Evaluation of the effect of PGPR on the growth of selected crops under controlled conditions in the laboratory.
- Biochemical and Molecular identification of the selected isolates.
- Study of disease resistance pattern of the isolates after exposure to PGPR.
- Comparative study of the PGPR traits of the isolates and the effect of consortium in growth and disease resistance of the selected crops.