"Studies on management of dry root rot of chickpea caused by *Rhizoctonia bataticola* (Taub.) Butler"

THESID

SUBMITTED TO THE

SARDAR VALLABHBHAI PATEL UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, MEERUT – 250110 (U.P)

BY

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CERTIFICATE

This is to certify that the thesis entitled "**Studies on management of dry root rot of chickpea caused by *Rhizoctonia bataticola* (Taub.) Butler"** submitted in partial fulfillment of the requirements for the **Master of Science in Agriculture** with major in **Plant pathology** and minor in **Entomology,** of the College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, is a record of *bona-fide* research work carried out by **Bipin Yadav, Id. No. PG/A-4863/2019,** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation and source of literature have been duly acknowledged.

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We, the undersigned, Members of the Advisory Committee of **Mr. Bipin Yadav, Id. No. PG/A-4863/2019,** a candidate for the degree of Master of Science in Agriculture with major in **Plant Pathology** and minor in **Entomology**, agree that the thesis entitled "**Studies on management of dry root rot of chickpea caused by *Rhizoctonia bataticola* (Taub.) Butler"** may be submitted by **Mr. Bipin Yadav** in partial fulfillment of the

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Place: ***Bipin Yadav***

(Author)

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LIST OF ABBREVIATIONS

DRR	Dry root rot
PDA	Potato dextrose agar
PDB	Potato dextrose broth
NAM	Nutrient agar media
CFU	Cell forming unit
min	Minutes
Sec	Seconds
Gm	Gram
Mg	Microgram
Hrs	Hours
Kb	Kilobases
LAF	Laminar air flow
UV	Ultra violet
w/v	Weight by volume
v/v	Volume by volume
ANOVA	Analysis of variance
Conc.	Concentration
CD	Critical difference
CV	Coefficient of variance
CRD	Completely randomized design
RBD	Random block design
e.g.	For example
et al.	And others
Fig.	Figure
g/l	Gram per liter
In vitro	Under aseptic condition
i.e.	That is
Mm	Millimeter
Ppm	Parts per molecules
pH	Negative logarithm of hydrogen ion concentration
%	Percentage
@	At the rate of
a.i.	Active ingredient
/	Per
$^{\circ}$C	Degree centigrade

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CHAPTER -1 INTRODUCTION

Chickpea (*Cicer arietinum L*.) is the world's leading pulse crop. It is an important pulse crop with a wide distribution across the tropics, subtropics and temperate regions (Ahmad *et al.* 2000). In India chickpea is also known as Bengal gram. Chickpea considered as world's second most widely grown legume after beans (*Phaseolus vulgaris*). Its ability to form nitrogen fixing nodules via interaction with rhizobia adds to its uniqueness which makes it's a valuable crop for maintaining soil fertility (Lakhran *et al*. 2018). Chickpea is member of family fabaceae and originated in south west Asia. It is diploid with 2n=2x=16 chromosome number and genome size of approximately 750 Mbp (Anmuganathan *et al*. 1991). Chickpea is cultivated for seeds, which are high in protein and are commonly consumed by humans. It is of two types, deshi type seed are brown to black in colour and have a rough surface whereas kabuli type seeds are white in colour, and with smooth surface and it have tap root system with numerous lateral rootlets that stretch out in all directions in the top layer of soil.

Chickpea seed contain 23% protein, 64% carbohydrates, 47% starch and 5% fat, 6% crude fiber, 6% soluble sugar, 3% ash and mineral and vitamins such as calcium (202 mg), phosphorous (312 mg), iron (10.2 mg), vitamins C (3 mg). Chickpea is commonly eaten as dhal or in a variety of snake meals. Husk and split beans can be used to feed cattle. The acidic liquid obtained from hairs of the plant, which contain 94% malic acid and 6% oxalic acid and is used to make vinegar and also responsible for sourness of leaves (Gaur *et al*. 2010).

India is the world's largest producer of chickpea, accounting for 65.25% of total area and 65.49% of total production. Chickpea are cultivated on 10.6 million hectare. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh, Gujarat, Jharkhand Chhattisgarh and Telangana produce more than 90% of chickpea and account for 93% of total

land. Uttar Pradesh produced 0.68 million tonnes of chickpea with a productivity of 872.1 kg/ha, covering nearly 0.61 million ha of land. Uttar Pradesh provides around 7% of the country's production (Anonymous, 2018-2019).

Chickpea cultivation in the tropics often faces significant yield losses from disease and insect pest, ranging from 50 to 100% (Van Emden *et al*. 1998). Chickpea is infected with 172 pathogens, including 67 fungi, 3 bacteria, 22 viruses and phytoplasma and 80 nematodes have been reported from 55 countries. The most common pathogens affecting chickpea are *Ascochyta rabiei* (35 countries), *Fusarium oxysporum f. sp. ciceri* (32 countries), and bean leaf curl virus (23 countries), *Rhizoctonia bataticola* (21 countries), *Sclerotium sclerotiorum* (15 countries) and cucumber mosaic virus (9 countries). In India, the maximum number of pathogens reported to infect chickpea is 89, while in other countries they range from 1 to 40 (Nene *et* al. 1996). Dry root rot of chickpea emerged as the most damaging constraint on productivity and yield of chickpea, and the disease is more severe at high temperature (30-35°C) and low soil moisture (Pande and Sharma 2010). Dry root rot caused by *Rhizoctonia bataticola* (Taub.) Butler is a soil and seed borne fungal pathogen that is occurred worldwide and affects more than 284 plant species including monocots and dicots such as chickpea, cotton, cowpea, jute and soybean (Farr*et et al.* 1995). *Rhizoctonia* causes various symptoms such as rot, blight and wilt *et*c. the hyphae are septate and 1.5-2.5 µm thick, producing brown to black and irregular shaped microsclerotia up to 100 µm in diameter. The perfect stage of *R. bataticola* is *Thanatephorus cucumeris* (Frank.) Donk. It also produces conidia, a stage known as *Macrophomina phaseolina* (Devi *et* al. 2016).

Rhizoctonia bataticola (Taub) Butler was identified as a plant pathogen by Halsted (1890). Taubenhaus (1913) named the genus Sclerotium due to absence of spores and the species

named as bataticola because it was pathogenic to *Ipomea batatas* L. Briton jones (1925) transferred the fungus to the genus *Rhizoctonia* based on Butler's (1918) cultures identification. Rhizoctonia is a genus of anamorphic fungi in the order Cantharellales and family Ceratobasidiaceace which means "root killer" described by French mycologist Augustin Pyramus de Candolle (1815) that produce both hyphae and sclerotia. A comprehensive survey and redisposition of species name Rhizoctonia was published by Anderson and Stalpus in (1994). According to the publication, *Rhizoctonia bataticola* is used as synonyms of *Macrophomina phaseolina* (Tassi) Goid. Currently *M. phaseolina* is officially recognized as having the correct taxonomic name for the sclerotial phase as *Rhizoctonia bataticola* (Holliday and Punithalingam 1970). Dry root rot in chickpea was first reported by Mitra (1931) in India. Later, the disease spread from most chickpea growing area in India and other countries such as Iran (Kaiser *et al*. 1968), the United State (Westerlund *et al.* 1974), and several countries in Asia and Africa (Nene *et* al. 1996). The disease was earlier known as "Rhizoctonia wilt" in chickpea however it was later named "Dry root rot." In the past, dry root rot of chickpea was not a major problem, however in recent year it has become a major threat to chickpea production due changing weather condition, especially prolonged drought spells. During the growing season, especially in post flowering phase, higher temperature and low soil moisture is predisposing chickpea for dry root rot (Sharma and Pandey 2013). Padwick (1948) was the first person who reported the occurrence of chickpea dry root rot with Fusarium wilt.

Environment conditions such as temperature, soil moisture and pH play a crucial role in the viability and growth of *Rhizoctonia bataticola* (Khan, 2007). *Rhizoctonia bataticola* is capable for producing microsclerotia under relative low water conditions, while the viability of microsclerotia is greatly reduced under high water potential conditions (Olaya *et al*. 1996).

Temperature and soil moisture are two important weather parameters that affect dry root rot infestation, colonization and root rot development. A better understanding of the role of temperature and soil moisture will help in screening technique for dry root rot resistance, which will help breeders to develop breeding strategies for dry root rot resistance across larger geographical areas.

Symptoms are usually observed during post flowering stage and include drooping and chlorosis of p*eti*oles and leaflets, initially confined to the upper leaves of plant, straw coloured stem of the affected plant, and blackened taproots with sign of rotting. Mostly bare lateral roots and finer roots. Tiny black sclerotia can be seen inside exposed roots and bark, or when vertically split open at the color region (Sharma *et al*. 2016).

Biopesticides are alternative of chemical pesticides to, so new aspects such as genetic engineering and biological control have emerged to manage plant diseases, among which the trend is microorganisms used to combat plant pathogens. These organisms represented by group of bacteria known as plant growth promoting Rhizobacteria, which include the genus of *Pseudomonas* and *Bacillus* and others. The potential of soil amendments, bioagents and bio-fertilizers was evaluated for management of dry root rot of chickpea. *Pseudomonas florescence* and *Rhizobium phaseoli* showed significant inhibition of *Rhizoctonia bataticola* (Deshmukh *et al.* 2016). Along with bio-agents such as *Pseudomonas florescence* and *Bacillus sp.* some botanicals such as garlic clove extract and onion bulb extract, ginger rhizome extract are used to combat the pathogen of dry root rot of chickpea have been found to be effective. All of these garlic clove extract was shown to be most effective in preventing root rot with a 77.65% inhibition rate (Ahmed *et al.* 2021). Dry root rot of chickpea can also manage with the uses of pesticides. It offers better and quick results than bio-pesticides and an integrated disease

management module, but it causes various environmental degradations and may be harmful to humans and animals. Therefore, we need strong antipathogenic strategy to manage disease with either less or no use of such pesticides.

The disease can also managed by integration of cultural, physical, chemical and biological methods (Lakhran *et al.* 2018). Integrated disease management has strong potential to manage disease with profitable cost and benefit ratio. In which bio-agents like *Pseudomonas florescence, Bacillus subtilis, Bacillus pumilis* and organic amendments neem cake, vermicompost and plant extract (garlic clove extract), press mud, and fungicides are used at appropriate stage of crop cultivation. IDM will be very profitable, if it prepared prior to sowing and applied at appropriate growth stage. Keeping in view these backgrounds of problems the present study was proposed to be carried out with the following objectives:

Objectives

(i). *In-vitro* evaluation of some biological agents/botanical against *Rhizoctonia bataticola (Taub.)*

(ii). *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola (Taub.)*

(iii). Integrated disease management in experimental field.

CHAPTER 2 REVIEW OF LITERATURE

A brief review of literature pertaining to occurrence and distribution of dry root rot disease, symptomatology, causal organism responsible for the disease and its cultural, morphological, pathological effect of temperature, moisture and pH on the development of the pathogen, various biochemical and physiological changes occurring with respect to disease development in plants were presented in this chapter.

2.1 Occurrence and distribution:

Dry root rot in chickpea was first reported by Mitra (1931) in India.

Rhizoctonia bataticola is the causal agent of dry root rot of chickpea was first observed in India by Haware and Nene (1978) in Hyderabad, Andhra Pradesh, India. Later, Tripathi and Sharma (1983) also reported the appearance of Rhizoctonia root rot in pulses. An association of *Fusarium sp.* and *Rhizoctonia sp.* with wilted chickpea was first reported by Narasimhan (1929). Subsequently, it was reported from Punjab by Luthra (1938), Madhya Pradesh (Sharma and Khare, 1969), West Bengal (Biswas and Guptha, 1981) and Haryana (Tripathi and Sharma, 1983). It has been reported from Egypt, Iran, Kenya, Lebanon, Mexico, Myanmar, Pakistan, Spain, Sudan, Syria, Tanzania, Turkey, Uganda and USA. It causes considerable yield losses that vary from 5-50% and may cause 100% losses in susceptible cultivars under favourable environmental conditions (**Nene *et al.* 1996).**

Khan *et al.* (2012) reported that dry root rot caused by *Rhizoctonia bataticola* (Taub.) Butler is a most harmful constraint for chickpea production. It is the most important and widespread soil borne disease of chickpea grown between latitudes 20’ North and 20’ South, where the climate is relatively dry and warm.

Deepa *et al.* (2018) reported that chickpea (*Cicer arietinum L.*) is one of the most important food legume crop, in India it accounts for approximately 75% of world's chickpea production. Despite the high total production, yields of chickpea are low due to many biotic and abiotic constraints. Among the biotic constraints more than 50 diseases have so far been reported on chickpea. Among them soil borne diseases, dry root rot caused by *Rhizoctonia bataticola* is the major limiting factor in chickpea production.

2.2 Disease symptomology:

Dastur (1935) reported that only mature plants were affected, showing bronzing colour of the leaves on one or more of the lower branches, later changed to yellow and then brown. The affected branches and leaf stalks of diseased plants were stiff and turned upwards and leaflets stand more or less vertically and shed prematurely. The terminal parts of the tap root become black or brown and shriveled.

Singh *et al.* (1990) reported that roots inoculated with *Rhizoctonia bataticola* caused disintegration of cortical tissues with mycelial and sceloritial bodies plugging the xylem vessels.

Nene *et al*. (1991) reported that dry root rot disease generally appeared during flowering and podding time. These were scattered in the field. The seedlings can also get infected. Drooping of petioles and leaflets was confined to those at top of the plant. Leaves and stem of affected plant usually straw coloured but in some cases, the lower portion of the stem was brown. When the infected plant was uprooted, lower portion of the tap root remains in the soil. It was devoid of lateral and finer roots. Dark minute sclerotial bodies can be seen on the roots exposed inside the root.

2.3 Pathogen:

2.3.1 Nomenclature and taxonomy of *Rhizoctonia bataticola*:

Rhizoctonia bataticola (Taub.) Butler as a plant pathogen was recognized by Halsted (1890). Taubenhaus (1913) gave the name of the genus as *Sclerotium* because of absence of spores and the species name as *bataticola* because it was pathogenic to *Ipomea batatus* (L.) Lam. Briton Jones (1925) transferred the fungus to the genus *Rhizoctonia* based on the identification of cultures by Butler (1918). Ashby (1927) accepted *Macrophomina* and rejected the binomial *Macrophomina phaseoli* and proposed a new binomial *M. phaseolina* as the pycnidial stage of *Rhizoctonia bataticola* on the basis that *Macrophomina phaseolina* was the earliest applicable binomial. Haigh (1930) suggested that *Rhizoctonia bataticola* be used for sclerotia isolate and pycnidial strains should be called *Macrophomina phaseolina* Goidanich (1947) examined the original material of Tassi and compared it with *M. phaseoli, M. corchori, M. cajani, M. sesami, M. philippinensis, Dothiorella cajani* and *D. phaseoli*. He confirmed all of them were identical. He corrected the mistake made by Ashby (1927). According to the International Code of Botanical Nomenclature, the binomial *M. phaseolina* was the valid name for the pycnidial stage of *Rhizoctonia bataticola*.

2.3.2 Morphological characteristics:

Mycelia width varied from approximately 2-11 μm and distance between two consecutive septa measured 46 μm. However, the most important character regarding taxonomy and classification were the production size and composition of microsclerotia **(Reichert and Hellinger, 1947).**

Commonwealth Mycological Institute (CMI), Kew, England explained about sclerotia. Sclerotia formed within plant parts were black, smooth and hard and varied in size from 100 μm-

1mm while in culture, it varied from 50-300 µm. During the sclerotial formation, 50–200 µm individual hyphal cells aggregate to give multicellular bodies called microsclerotia. The microsclerotia were black and variable in size from 50 – 150 µm depending on the available nutrients of the substrate on which the propagules were produced **(Short and Wyllie, 1978).**

Sharma *et al.* (2012) reported that the fungus grows rapidly on potato dextrose agar (PDA) and produces brown to grey coloured mycelium that become darker with age. The young hyphae are thin, hyaline, aseptate and dichotomously branched and later produce typical black sclerotia. The fungus may produce abundant aerial mycelium, as high as to touch the cover of the culture plates, or mycelium is found to be completely or partially suppressed.

2.3.3 Disease cycle and histopathology:

Sharma *et al*. (2016) reported that infection of dry root rot initiated generally by soil-borne inoculum present in the form of hyphae and sclerotia. The pathogen causes destruction of epidermal cells and penetrates through the roots. The mechanical plugging of the xylem vessels by microsclerotia, toxin production, enzymatic action and mechanical pressure during penetration leads to disease development. However, infection of *R. bataticola* on chickpea may also occur through cotyledons during emergence, through small rootlets or through small wounds on the root surface. The fungus grows inter and intra cellularly and invades the cortical cells. It primarily grows inter-cellularly forming thick, short and dark coloured cells that result in the formation of large depressed necrotic lesions. The invaded cortical cells result in disintegrated or severe rotting of the roots. Hyphae colonize the vascular system and sclerotial bodies of *R. bataticola* plug the xylem vessels as observed by Singh *et al*. (1990). The extent of root necrosis gradually increases with time without any apparent symptoms on the parts of the above ground till flowering and podding growth stages.

2.4 Biological control:

2.4.1 In-vitro evaluation of some biological agents/botanical against *Rhizoctonia bataticola* (Taub.)

Ahmed *et al*. (2021) evaluated garlic leaf extract and onion bulb extract, ginger rhizome extract @ 2%, 5%, 10% concentration against *Macrophomina phaseolina* causal organism of dry root rot of green gram. Among them garlic leaf extract was found to be the most effective against pathogen with 77.65% mycelial growth inhibition followed by onion bulb extract (63.98%), while least growth inhibition was recorded in ginger rhizome extract (32.34%).

Brubda *et al.* (2018) reported antagonistic effect of bacterial endophytes of soybean against *Sclerotium rolfsii, Rhizoctonia bataticola* and *Fusarium oxysporum in vitro* by using dual culture plate technique. Two isolate (SB-DG-11) and (LB-BiN-8) of *Bacillus pumilis* were found effective against *Rhizoctonia bataticola* with 47.41% and 41.22% mycelial growth inhibition respectively.

Kumar *et al.* (2018) studied nine botanicals by poisoned food technique @ 20% concentration against *Rhizoctonia bataticola* under *in vitro* condition. Among the botanicals, maximum mycelium inhibition was recorded in *Zingiber officinale* rhizome (47.98%) followed by *Datura stramonium* leaf (43.35%), *Allium sativum* clove (39.74%) and *Eucalyptus globus* leaf (37.86%).

Karibasappa *et al.* (2018) evaluated the efficacy of *Trichoderma viride* (Tv1) and *Pseudomonas fluorescence* (Pf1) against *Rhizoctonia bataticola,* were found effective with mycelial growth inhibition percentage of 71.05 and 40.58 percent, respectively.

Latha *et al.* (2017) collected 10 fungal (*Trichoderma*) and 30 bacterial (*Pseudomonas* and *Bacillus*) isolates and screened for their antagonistic activity against mycelial growth of *Rhizoctonia bataticola* under *in-vitro* condition. Among these, *Trichoderma* (TL1),

Pseudomonas fluorescence [PfUL(A)] and *Bacillus subtilis* (BsOP2) isolates exhibited maximum inhibition 55.6%, 41.1%, 44.4% respectively against *Rhizoctonia bataticola*. Result of the compatibility of the bio-control agents revealed that *P. fluorescence* strains were compatible with *B. subtilis* and *Trichoderma* but *B. subtilis* strains were not compatible with *Trichoderma* strains.

Maruti *et al.* (2017) evaluated seven bio-agents against *Rhizoctonia bataticola* (dry root rot of pigeon pea) using dual culture technique. Among the bioagents *Trichoderma viride* was found to be more effective and showed (77.20%) mycelial growth inhibition of *R. bataticola* followed by *T. virense* (75.76%) however, *Pseudomonas florescence* and *Bacillus subtillis* showed 38.13% and 27.87% mycelial growth inhibition respectively.

Kapali *et al.* (2016) isolated rhizobacteria from rhizosphere of chickpea, pigeonpea, cotton and soybean. All the cultural and biochemical studies confirmed them to be *Pseudomonas fluorescence* and *Bacillus subtilis* used against *Rhizoctonia bataticola*. *Pseudomonas fluorescence* (Pf1) and *Bacillus subtilis* (Bs4) were found most effective with maximum mycelial growth inhibition of *Rhizoctonia bataticola* (53.83%) and (49.83%) respectively under *in vitro* condition.

Savaliya *et al.* (2015) evaluated efficacy of some botanicals against *Macrophomina phaseolina* (Tassi.) Goid caused root rot of sesame. The phytoextracts of nine plant species were evaluated *in vitro* by poisoned food technique against *Macrophomina phaseolina*. The garlic clove extract used @ 2%, 5%, 10% concentrations was proved excellent with maximum mycelial growth inhibition (77.65%), followed by onion bulb extract at same concentration and shown 63.98% average mycelial growth inhibition while least growth inhibition was recorded in ginger rhizome extract (32.34%).

Deshmukh *et al.* (2014) evaluated the potential of bioagents for management of dry root rot caused by *Rhizoctonia bataticola* in chickpea under controlled conditions. Bio agents i.e. *Trichoderma harzianum, Pseudomonas fluorescence* (39.2%) and *Rhizobium phaseoli* (27.8%) exhibited significant inhibition of *Rhizoctonia bataticola*. Maximum inhibition was achieved by *Trichoderma harzianum* (80.5%).

2.5. Chemical control:

***2.5.1 In vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.)**

Karkee *et al.* (2020) evaluated the efficacy of various fungicides by adopting poisoned bait method against *Rhizoctonia solani* under *in vitro* condition. Two level of concentration of the fungicides (10 ppm and 100 ppm) were used and concentration was calculated based on active ingredients of the fungicides. At lower concentration (10 ppm), Nativo (Tubeconazole 50% + Trifloxystrobin 25 WG) and Dhanustan (Carbendazim 50% WP) show 100% inhibition, whereas at higher concentration (100 ppm), Folicur (Tubeconazole 25.9%) and Saaf (Carbendazim 12% + Mancozeb 63% WP) inhibit 93% and 70% of mycelia growth of *Rhizoctonia solani* respectively. For the control of *R. solani*, Nativo and Dhanustan showed highest inhibition (100%) of mycelia growth at 10 ppm concentration as compared to other fungicides.

Lokesh *et al.* (2020) studied some fungicides *in-vitro* at 50, 250, 500 ppm concentrations by poisoned food technique for evaluating their efficacy against *Macrophomina phaseolina*. Among systemic fungicides, significantly highest average mycelial growth inhibition was recorded with carbendazim (85.88%), thiophanate methyl (84.32%) followed by hexaconazole (75.29%) but tebuconazole (47.06%), azoxystrobin (36.08%), propiconazole (36.86%) proved comparatively inferior in their efficacy against *M. phaseolina.* Among non-systemic fungicides,

significantly highest average mycelial growth inhibition over control was recorded in mancozeb (90.20%), followed by chlorothalonil (88.24%).

Savaliya *et al.* (2020) studied efficacy of some systemic and non-systemic fungicides against *Macrophomina phaseolina in vitro* condition @1000, 1500, 2000 ppm, among six non-systemic fungicides thiram, mancozeb and zineb were effective in inhibiting the radial growth and gave 92.31, 84.62 and 72.49 percent inhibition, respectively. Propiconazole and tebuconazole gave cent percent inhibition among systemic fungicides tested at all concentration.

Pathak *et al.* 2019 evaluated the efficacy of some fungicides against *M. phaseolina in vitro.* Mancozeb and Sixer 75% WP (carbendazim + mancozeb) used at 1500, 2000, 2500 ppm concentration and mancozeb (dithane M-45, 75% WP), carbendazim + mancozeb (sixer, 75% WP) were found most effective with cent percent mycelial growth inhibition at all concentration. Carbendazim (bavistin, 50% WP), and propiconazole were used at 250, 500, 1000 ppm concentration, in which carbendazim shown cent percent inhibition at all concentration whereas propiconazole 25% EC shown 90.48% growth inhibion at 250 ppm and 91.67% growth inhibion at 500 ppm, 92.86% growth inhibition at 1000 ppm.

Uikey *et al.* (2018) evaluated efficacy of commonly used fungicides i.e. carbendazim @0.1% and carboxin + thiram (combined products) @0.3% against *Rhizoctonia bataticola* were found efficient with cent per cent mycelial inhibition of *Rhizoctonia bataticola in vitro* condition.

Agale *et al.* (2018) evaluated some fungicides against *Rhizoctonia bataticola* under *in vitro.* Carbendazim 50% WP (@500, 1000 and 1500 ppm), carboxin 37.5% + thiram 37.5% WP (@1500, 2000 and 2500 ppm) and carbendazim 12% WP + Mancozeb 63% WP (@2000 and 2500 ppm) were found very effective and shown cent percent (100%) inhibition, followed by thiophanate methyl 70% WP with 93.57 percent inhibition, captan 50% WP with 89.48%

inhibition) and hexaconazole 5% EC with 87.62% inhibition of mycelial growth of pathogen, over control.

Brahmbhatt and Aravind (2018) studied different fungicides against *Macrophomina phaseolina* under *in vitro*. They used tebuconazole at 100 ppm and 500 ppm concentration was found very effective and showed cent percent growth inhibition at both concentration followed by carbendazim 12% + mancozeb 63% (89.63% and 91.86 per cent growth inhibition at 500 and 1000 ppm), respectively.

Chaudhary *et al*. (2017) studied that chemical control is one of the measures to manage the disease and avoid the losses. Ten fungicides were tested against *Macrophomina phaseolina* under *in vitro*. The highest inhibition (100%) of *M. phaseolina* was observed due to carbendazim 50% WP at different concentration (250, 500, 1000 ppm), mancozeb 75% WP (1500, 2000, 2500 ppm), ridomil-MZ 72% WP (1000, 1500, 2000 ppm) and carbendazim 12% + mancozeb 63% (1500, 2000, 2500 ppm) followed by propiconazole at 250 ppm with 87.21% inhibition, 500 ppm (89.92% inhibition) and 1000 ppm (92.64% inhibition).

Ravichandran and Hegde (2017) observed that the lab experiment to evaluate six combi product, five contact and four systemic fungicides against *Rhizoctonia bataticola* causing dry root rot in chickpea. Among combi products evaluated, carbendazim 25% + mancozeb 50% (Sprint), carboxin 37.5%+ thiram 37.5% (Vitavax powder 75% WP) and carbendazim 12% + mancozeb 63% (Saaf) were found to be most effective with complete inhibition (100%) of mycelial growth of *R. bataticola* at all the concentrations tested. Among the contact fungicides tested, chlorothalonil and mancozeb at 0.2% were effective with 100% inhibition. Among the four systemic fungicides evaluated against *R. bataticola*, carbendazim, difenconazole and

tebuconazole were best with cent per cent inhibition of mycelial growth at all concentrations tested.

Veena *et al.* (2014) tested the efficacy of two non-systemic fungicides at 0.25% concentration (Copper oxychloride and Captan), two systemic fungicides (Hexaconazole at 0.20% and Tebuconazole at 0.10%) and one antifungal antibiotic validamycin at 0.10% concentration against *Rhizoctonia bataticola*, causal organism of dry root rot of chickpea under *in-vitro*. The fungicides copper oxychloride, captan, hexaconazole and tebuconazole were found to be highly effective 100% inhibiting of mycelial growth of pathogen at all the concentrations tested.

2.6. Integrated management of disease in experimental field:

Gaikwad *et al.* (2020) studied integrated disease management of *Rhizoctonia bataticola* causing dry root of chickpea. Seed treatment with carbendazim 50 WP @1 g/kg seed was found most effective with 24.69% disease incidence followed by seed treatment with carboxin 37.5% + thiram 37.5% WP @3 g/kg seed with 30.23% disease incidence and seed treatment with carbendazim 12% + mancozeb 63% @ 2.5 g/kg seed with 30.25% disease incidence, over untreated control (91.67% disease incidence).

Sharma *et al.* (2020) studied efficacy of various soil amendments and bioagents like wheat straw @20 g/kg of soil, bajra straw @20g/kg, mung bean straw @20 g/kg, mustard cake @5 g/kg, ground nut cake @5 g/kg and farm yard manure @20 g/kg of soil applied in soil whereas seed treatment with *Tricoderma viride* @ 4 gm/kg seed, *T. harzianum* @4 gm/kg seed, *T. virens* 5 gm/kg seed & *Bacillus subtilis* @6 gm/kg respectively were evaluated against *Rhizoctonia bataticola* causing root rot in Chickpea. Soil amendment with mustard cake was found most effective in reducing the disease incidence (33.33 & 38.33%) during both years

(2018- 2019 & 2019-2020) of study followed by wheat straw, bajra straw and FYM. Among the bioagents *Trichoderma viride* (24.44 and 26.66%) was found most effective in minimizing disease incidence.

Sanjivkumar *et al.* (2019) studied the management of *Macrophomina phaseolina* with the help of *Bacillus subtilis*. The results revealed that seed treatment with *B. subtilis* @10 ml kg-1 of seed recorded the minimum root rot incidence (24.95%) in cowpea after 90 DAS. Also, among the soil application dosages, *B. subtilis* @3 lit/ha recorded the minimum disease incidence (19.84%) at 90 DAS while seed treatment with carbendazim @4 g/kg seed exhibited 22.16 percent disease incidence at 90 DAS.

Kaulage *et al.* (2019) studied that chickpea is severely attacked by *Rhizoctonia bataticola.* Organic amendments, such as neem, soybean, safflower, groundnut cakes and vermicompost, FYM, gypsum, poultry manure were applied to chickpea. The lowest *Rhizoctonia bataticola* population was observed in neem cake treatment (4.5×10^3 /g soil) followed by castor cake (6×10^3 /g) and cotton cake (8×10^3 /g) as compared to control (30.5×10^3 /g).In case of organic amendment level assessment it observed that as level increases, the population of *Rhizoctonia bataticola* decreases. Least incidence of *Rhizoctonia* root rot was observed in neem cake treatment (0-10% disease incidence) followed by gypsum and poultry manure (5-10% disease incidence) at different growth stages as compared to control (70% disease incidence). Groundnut cake (15-40%) and safflower cake (25-35%) showed least adverse effect over incidence *Rhizoctonia* root rot of chickpea.

Lakhran *et al*. (2018) evaluated the efficacy of bio-agent *viz*. *Tricoderma viride*, organic amendment, neem cake and carbendanzim through seed and soil treatment against *Macrophomina phaseolina* causing dry root rot disease of chickpea. Among the treatments, soil

application with neem cake @25g/pot + seed treatment with carbendazim @2g/kg seed was found most effective for reducing disease incidence (16.66% and 20%) followed by seed treatment with *Trichoderma viride* @4 g/kg seed + carbendazim @2 g/kg seed (20% and 20.83% disease incidence) over control at 40 and 60 days after sowing respectively.

Dhingani and Solanky (2016) evaluated efficacy of some bio agents *viz. Trichoderma viride, T. harzianum* and organic amendment like neem cake and castor cake, FYM and carbendanzim through seed treatment and soil application against *Macrophomina phaseolina* (Tassi.) Goid caused root rot disease of chickpea. In field condition *T. harzianum used* @5 kg in 500 kg neem cake per ha in furrow 5 days prior to sowing and found most effective to reducing disease incidence (11.81%) with higher seed germination (74.90%) and gave highest yield (1553 kg/ha).

Sayyad *et al.* (2015) evaluated seed treatment with carbendazim @2 g/kg seed was recorded highest seed germination (90%), least disease incidence (14%). *Trichoderma viride* used @5 kg/ha against *Rhizoctonia bataticola* was found effective with 31.1% disease incidence, followed by organic amendment neem cake with 14.7% disease incidence.

Heiarzadeha and Baghaee-Ravari (2015) evaluated the potential of *Bacillus pumilis* (3.1×10^4 CFU/g) to control Fusarium wilt in tomato in pot condition. *Bacillus pumilis* were used @10 g/kg soil and reduced 73% disease incidence during *in vivo* experiments. In, consequence, this study suggests *B. pumilus* ToIrMA strain as a possible bio control agent in the field experiments.

Pandey *et al.* (2011) studied seed treatment with garlic clove extract @10% concentration, was the most effective in reducing the disease incidence (92.22 percent) and increased germination (12.36 percent) followed by neem powder @6 g/kg seed which resulted in

the reduction of disease incidence (86.83%) and increased germination similar as garlic clove extract, respectively. In the field experiments, vermi-compost @5.0 tones/ha + *T. harzianum* @5.0 kg/ha was the most effective in reducing the disease incidence (72.73 percent) and increase in yield (39.69 percent) followed by FYM @2.5 tones/ha + *T. harzianum* @5.0 kg/ha, which resulted in the reduction of disease incidence (64.85 percent) and increasing the grain yield up to 38.17 per cent. Minimum reduction in disease incidence was found in foliar spray with *P. fluorescence* @5.0 g/liter (14.55 percent).

CHAPTER-3 MATERIAL AND METHODS

The present study was conducted at the Center of Excellence for Sanitary and Phytosanitory (SPS), Department of Plant Pathology entitled "**Studies on management of dry root rot of chickpea caused by *Rhizoctonia bataticola* (Taub) Butler"** is as follows.

3.1. Experiment site and location:

Field trail was conducted at crop research center (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut. The pot experiment and laboratory experiments were conducted at center of excellence for sanitary and phytosanitory (SPS), department of plant pathology, College of Agriculture, situated in main campus of university during 2021-2022. Meerut district is located between latitude 29° 01' North longitude and 77° 45' east longitudes at an altitude of 237 meters above the mean sea level. The Meerut district comes under northwestern plains sub region of the upper gangatic plain. Usually climate of the district is semi-arid and subtropical, with hot summers and cold winters. Maximum temperature in summer goes up to 42° C whereas minimum temperature remains 6-8° C during winter season. The average annual precipitation is 863 mm, in which 70-80 percent is received due to southwest monsoon from July to September, but there is occasional rainfall take place during winter due to western disturbance.

3.2. General laboratory procedure:

3.2.1. Sterilization of glassware's and culture media

Laboratory experiments were conducted using Borosil glasswares. First of all glasswares were autoclaved at 121° C and then kept in cleaning solution containing potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2So_4), 60 gram and 60 ml respectively in one liter of water. All glasswares were sterilized in hot air oven at 161° C temperature for two hours while

all solid and liquid media were sterilizes by autoclave at 15 psi/121° C for 15 minutes. Soil used for experiment was sterilized in autoclave at 15 psi/121° C for two hours. All cultural studies were performed under aseptic conditions in laminar air flow (LAF). Blades, scissors, forceps and fungal inoculum needle were autoclaved and surface sterilized with 70% alcohol and using flame.

3.3. Collection of disease specimens:

Chickpea plants showing the typical symptoms of dry root rot were collected from crop research center as well as farmer's fields during the 2020-21 Rabi season. Samples were brought to the laboratory for detection and further study.

3.4. Isolation and purification of *Rhizoctonia bataticola* isolates:

Collected disease samples were brought in laboratory and washed under running tap water and dried by using tissue papers. Infected roots were cut into pieces of 5-6 mm size and were surface sterilized by dipping in one percent sodium hypochlorite solution for one minute then washed two times through distilled water and dried by using tissue paper under laminar air flow. The sterilized pieces were transferred on to poured potato dextrose agar medium in petri plates by using forceps and incubated at 28± 2° C to obtain mycelial growth. After 48 hours of incubation, hyphal tip of growing mycelium were examined by light microscope. The hyphal tips from the margins of resulting colonies were cut with help of sterilized 2 mm cork borer and transferred to petri plates containing PDA. The culture was purified by single hyphal isolation method. On the basis of mycelial characteristics of mycelium and sclerotia, the isolate was identified as *Rhizoctonia bataticola*. The pure culture was stored at 4 ± 1°C for further study.

3.5. Proving the pathogenicity:

Pathogenicity test of the isolated fungus were carried out to prove the Koch's postulate (1876). During the experiment the inoculum were applied in two ways i.e. one, by mixing the inoculum in the sterilized soil before sowing and second, placement of inoculum near the growing plant after sowing in the pots. Sterilized soil was filled in pots and 15 days old culture grown on PDA media was mixed thoroughly in the upper layer of the soil at 1% weight basis. Sterilized healthy five seeds were sown in each pot without inoculum served as control. Moisture was maintained by providing water at appropriate interval, after 15 days of inoculation the plants sowing the typical dry root rot symptoms were pulled out from the soil then washed thoroughly with distilled water. Re-isolation was made from such artificially infected plants and culture obtained was compare with that of original culture.

3.5.1. Preparation of the soil:

Sandy loam soil collected from C.R.C. of SVPUA&T Meerut was used throughout the course of study. Such soil was pulverized and passed through 10 mesh size sieve and slightly moistened with water.

3.5.2. Sterilization of soil:

Soil used for pot culture experiment was sterilized in autoclave at 15psi/121° C for 2 hours was used throughout the course of study.

3.5.3. Sowing:

Pathogenicity test of the isolated fungus was conducted on chickpea plants. After 7 days, surface sterilized seed with 1% sodium hypochlorite, were sown at the rate of 5 seeds in each pot containing infested and uninfested soil at the depth of 2-3 cm to establish the fungal growth in the soil.

3.5.4. Proving of pathogenicity by agar plate method:

Rhizoctonia bataticola isolated from infected root of chickpea plants was also found pathogenic when pure were inoculated on 2% agar medium under controlled condition. In which a dish of pure culture was put in center of 9 mm petriplate then allowed for incubation at 28° C temperature for 48 hours. Seed were soaked in tap water for 16 hours then sterilized by 1% NaOCl solution for five minutes and washed three times with distilled water. Sterilized seeds were put around the colony of the pathogen. Petriplate was containing 2% agar media without pathogen colony, served as control in that 7 seed were also placed in same manner and again allowed incubate at 28° C with 12 hours photoperiod for 10 days. Subsequently, by microscopic examination the hypocotyl of germinated seeds confirmed that growth of fungus on seed was mycelium of *Rhizoctonia bataticola* (Basbagci, G., and Dolar, F.S. 2020).

3.5.5. Identification of pathogen:

The pathogen was identified on the basis of its morphological characters. For identification of pathogen, the fungus was grown on PDA plates. Seven days after inoculation a brown black mycelial mat was developed and covered entire petri plates. The morphological characters were studied on the basis of mycelial and sclerotial characters.

3.6. Morphological study of the fungus:

The following characters were examined after 10 days of incubation. The important morphological characters of the fungus taken under consideration are given bellow

a) Colony characters:

- Colour of colony
- Nature of colony growth

Above characters were studied visually

b) Mycelial characters:

- Colour of hyphae
- Septation of hyphae
- Branching of hyphae

Above characters were studied under microscope

c) Sclerotial characters:

- Shape
- Colour
- Size

Above characters were studied microscopically

3.7. Growth medium used:

(a) Potato dextrose agar medium:

For all the laboratory experimental study, potato dextrose agar medium was used for culturing *Rhizoctonia bataticola.* The composition of PDA is given below:

S. No	**Ingredients**	**Quantity (gm)**
1	Peeled potato	200
2	Dextrose ($C_6H_{12}O_6$)	20
3	Agar-agar	20
4	Distilled water	1000 ml

Potatoes were cleaned, washed with tap water and peeled, chopped into slices. Later 200 gm of potato pieces were boiled in 500 ml of distilled water, after boiling extract was collecting through clean muslin cloth. 20 gm of dextrose and 20 gm of agar-agar were dissolved in 500 ml

distilled water slowly and stirred with the help of glass rod. The potato extract and agar solution were mixed properly and the final volume was made 1000 ml by adding distilled water. Known quantity of medium was dispensed into number of conical flasks and plugged with non-absorbent cotton plugs and finally wrapped with aluminum foil. The flasks containing PDA media were sterilized at 121° C temperature for 15 minutes.

(b) Potato dextrose (PD) broth:

Composition of PD broth:

S. No	Ingredients	Quantity (gm)
1	Peeled potato	200
2	Dextrose ($C_6H_{12}O_6$)	20
3	Distilled water	1000 ml

(c) Preparation procedure of potato dextrose broth:

Required quantity of peeled potatoes were cut into small pieces and boiled in 500 ml of distilled water till the pieces become soft. Potato extract was filtered through muslin cloth and the filtrate was collected in the 500 ml beaker. 20 gm of dextrose were mixed properly by shaking through glass rod in boiled potato extract. The volume was made up to 1000 ml and requisite quantity of broth was poured into number of conical flasks and plugged with non-absorbent cotton plugs and finally wrapped with aluminum foil. The flasks containing PD broth were sterilized at 121° C temperature for 15 minutes.

(d) Nutrient agar medium (NAM):

Composition:-

S. No	Ingredients	Quantity (gm)
1	Peptone	5
2	Sodium chloride	5
3	Yeast extract	1.5
4	Agar-agar	15
5	Distilled water	1000 ml

(e) NAM preparation procedure:

The required quantity of ingredients were measured by weighing balance and dissolved in 1000 ml distilled water then shaken carefully and warmed by micro-oven. Requisite quantity of media was taken in conical flasks and insert cotton plugs covered by aluminum foil and go for autoclaving at 121° C for 15 minutes.

(f) Nutrient medium broth (NMB):

Composition:-

S. No	Ingredients	Quantity (gm)
1	Peptone	5
2	Sodium chloride	5
3	Yeast extract	1.5
4	Distilled water	1000 ml

(g) Preparation procedure:

The required quantity of ingredients were measured by weighing balance and dissolved in 1000 ml distilled water then shaken carefully and warmed by micro-oven. Requisite quantity of media were taken in conical flasks and insert the cotton plugs, covered by aluminum foil and go for autoclaving at 121° C for 15 minutes.

(h) King's 'B' medium (*Pseudomonas florescence* selective medium):

For culturing the *Pseudomonas florescence*, King's 'B' medium was used during the experiments. Composition and preparation procedure are given below:

S. No	Ingredients	Quantity (gm)
1	Peptone	20
2	Agar-agar	1.5
3	Potassium monophosphate	1.5
4	Magnesium sulphate	1.5
5	Glycerol	10
6	Distilled water	1000 ml

(i) Preparation procedure:

All the ingredients of King's 'B' medium were measured by weighing balance then mixed properly in 1000 ml distilled water. Two hundred ml of that solution were poured in each 250 ml capacity flask. Flasks were tightly plugged with no-absorbent cotton plug, wrapped with

aluminum foil and autoclaved at 121° C temperature for 15 minutes. Sterilized media was allowed to cool up to 45-47° C before pouring into petri plates.

3.7.1. Plating of medium:

Sterilized and melted media was poured in well sterilized petriplate (9 mm dia.) at the rate of 20 ml aseptically in a laminar air flow chamber and allowed to solidify. The plates containing the medium were used for culturing and maintaining of *Pseudomonas florescence* in the laboratory.

3.8. Mass multiplication of pathogen and bioagents:

3.8.1. Mass multiplication of *Rhizoctonia bataticola*:

Wheat grain media was used to get mass multiplication of *Rhizoctonia bataticola*. About 200 gm wheat grains were soaked in 2% sucrose solution for 16 hours, these wheat grains were filled in one fourth of 250 ml conical flasks and autoclaved at 121° C for 45 minutes. After autoclave each flask was seeded with a mycelial disc (5mm) from 10 days old culture of *Rhizoctonia bataticola* grown on PDA under aseptic condition and allowed to incubate at 28 ± 2 °C for 15 days. The flasks were shaken on alternate days to get uniform growth.

3.8.2. Mass culture of *Psuedomonas florescence*:

For mass culturing of *Pseudomonas florescence*, one liter capacity conical flask containing 500 ml King's 'B' broth were autoclaved at 121° C temperature for 15 minutes. After cooling of the media, each flask was inoculated by culture of *Psuedomonas florescence* with the help of inoculation loop under laminar air flow. The flasks were kept at 22° C temperature in BOD incubator for 5 days and were shaken twice a day.

3.8.3. Mass culture of *Bacillus subtilis*:

For preparation of mass culture of *Bacillus subtilis*, one liter capacity conical flasks containing 500 ml nutrient broth medium were autoclaved at 121° C temperature for 15 minutes. After cooling of medium, each flask was inoculated with culture of *Bacillus subtilis* with the help of inoculation loop under laminar air flow. The flasks were kept at 22° C temperature in BOD incubator for 5 days and were shaken twice a day.

3.8.4. Mass culture of *Bacillus pumilis*:

For preparation of mass culture of *Bacillus pumilis*, one liter capacity conical flasks containing 500 ml nutrient broth medium were autoclaved at 121° C temperature for 15 minutes. After cooling of medium, each flask was inoculated with culture of *Bacillus pumilis* with the help of inoculation loop under laminar air flow. The flasks were kept at 22° C temperature in BOD incubator for 5 days and were shaken twice a day.

3.8.5. Preparation of talc based formulation:

Prior to talc based powder preparation CFU value of liquid broth of bioagents were calculated by serial dilution method. 1000 gm talc powder and 10 gm corboxymethyl cellulose (CMC) were taken and mixed thoroughly in 400 ml liquid broth of bioagents in aseptic condition. Prepared talc based powder were packed in plastic bags for further uses.

3.9. Symptomology:

Symptoms of disease were studied at different stage of crop and on different plant parts like root, leave and stem etc., on the naturally infected plants collected from SVPUA&T Meerut and farmer's field and also on artificially inoculated plants.

3.10 Dual Culture Interaction:

3.10.1. *In vitro* evaluation of biological agents/botanical against *Rhizoctonia bataticola* (Taub.)

The antifungal activity of three bacterial bioagents *viz*. *Psuedomonas florescence*, *Bacillus subtilis* and *Bacillus pumilis* was tested against the pathogen under *in vitro* condition, to know about their potential to inhibit the growth of pathogen to a maximum extend in dual culture technique (Morton and Strouvle, 1935). Antagonistic activity of garlic clove extract was tested against pathogen *in vitro* by poisoned food technique (Ahmed *et al.* 2021).

Sterilized potato agar medium was poured in petri plates under laminar air flow and allowed for solidification. Effect on the growth of *Rhizoctonia bataticola* was studied by inoculating the 5 mm circular bit of freshly growing pathogen put in the center of PDA poured perti plate and bacterial bioagents culture were streaked at both peripheral ends of petri plates with the help of inoculation loop under laminar air flow. Whereas in case of garlic clove extract requisite amount of garlic extract were mixed properly in 100 ml PDA after autoclave and poured in the perti plates. After solidification of media, a 5 mm circular bit of pathogen was kept in center of petri plates. Petriplates containing PDA inoculated with pathogen bits without any bacterial bioagent and antagonist served as control. For this, actively growing culture was used and three replications were maintained for each treatment then incubated at 28° C temperature. After 24 hours, 48 hours and 72 hours of inoculation the radial growth of pathogen was measured. The percent inhibition of the growth over control was calculated by following equation given by Vincent (1972).

$$\mathbf{I= (C-T)/C \times 100}$$

Where,

I= Per cent inhibition

C = Growth in control

T= Growth in treatment

Table No. 3.1. List of bioagents/botanical used in experiment.

S. No.	Treatment	Bioagents/botanical
1	$\mathbf{T_1}$	*Psuedomonas fluorescence*
2	$\mathbf{T_2}$	*Bacillus subtilis*
3	$\mathbf{T_3}$	*Bacillus pumilis*
4	$\mathbf{T_4}$	Garlic clove extract 5%
5	$\mathbf{T_5}$	Control

3.11. Poisoned Food technique:

3.11.1 *In vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.)

The effect of seven fungicides belonging to different groups was tested at 0.005%, 0.010% and 0.015% concentration under *in vitro* condition to know about their efficacy to inhibit mycelial growth of pathogen to a maximum extent by using poisoned food technique (Nene and Thapliyal, 1982).

Potato dextrose agar (PDA) was prepared and 100 ml of the media were taken in 250 ml flasks and autoclaved at 121° C for 15 minutes. Requisite quantity of fungicides was added in 100 ml of cooled and molten sterile media thoroughly to get the required concentration for each of fungicide. Amount of fungicide was calculated on the basis of active ingredient found in fungicide. 20 ml of poisoned media was poured in each of the 90 mm sterilized perti plates. Each plate was inoculated with 5 mm disc of mycelium of pathogen at the center and incubated at 28+ 2°C temperature. Three replications were maintained for each treatment and for each concentration of fungicide. Potato dextrose agar medium without any of the fungicide served as control and plates were incubated at 28+ 2° C till the growth of the colony touched the periphery

in control plate. The percent inhibition of the growth over control was calculated by following equation given by Vincent (1927).

I= (C- T)/C x 100

Where,

I= Per cent inhibition

C= Growth in control

T= Growth in treatment

Table No. 3.2 List of fungicides used in experiment:

S. No.	Treatment	Common name	Trade name	Active ingredient	Concentration (%)
1	T_1	Tebuconozol	Folicur	29.5%EC	0.005,0.010, 0.015
2	T_2	Azoxystrobin + Difenoconazole	Amitsar	18.2%w/w+11.4%w/w	0.005,0.010, 0.015
3	T_3	Pencycuron	Monceren	22.9%SC	0.005,0.010, 0.015
4	T_4	Chlorothalonil	Karach	75%WP	0.005,0.010, 0.015
5	T_5	Hexaconazole	Tumus	5%SC	0.005,0.010, 0.015
6	T_6	Propiconozole	Tilt	25%EC	0.005,0.010, 0.015
7	T_7	Carbendazim	Zen	50%WP	0.005,0.010, 0.015
8	T_8	Control			

3.12. Statistical analysis:

The data were subjected to analysis of variance and treatment means were differentiated using Fischer's T test. The data taken into percentage were first transformed into angular value and then analyzed for test of significance (Gomez, 1996 and Chandel, 2002).

Table No. 3.3. List of treatments used for management of dry root rot of chickpea in experimental field.

S. No	Treatment	Treatment details
1	**T_1**	Seed bio- priming with *Pseudomonas fluorescence* (CFU $2x10^8$/g) @10 g/kg seed.
2	**T_2**	Seed bio- priming with *Bacillus subtilis* (CFU $2x\ 10^8$/g) @10 g/kg seed.
3	**T_3**	Seed bio- priming with *Bacillus pumilis* (CFU $2x10^8$/g) @10 g/kg seed.
4	**T_4**	Soil application of vermicompost @ 10 quintal / hectare with *Pseudomonas fluorescence* (CFU $2x10^8$/g) @5 kg/hectare.
5	**T_5**	Soil application of vermicompost @10 quintal/hectare with *Bacillus pumilis* (CFU $2x10^8$/g) @5 kg/hectare.
6	**T_6**	Soil application of press mud @10 quintal / hectare with *Pseudomonas fluorescence* (CFU $2x10^8$/g) @5 kg/hectare.
7	**T_7**	Soil application of press mud @10 quintal / hectare with *Bacillus pumilis* (CFU $2x10^8$/g) @5 kg/hectare.
8	**T_8**	Seed treatment with carbendazim 50%WP @2 g/kg seed
9	**T_9**	Foliar spray of Azoxystrobin @0.01% at tillering stage.
10	**T_{10}**	Control.

CHAPTER- 4 EXPERIMENTAL RESULT

The present study was conducted on the dry root rot of chickpea caused by *Rhizoctonia bataticola* (Taub.) Butler. Among the various diseases of chickpea, dry root rot is one of the major soil and seed borne disease causing huge loss of productivity and production. Hence, the present study for *in vitro* evaluation of bacterial bioagents, fungicides, and integrated management of disease under field conditions were conducted at Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut. Experiments of some bacterial bioagents, botanical and fungicides were conducted either alone or in combination at department of plant pathology, college of agriculture, main campus of university. The results of different experiments related to the study are mentioned in this chapter with appropriate tables and illustrations.

4.1. Collection of samples, isolation and purification of *Rhizoctonia bataticola*:

Infected plants of chickpea were collected from C.R.C. farm Chirori of the university at Meerut and farmer's fields near the university where disease was commonly occurred. Samples were brought in the lab for isolation and further study. The pathogen was isolated on PDA from infected root of chickpea plants under aseptic condition. The fungus isolated from roots, bits of sample placed on PDA and culture was purified by hyphal tip technique.

4.2. Identification of pathogen:

Identification of the isolated fungus was done on the basis of morphological, cultural characteristics. Characters were observed by the naked eyes and with the help of microscope. The characters observed were as given below:

(A) Growth habit characteristics: Light to dark greyish brown colored colonies with fluffy mycelium developed on potato dextrose agar medium. The fungus produced profuse surface

mycelium with micro sclerotia. Pycnidia were also formed on host tissues and were larger than the sclerotia.

(B) Colony characters: Colonies were fluffy, fast growing, dark brown with minute microsclerotia production and plate filled by mycelium within 3-4 days. The colony appeared black in colour on reverse side of the petri plate.(Fig. no. 4.2.a)

(C) Mycelium: Mycelium initially grayish white and became brown with age, septate, profusely branched, 4.5-7.3 um in width in the xylem of root while 3.5-7.2 um in width on potato dextrose agar medium, septa were more abundant in older portion of mycelium than younger once. Branches arise often at right angle with construction at their point of origin of the branches.(Fig. no. 4.2.b)

(D) Sclerotia: Sclerotia were irregular in shape and dark brown to black in colour and commonly produced on both xylem of affected plant and potato dextrose agar medium. It takes 2 days for microsclerotia formation. Size of sclerotia below the bark of root of affected plant is measured about 81.5-90.5 µm in diameter.(Fig. no. 4.2.c)

(E) Pycnidia and pycnidiospore: Pycnidia developed only on host tissue in field. These were globule to oval, ostiolate, beaked or without beak, light to dark brown in colour, superficial or submerged, scattered all over the outer surface of the root of plant. Pycnidiospores single celled, hyaline, oval, elongated to elliptical in shape and gazing out in the form of dull white cirrhus.

4.3. Pathogenicity:

Rhizoctonia bataticola (Taub.) Butler isolated from the roots of the infected plants was found to be pathogenic when seeds of chickpea and soil were artificially inoculated with it under artificial inoculation conditions. Characteristics root rot symptoms appeared after 15 days of

inoculation. The most obvious symptoms were the sudden death of chickpea seedlings. First leave start to turn yellow and dry then root rot gradually killed whole plant. Roots of diseased plants showed brown to black lesions. Pathogen was isolated from root of artificially inoculated plants similar as pure culture of *Rhizoctonia bataticola*.

Rhizoctonia bataticola isolated from infected root of chickpea plants was also found pathogenic when pure culture were inoculated on 2 % agar medium under controlled conditions. In which a dish of pure culture was put in center of 9 mm petriplate then allowed for incubation at 28°C temperature for 48 hours. Seed sterilization was done with 1 % NaOCl solution for five minutes and washed three times with sterile distilled water. Sterilized seeds were put around the colony of pathogen and again allowed incubate at 28°C with 12 hours photoperiod for 10 days. Subsequently, by microscopic examination the hypocotyls of germinated seeds confirmed that growth of fungus on seed was mycelium of *Rhizoctonia bataticola.*

4.4. Effect of different bioagents/botanical on mycelial growth of *Rhizoctonia bataticola* under *in vitro* condition.

Antifungal activities of four antagonist viz. *Pseudomonas florescence, Bacillus subtilis, Bacillus pumilis* and Garlic clove extract @5% were evaluated against *Rhizoctonia bataticola* under in vitro conditions. The data for results is indicating in **table no. 4.1, fig. no. 4.4, 4.5**. The result from the tables indicates that there was significant difference observed in percent inhibition of mycelial growth of *Rhizoctonia bataticola* by all the tested bioagents/botanical. Among all the treatments maximum inhibition percent (76.07%) of *Rhizoctonia bataticola* was recorded with garlic clove extract @5% after 72 hours, which is significantly superior from all tested bioagents followed by *Pseudomonas florescence* (67.25%) and *Bacillus subtilis* (60%). While minimum mycelial growth inhibition was recorded with *Bacillus pumilis* (49.66%).

Table. 4.1. Effect of different bioagents/botanical on mycelial growth of *Rhizoctonia bataticola* under *in vitro* condition.

S. No.	Name of Antagonist	24 hours		48 hours		72 hours	
		Avg. radial growth (mm)	% Inhibition	Avg. radial growth (mm)	% Inhibition	Avg. radial growth (mm)	% Inhibition
T_1	*Pseudomonas florescence*	16.64	56.96	24.53	65.04	29.47	67.25
T_2	*Bacillus subtilis*	25.25	34.70	36.00	48.70	36.00	60.00
T_3	*Bacillus pumilis*	27.47	28.97	38.43	45.23	45.30	49.66
T_4	Garlic clove extract @ 5%	8.23	78.70	14.22	79.73	21.53	76.07
T_5	Control	38.67	-	70.17	-	90	-
C.D(0.05)		**1.412**		**1.722**		**1.308**	
S.E. (m)		**0.602**		**0.896**		**0.517**	

4.5. Effect of different fungicides on mycelial growth of *Rhizoctonia bataticola* under *in vitro* condition.

Efficacy of some fungicides viz. Tebuconazole (T_1), Azoxystrobin + Difenoconazole (T_2), Pencycuron (T_3), Chlorothalonil (T_4), Hexaconazole (T_5), Propiconazole (T_6) and Carbendazim (T_7) were tested at 0.005 %, 0.010 % and 0.015 % concentrations using poisoned food technique. The radial growth of pathogen was recorded at 24 hours, 48 hours and 72 hours after inoculation. **(Table no. 4.2 – 4.4, Fig.no. 4.6-4.11)** The result from tables revealed that there is significant difference in percent inhibition of mycelial growth of *Rhizoctonia bataticola* with the fungicides evaluated. The cent percent inhibition of mycelial growth of *Rhizoctonia bataticola* was recorded with carbendazim at all concentration i.e. 0.005 %, 0.010% and 0.015%. While tebuconazole inhibited the mycelial growth of pathogen 88.15% at 0.015% concentration

followed by 87.22% and 83.89% at 0.010% and 0.005% concentrations respectively. In case of hexaconazole 75.83%, 76.94% and 79.44% inhibition at all concentrations (0.005%, 0.010% and 0.015%) was recorded, while in case of azoxystrobin + difenconazole, it was 68.78%, 76.73% and 78.33% at all three concentrations (0.005%, 0.010% and 0.015%) after 72 hours of inoculation. In case of pencycuron 57.04%, 59.81% and 61.85% inhibition at all concentration (0.005%, 0.010% and 0.015%) after 72 hours of inoculation. Least mycelial growth inhibition i.e. 48.80%, 57.59% and 60.56% was recorded with fungicide chlorothalonil at all concentration after 72 hours of inoculation respectively.

Table 4.2 Effect of different fungicides on mycelial growth of pathogen at 0.005% concentration

Treatment	24 hours		48 hours		72 hours	
	Mycelial growth (mm)	**% inhibition**	**Mycelial growth (mm)**	**% inhibition**	**Mycelial growth (mm)**	**% inhibition**
T_1	0.00	100	9.64	86.27	14.50	83.89
T_2	8.89	77.30	18.00	74.35	28.10	68.78
T_3	21.71	44.58	30.83	56.06	38.67	57.04
T_4	19.31	50.71	30.50	56.53	46.17	48.70
T_5	12.61	67.81	17.17	75.54	21.75	75.83
T_6	18.81	51.97	20.67	70.55	29.33	67.41
T_7	0.00	100	0.00	100.00	0.00	100.00
T_8 Control	39.17	--	70.17	--	90	---
C.D. (0.05)	**0.963**		**1.620**		**1.900**	
S.E(m)	**0.309**		**0.876**		**1.205**	

Table.No.4.3. Effect of different fungicides on mycelial growth of pathogen at 0.010% concentration

	24 hrs.	**48 hrs.**	**72 hrs.**

Treatment	Mycelial growth (mm)	% inhibition	Mycelial growth (mm)	% inhibition	Mycelial growth (mm)	% inhibition
T_1	0.00	100.00	7.36	89.51	11.50	87.22
T_2	7.17	81.47	14.70	79.05	20.95	76.73
T_3	19.17	50.43	29.67	57.72	36.17	59.81
T_4	15.80	59.14	26.83	61.76	38.17	57.59
T_5	11.17	71.12	17.08	75.65	20.75	76.94
T_6	15.67	59.48	18.33	73.87	19.67	78.15
T_7	0.00	100	0.00	100.00	0.00	100.00
T_8 Control	38.67	--	70.17	--	90	--
C.D.(0.05)	**1.318**		**1.661**		**1.876**	
S.E.	**0.580**		**0.921**		**1.175**	

Table.No.4.4. Effect of different fungicides on mycelial growth of pathogen at 0.015% concentration

Treatment	24 hours		48 hours		72 hours	
	Mycelial growth (mm)	% inhibition	Mycelial growth (mm)	% inhibition	Mycelial growth (mm)	% inhibition
T_1	0.00	100.00	5.36	92.37	10.67	88.15
T_2	6.47	83.28	13.31	81.03	19.50	78.33
T_3	18.33	52.59	29.17	58.43	34.33	61.85
T_4	14.80	61.72	23.50	66.51	35.50	60.56
T_5	10.00	74.14	15.00	78.86	18.50	79.44
T_6	0.00	100.00	14.83	66.51	15.83	82.41
T_7	0.00	100.00	0.00	100.00	0.00	100.00
T_8 Control	38.67	--	70.17	--	90	--
C.D.(0.05)	**0.796**		**1.712**		**1.810**	
S.E.	**0.211**		**0.978**		**1.094**	

4.6. Development of eco-friendly management strategy against dry root rot of chickpea.

4.6.1. Integrated management of disease in experimental field.

Field trail was conducted during Rabi season 2021-2022 at crop research center of university, for management of disease. The result revealed that all treatments significantly reduced the percentage of disease incidence, increased yield. The lowest percent disease incidence (10.11%) was recorded in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed, followed by (13.90%) in (T_8) seed treatment with carbendazim @2 g/kg seed and (15.10%) in (T_4) soil application of vermicompost @10 quintal/ hectare with *Pseudomonas florescence* @5 kg/ hectare. In case of (T_2) seed bio-priming with *Bacillus subtilis* @10 g/kg seed (15.89%) disease incidence was recorded and 16.67% in (T_9) foliar spray of azoxystrobin @0.01% at tillering and 17.35% in (T_6) soil application of press mud @10 quintal/hectare with *Pseudomonas florescence* @5kg/hectare and in (T_3) seed bio-priming with *Bacillus pumilis* @10 g/kg seed 18.08% disease incidence was recorded. Least reduction in disease incidence (19.17%) in (T_7) soil application of press mud @10 quintal/hectare with *Bacillus pumilis* @5 kg/ hectare followed by 18.44% in (T_5) soil application of vermicompost @10 quintal/hectare with *Bacillus pumilis* @5 kg/ hectare.

Maximum yield per hectare was recorded 17.34 quintal/hectare in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed followed by 15.19 quintal/ha in (T_8) seed treatment with carbendazim @2 g/kg seed and 14.77 quintal/ha in (T_4) soil application of vermi compost @10 quintal/ ha with *Pseudomonas florescence* @5 kg/ha and 13.75 quintal/ha in (T_2) seed bio-priming with *Bacillus subtilis* @10 g/kg seed and 13.41quintal/ha in (T_9) foliar spray with azoxystrobin @0.01 % at tillering and 12.72 quintal/ha in (T_6) soil application of press mud @10 quintal/ ha with *Pseudomonas florescence* @5 kg/ha and 12.32 in (T_3) seed bio-priming with *Bacillus pumilis* @10 g/kg seed and 12.14 quintal/ha in (T_5) soil application of vermicompost @10 quintal/ha with *Bacillus pumilis* @5 kg/ha. Least yield 10.69 quintal/ha

found in (T_7) soil application of press mud @10 quintal/ha with *Bacillus pumilis* @5 kg/ha , while in control yield was produced as 8.89 quintal/ ha.

Table No. 4.5. List of different treatments on percentage disease incidence of dry root rot disease and yield of chickpea

S.no	Treatment	Disease incidence %	Yield (q/ha)
1	Seed bio priming with *Pseudomonas florescence* (CFU 2×10^8) @10 g/kg seed	10.11	17.34
2	Seed bio priming with *Bacillus subtilis* (CFU 2×10^8) @10 g/kg seed	15.89	13.83
3	Seed bio priming with *Bacillus pumilis* (CFU 2×10^8) @ 10 g/kg seed	17.97	12.72
4	Soil application of vermi compost @ 10 quintal/ hectare with *Pseudomonas florescence* (CFU 2×10^8) @5 kg/ hectare	15.10	14.77
5	Soil application of vermi compost @ 10 quintal/ hectare with *Bacillus pumilis* (CFU 2×10^8) @5 kg/ hectare	18.44	12.32
6	Soil application of press mud @10 quintal/ hectare with *Pseudomonas florescence* (CFU 2×10^8) @5 kg/ hectare	17.35	13.41
7	Soil application of press mud @10 quintal/ hectare with *Bacillus pumilis* (CFU 2×10^8) @5 kg/ hectare	19.17	10.69
8	Seed treatment with carbendazim 2g/kg seed	13.90	15.19
9	Foliar spray with Azoxystrobin @0.01% at tillering	16.66	12.14
10	Control	49.51	8.89
	C.D.(0.05)	**0.747**	**0.959**
	S.E.(m)	**0.190**	**0.312**

CHAPTER- 5 DISCUSSION

Chickpea is major legume crop in India, covering 40% of legume area under pulse crops. In chickpea, dry root rot caused by *Rhizoctonia bataticola* is an important disease with typical symptoms including wilting and drying of the plants and presence of rotting signs on root system, devoid of lateral and finer rootlets (Haware, 1990). *Rhizoctonia bataticola* is a soil borne fungal pathogen of worldwide distribution with a wide host range of 500 plant species (Sinclair, 1982). The fungus induces a variety of symptoms like root rot, seedling blight, wilting etc., in a various host plants. Biological control has been considered as a potential management strategy for soil borne pathogens (Mukhopadhy and Kaur, 1990). Bioagents also induce systemic resistance in plants by inactivation of pathogenic enzymes and helpful in increasing the nutrient uptake capacity of plants and make them unavailable for pathogens (Chaube *et* al. 2001). An integrated module for management of disease with including the fungicides appears to be possible solution for effective and economic management of dry root rot of chickpea.

Disease was found irrespective of soil types, cropping system and cultivars used and incidence ranged from 5 to 50% or more in badly infected soils. The root system became black with signs of rotting and devoid of lateral and finer roots. The roots were quite brittle and show shredding of the bark. When infected plants were uprooted the lower portion of tap root remains in the soil. Keeping in view these backgrounds of problems the study is proposed to be carried out.

5.1. *In vitro* evaluation of some bioagents /botanical against *Rhizoctonia bataticola* (Taub.)

In the present study some bioagents were tested against the pathogen. Among the four antagonists, Garlic clove extract @5% showed maximum inhibition (76.06%) of mycelial growth

of pathogen. Similarly Ahmed *et al*. (2021) studied the maximum inhibition of mycelial growth of *Rhizoctonia bataticola* causal organism of dry root rot of chickpea by garlic clove extract in poisoned food technique under *in vitro* condition.

Second highest inhibiting antagonist was *Pseudomonas florescence* exhibited (67.25%) inhibition of pathogen under *in vitro* condition by dual culture technique followed by *Bacillus subtilis* (60.00%).

Latha *et al.* (2017) studied the efficacy of *Pseudomonas florescence* and *Bacillus subtilis* against *Rhizoctonia bataticola* under *in vitro* condition and reported that both bioagents were found to be effective in inhibition of mycelial growth of pathogen.

Least inhibition was recorded with *Bacillus pumilis* (49.66%) similarly Brubda *et al*. (2018) studied *Bacillus pumilis* against *Rhizoctonia bataticola* under *in vitro* condition found effective with (49.66%) inhibition.

5.2. *In vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.):

It is an objective of present study to find out most effective fungicides for management of *Rhizoctonia bataticola* under *in vitro* condition. Seven fungicides viz. Tebuconazole, Azoxystrobin + Difenoconazole, Pencycuron, Chlorothalonil, Hexaconazole, Propiconazole and Carbendazim were evaluated against *Rhizoctonia bataticola* at different concentrations (0.005%, 0.010% and 0.015%) by using poisoned food technique.

Among the all tested fungicides, cent percent inhibition of mycelial growth of pathogen was recorded with carbendazim followed by tebuconazole and hexaconazole. The chlorothalonil was found to be least effective against *Rhizoctonia bataticola* under *in vitro* condition. The results were more or less agreement with Lokesh *et* al. (2020) reported that carbendazim was highly effective against *Rhizoctonia bataticola* with (85%) inhibition under *in vitro* condition.

Chaudhary *et al.* (2017) evaluated fungicides against *Macrophomina phaseolina* under *in vitro* condition and revealed that carbendazim found most effective with cent percent inhibition.

Brahmbhatt and Aravind (2018) studied different fungicides against *Macrophomina phaseolina.* They used tebuconazole at 100 ppm and 500 ppm concentration was found very effective and exhibited cent percent growth inhibition at both concentrations.

Savaliya *et al.* (2020) studied efficacy of some systemic and non-systemic fungicides against *Macrophomina phaseolina* under *in vitro* condition @1000, 1500, 2000 ppm. Propiconazole and tebuconazole exhibited cent percent inhibition among systemic fungicides tested at all concentration.

5.3. Integrated management of disease in experimental field:

Management of soil borne disease is not possible by only one approach, in recent years efforts were made to reduce environment hazardous that allowed minimum use of pesticides to manage disease more effectively and economically, which lead to the development of a new discipline called integrated disease management (IDM). For sustainable crop production the components in IDM module should be eco-friendly which helps in stabilization of crop yield (Anahosur, 2001) in this contest the biological control, integration with fungicides was found to be more reliable approach to manage soil borne plant pathogens (Mukhopadhay,1987). Keeping in view the importance of integrated disease management and based on the results obtained in the present investigation, a study was undertaken for management of dry root rot disease in chickpea caused by *Rhizoctonia bataticola* by combining bioagents, fungicides and organic amendments. All treatments significantly reduced the percentage of disease incidence and increase the yield of chickpea. The lowest percent disease incidence (10.11%) was recorded in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed, followed by (13.90%) in

(T_8) seed treatment with carbendazim @2 g/kg seed and (15.10%) in (T_4) soil application of vermicompost @10 quintal/ hectare with *Pseudomonas florescence* @5 kg/ hectare.

Maximum yield per hectare was recorded 17.34 quintal/hectare in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed followed by 15.19 quintal/ha in (T_8) seed treatment with carbendazim @2 g/kg seed and 14.77 quintal/ha in (T_4) soil application of vermi compost @10 quintal/ ha with *Pseudomonas florescence* @5 kg/ha. The results are in agreement with Pandey *et al.* (2017) who reported satisfactory disease management when seed bio-priming was done by *Pseudomonas florescence* and soil application of *Pseudomonas florescence* against *Rhizoctonia bataticola* in chickpea.

Smitha *et al.* (2017) reported that use of *Bacillus subtilis* as seed treatment and soil application were found effective against *Rhizoctonia bataticola* and also found helpful in increasing the yield of chickpea.

Lakhran *et al.* (2018) used carbendazim through seed treatment were found very effective against *Rhizoctonia bataticola* with 16.66% disease incidence in chickpea.

CHAPTER- 6 SUMMARY AND CONCLUSION

Chickpea is highly nutritious legume crop with good content of protein. Therefore it is called as poor man's meat. Diseases are one of the main factors that reduced the yield of chickpea crop as well as nutritive value. Some are severe diseases in order of importance are wilt (*Fusarium oxysporum f.* sp. Cicer), dry root rot (*Rhizoctonia bataticola*), ascochyta blight (*Ascochyta rabiei*) and collar rot (*Sclerotium rolfsii*). Among the fungal diseases, the incidence of chickpea root rot has increased especially in recent years. Several recommended high yielding varieties, as well as local varieties have been observed to suffer from dry root rot caused by *Rhizoctonia bataticola* (Taub.) Butler. The objectives of present study were (a) *In vitro* evaluation of some biological agents/botanical against *Rhizoctonia bataticola* (Taub.) (b) *In vitr*o evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) (c) Integrated disease management in experimental field. The information obtained on various aspects is presented in the study is summarized here briefly.

Visual observations on dry root rot of chickpea plants were recorded at different stage of plant growth. Usually symptoms appeared at post flowering stage and affected plants exhibited different type of symptoms viz. yellowing and dropping of leaves, roots of infected plants exhibited dark black and extensive rotting. The roots become brittle, bark peeled off easily, lateral roots were destroyed. Diseased plant that could be easily pulled from the soil showed discoloration of the roots due to presence of black coloured microsclerotia. Production of microsclerotia and growth pattern of pathogen studied on PDA indicated that the mycelial was whitish at initial stage of growth but, later turned in dark to black colour when microsclerotia began to form. The hypha exhibited right angled branching and microsclerotia varied in shape and size, with growth pattern ranging from scattered to cluster.

Antagonistic activities of four antagonist viz. *Pseudomonas florescence*, *Bacillus subtilis*, *Bacillus pumilis* and garlic clove extract @5% were evaluated against *Rhizoctonia bataticola* under *in vitro* condition. The inhibition of mycelial growth of pathogen was recorded after 24 hours, 48 hours and 72 hours. The result revealed that there was significant mycelial growth inhibition of Rhizoctonia bataticola by all the tested antagonists. The maximum inhibition percent (76.06%) of *R. bataticola* was recorded with garlic clove extract @5% after 72 hours of inoculation followed by *Pseudomonas florescence* (67.25%) and *Bacillus subtilis* (60.00%). While minimum mycelial growth inhibition was recorded with *Bacillus pumilis* (49.66 %).

Efficacy of different fungicides viz. Tebuconazole (T1), Azoxystrobin + Difenoconazole (T2), Pencycuron (T3), Chlorothalonil (T5), hexaconazole (T5), Propiconazole (T6), Carbendazim (T7) were tested at 0.005%, 0.010% and 0.015% concentrations using poisoned food technique. The radial growth of pathogen was recorded at 24 hours, 48 hours and 72 hours after inoculation. The result revealed that there is significant difference in percent inhibition of mycelial growth of *Rhizoctonia bataticola* with all the fungicides evaluated. The cent percent mycelial growth inhibition of *Rhizoctonia bataticola* was recorded with carbendazim at all concentration i.e. 0.005%, 0.010% and 0.015%. While tebuconazole inhibited the mycelial growth of pathogen 88.15% at 0.015% concentration followed by 87.22% and 83.89% at 0.010% and 0.005% concentrations respectively. In case of hexaconazole 75.83%, 76.94% and 79.44% inhibition at all three concentrations (0.005%, 0.010%, 0.015%) while in case of azoxystrobin + difenconazole, it was 68.78%, 76.73%, 78.33% at all three concentrations (0.005%, 0.010%, 0.015%), while in case of propiconazole 67.41%, 78.15% 82.41% at all concentrations and pencycuron inhibited 57.04%, 59.81%, 61.85% at all concentrations (0.005%, 0.010%, 0.015%)

after 72 hours of inoculation. Least mycelial growth inhibition i.e. 48.80%, 57.59%, 60.56% was recorded with chlorothalonil at all concentration after 72 hours of inoculation respectively.

Field experiment was conducted during Rabi season 2021-2022 at crop research center of the university for management of disease. The result revealed that all treatments significantly reduced the percentage of disease incidence and increased the yield. The lowest percent disease incidence (10.11%) was recorded in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed, followed by (13.90%) in (T_8) seed treatment with carbendazim @2 g/kg seed and (15.10%) in (T_4) soil application of vermicompost @10 quintal/ hectare with *Pseudomonas florescence* @5 kg/ hectare. In case of (T_2) seed bio-priming with *Bacillus subtilis* @10 g/kg seed (15.89%) disease incidence was recorded and 16.67% in (T_9) foliar spray of azoxystrobin @0.01% at tillering and 17.35% in (T_6) soil application of press mud @10 quintal/hectare with *Pseudomonas florescence* @5 kg/hectare and in (T_3) seed bio-priming with *Bacillus pumilis* @10 g/kg seed 18.08% disease incidence was recorded. Least reduction in disease incidence (19.17%) in (T_7) soil application of press mud @10 quintal/hectare with *Bacillus pumilis* @ 5 kg/ hectare followed by 18.44% in (T_5) soil application of vermicompost @10 quintal/hectare with *Bacillus pumilis* @5 kg/ hectare.

Maximum yield per hectare was recorded 17.34 quintal/hectare in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed followed by 15.19 quintal/ha in (T_8) seed treatment with carbendazim @2 g/kg seed and 14.77 quintal/ha in (T_4) soil application of vermi compost @10 quintal/ ha with *Pseudomonas florescence* @5 kg/ha and 13.75 quintal/ha in (T_2) seed bio-priming with *Bacillus subtilis* @10 g/kg seed and 13.41quintal/ha in (T_9) foliar spray with azoxystrobin @0.01 % at tillering and 12.72 quintal/ha in (T_6) soil application of press mud @10 quintal/ ha with *Pseudomonas florescence* @5 kg/ha and 12.32 in (T_3) seed bio-priming

with *Bacillus pumilis* @10 g/kg seed and 12.14 quintal/ha in (T_5) soil application of vermicompost @10 quintal/ha with *Bacillus pumilis* @5 kg/ha. Least yield 10.69 quintal/ha found in (T_7) soil application of press mud @10 quintal/ha with *Bacillus pumilis* @5 kg/ha , while in control yield was produced as 8.89 quintal/ ha.

CONCLUSION

- Among all the tested antagonists, garlic clove extract @5% was highly effective against pathogen growth under *in vitro* condition followed by *Pseudomonas florescence.*
- Among all the tested fungicides, carbendazim, tebuconazole, propiconozole and hexaconazole were proved highly effective in inhabiting the growth of pathogen under *in vitro* condition at 0.015% concentration.
- Seed bio-priming with *Pseudomonas florescence @10 g/kg seed* was found most effective in increasing yield and reducing the disease incidence of dry root rot of chickpea caused by *Rhizoctonia bataticola*.
- I suggest to farmers, during development of integrated disease management module for dry root rot of chickpea we can use seed bio-priming with *Pseudomonas florescence* @10 g/kg seed instead of seed treatment with fungicide because it provides better protection from dry root rot without any environmental hazards.

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REFERENCES

Ahmed, M. F., Shete, P. P., Dhaval, P., and Dholu, D. (2021). Integrated management of dry root rot of green gram caused by *Macrophomina phaseolina* by using bio agents, botanicals and fungicides. *The Pharma Innovation Journal*, **10**(5), 1403-1409.

Agale, R. C., Suryawanshi, A. P., Rathod, R. R., and Apet, K. T. (2018). Bio efficacy of various fungicides against *Rhizoctonia bataticola*, causing dry root rot of soybean. *International Journal Current Microbiology and Applied Science,* **7**(10), 1856-1864.

Akhtar, M. S. and Siddiqui, Z. A. (2013). Use of plant growth promoting rhizobacteria for the bio control of root rot disease complex of chickpea. *Journal Australian plant pathology*, **38**(1): 44-50.

Ali, S. M. and Dennis, J., (1992). Host range and physiological specialization of *Macrophomina phaseolina* isolated from field peas in South Australia. *Australian Journal Expt. Agriculture.,* **32**: 11211125.

AR. Bharati., Benagi, (2017). *In vitro* evaluation of botanicals and bio-agents against *Sclerotium rolfsii Sacc*. incitant of wilt complex disease of betelvine. *The Pharma Innovation*, **7**(6), 334-336.

Basbagci, G., & Dolar, F. S. (2020). First report of binucleate Rhizoctonia AG-K causing root rot on chickpea. *Archives of Phytopathology and Plant Protection*, *53*(13-14), 640-652.

Bharti, O. P., Jatav, R. C., Bankoliya, M. K., Kumar, S., Tiwari, S. K., & Sharma, R. C. (2021). Efficacy of fungicides on dry root rot of chickpea under field condition. *International Journal of Chemical Studies*, **9**(2), 2349–8528.

Brahmbhatt, A. T. D. A. (2018). Management of root and collar rot (*Macrophomina phaseolina* (Tassi) Goid.) of okra (*Abelmoschus esculentus (L.) Moench)* through bioagents, oil cakes and fungicides. *Journal of Pharmacognosy and Phytochemistry*, ***7***(4), 631-635.

Brunda, K. S., Jahagirdar, S., and Kambrekar, D. N. (2018). Antagonistic activity of bacterial endophytes against major soil borne pathogens of soybean. *Journal of Entomology and Zoology Studies*, **6**(6): 43-46.

Chaube, H. S, Vishwakarma, S. N, Arvinder Kaur**,** Jameel Akhatar and Anurag (2001). Biological control of plant diseases. *Indian farmers digest October* pp. **23-29.**

Chaudhary, D. H., Pathak, D. M., & Chaudhary, M. M. (2017). *In vitro* efficacy of fungicides against dry root rot (*Macrophomina phaseolina*) of soybean. *International Journal of Current Microbiology and Applied Sciences*, ***6***(8), 1298-1301.

Dastur, J.F. 1935. Gram wilts in the central provinces. *Agriculture livestock India*. **4**: 615- 627.

De Candolle, A. P. (1964). Origin of cultivated plant, 1886; 2nd edition. Reprinted by Hafner Publishing Company, New York.

De Meyer, G., Capieau, K., Audenaert, K., Buchala, A., Metraux, J. P., Hofte, M. and Nanogram (1999). Amounts of salicylic acid produced by the rhizobacteria *Pseudomonas fluorscence* 7NSK2 activate the systemic acquired resistance pathway in bean. *Molecular Plant-Microbe Interaction*. **12,** 450-458**.**

Deepa (2018). Distribution and Severity of dry root rot of chickpea caused by *Rhizoctonia bataticola* in parts of North Karnataka, India, *International Journal Current Microbiology and Applied Science*. **7**(4): 194-200**.**

Deshmukh, M. A., Gade, R. M., Belkar, Y. K., & Koche, M. D. (2014). Efficacy of bioagents, bio fertilizers and soil amendments to manage root rot in chickpea. *Legume Research*, **39**(1), 140-144.

Devi, T. P., Kamil, D., Mehndiratta, R., Prabhakaran, N., & Toppo, R. S. (2016). Molecular and morphological diversity of *Rhizoctonia bataticola* causing dry root rot disease from India. *Journal of Pure and Applied Microbiology*, **10**(4), 2735-2745.

Dhingani, J. C., & Solanky, K. U. (2016). Integrated management of root rot disease [*Macrophomina phaseolina* (Tassi.) Goid] of chickpea through bioagents, oil cakes and chemicals under field conditions in south Gujarat conditions. *Plant Archives*, **16**(1), 186-186.

Dinesh., H. Chaudhary (2017). *In-vitro* efficacy of fungicides against dry root rot (*Macrophomina phaseolina*) of soybean. *International Journal of Current Microbiology and Applied Sciences*, **6**(8):1298-1101**.**

Ferguson, B. J., Indrasumunar, A., Hayashi, S., Lin. M. H. Lin, Y. H., Reid, D. E. and Gresshoff, P. M. (2010). Molecular analyses of legume nodule development and auto regulation. *Journal of Integrated Plant Biology*, **52**: 61-7.

Gaikwad, P. A., Dhutraj, D. N.,and Ambadkar, C. V. (2020). Cultural and genetic diversity *Rhizoctonia bataticola* isolates causing dry root rot of chickpea. *International Journal of Current Microbiology and Applied Science*, **9**(4), 981-996.

Gaur, R. B. and Sharma, R. N. (2010). Bio-control technology: Development production and popularization for plant disease control in semi-arid region of Rajasthan, India- A success story. *Journal of Progressive Agriculture* **3**(1):317-320.

Ghosh, R., Sharma, M., Telangre. R and Pande, S. (2013). Occurrence distribution of chickpea diseases in central and southern parts of India. *American Journal of Plant Sciences*, **4**: 940-944.

Heidarzadeh, N., & Baghaee-Ravari, S. (2015). Application of *Bacillus pumilus* as a potential biocontrol agent of fusarium wilt of tomato. *Archives of Phytopathology and Plant Protection*. **48**(13-16), 841-849.

Hussain, S., and Ghaffar, A. (1990). Biological control of *Macrophomina phaseolina* charcoal rot of sunflower and mungbean. *Phytopathology*. **130**: 157160.

Jukanti, A. K., Gaur, P. M., Gowda, C.L.L. and Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum L.*): a review. *British Journal of Nutrition*. **108** (1): 11-26.

Kapali, S., Gade, R. M., Shitole, A. V., & Aswathi, S. (2016). Isolation and characterization of *Pseudomonas fluoresces* and *Bacillus subtilis* and their evaluation *in vitro*. *Advance Life Science.* **5,** 5856-5859.

Karibasappa, C. S., Bhat, B. N., & RAO, S. C. (2018). *In-vitro* evaluation of fungicides, botanicals and bio control agents against *Macrophomina phaseolina* (Tassi.) Goid the causal organism of root rot of sesame. *The Indian Society of Oilseeds Research,* 184.

Karkee, A., & Mandal, D. L. (2020). Efficacy of Fungicides Against Rhizoctonia solani Inciting Rhizome Rot Diseases on Large Cardamom (Amomum subulatum Roxb.). *International Journal of Applied Sciences and Biotechnology*, **8**(1), 61-64.

Karunanithi, K., Muthusamy, M., Seetharaman, K. (2000). Pyrolnitrin production by *Pseudomonas florescence* effective against *Macrophomina phaseolina*. *Crop Protection.* **19**: 368-370.

Kaulage, S. A., Sadaphule, S. P., & Vyavahare, Y. V. (2019**).** Assessment of organic amendments on population dynamics and incidence of *Rhizoctonia root* rot of gram. *International Journal of Chemistry Studies*, **3**(1), 2581-348X.

Kaushal, R.P. and Richa Sood (2008). Management of root rot in chickpea. *Journal of Food Legumes* **21**:175-181

Khan (2012). Management of chickpea (*Cicer arietinum L.*) dry root rot caused by *Rhizoctonia bataticola (Taub.)* Butler. *Internal Journal of Research in Pharmaceutical and Biomedical Science*, **3**(4) Oct-Dec 2012.

Khan, M. A., and Gangopadhyay, S. (2008). Efficacy of *Pseudomonas florescence* in controlling root rot of chickpea caused by *Macrophomina phaseolina. Indian Journal of Mycology and Plant Pathology*, **38**(3) 30-587.

Khan, S. N. (2007). *Macrophomina phaseolina* as causal agent for charcoal rot of sunflower. *Mycopathology*, **5**(2), 111-118.

Konde, S. A., Raut, B. T. and Glade, M. R. (2008). Chemical and biological management of root rot (*Rhizoctonia bataticola*) of soybean. *Annals of Plant Physiology*, **22**(2): 275-277.

Kumar, Kumar. A, (2019). Seed Biopriming steps towards disease management. *Think India Journal*, **22**(34), 0971-1260.

Kumar, P. J. (2018). Evaluation of botanicals and bio-agents against *Rhizoctonia bataticola* causing dry root rot of chickpea. *International Journal of Microbiology Research, ISSN*, 0975-5276.

Laha, G.S, Verma, J.P. (1998). Role of *Pseudomonas florescence* in suppression of root rot and damping- off of cotton. *Indian phytopathology*. **51**: 275-278.

Lakhran, L., & Ahir, R. R. (2018). Integrated management and host plant resistance against dry root rot *[Macrophomina phaseolina* (Tassi.) Goid] of chickpea. *International Journal of Current Microbiology and Applied Sciences*, ***7***(7), 1266-1273.

Latha, P., Karthikeyan, M., and Rajeshwari, E., (2017). Development of bioformulations for the management of black gram dry root rot caused by *Rhizoctonia bataticola* (Taub.) Butler. *Advances in Research*, **9**(4), 2348-0394.

Lokesh, R., Rakholiya, K. B., & Thesiya, M. R. (2020). Evaluation of different fungicides against *Macrophomina phaseolina (Tassi) Goid.* causing dry root rot of chickpea (*Cicer arietinum L.*) *in vitro*.*International Journal of Current Microbiology and Ap plied Science*, **9**(7), 2319-7706.

M, Piga Belanger, R. R. Paulitz, T. C., Benhamou, N. (1997). Increased resistance to *Fusarium oxysporum f*. sp. radicis- lycopersici in tomato plants treated with the entophytic bacterium *Psuedomonas florescence* strains. *Physiological and Molecular Plant Pathology*, 301-320.

M. and Nanogram (1999). Amounts of salicylic acid produced by the rhizobacterium *Pseudomonas aeruginosa* 7NSK2 activate the systemic acquired resistance pathway in bean, *Molecular Plant-Microbe Interaction*, **12**,450-458.

Malik, S. R., Shabbir, G., Zubir, M., Iqbal, S. M., & Ali, A. (2014). Genetic diversity analysis of moroho-genetic traits in deshi chickpea (*Cicer arietinum*). *International Journal of Agriculture and Biology*, **16**(5), 1560-8530.

Manjunath, S. V., Naik, M. K., Khan, M. F. R. and Goswami, R. S. (2013). Evaluation of bio control agents for management of dry root rot of chickpea caused by *Macrophomina phaseolina*. *Crop Protection*, **45**: 147-150.

Maruti, S., Gururaj, A. S., & Amaresh, Y. S. (2017). *In vitro* efficacy of fungicides and bioagents against dry root rot of pigeon pea caused by *Rhizoctonia bataticola* (Taub.) Butler. *International Journal of Pure & Applied Bioscience*, **5**(6), 1341-1347.

Masood Ali and Shivkumar., (2001). An overview of chickpea research in India. *Indian Journal of Pulses Research*, **14**(2): 81-89.

Mnif, I., Grau Campistany, A., Coronel-León, J., Hammami, I., Triki, M. A., Manresa, A., and Ghribi, D. (2016). Purification and identification of *Bacillus subtilis* SPB1 lipopeptide bio surfactant exhibiting antifungal activity against *Rhizoctonia bataticola* and *Rhizoctonia solani*. *Environmental Science and Pollution Research***, 23**(7), 6690-6699.

Nene, Y. L, Reddy, M. V, Ghanekar, A. M, Amin, K. S. (1991). Field diagnosis of chickpea disease and their control. ICRISAT Information bulletin, **28**: 52.

Nene, Y. L., Sheila, V. K and Sharma, S. B. (1996). A world list of chickpea and pigeon pea pathogens. *ICRISAT, 5th edition.* 1-27.

Olaya, G., Abawi, G.S., and Barnard, J. 1996. Influence of water potential on survival of sclerotia in soil and on colonization of bean stem segments by *Macrophomina phaseolina*. *Plant Disease*. **80**: 1351-1354.

Pande, S. and Sharma, M. 2010. Climate Change: Potential Impact on Chickpea and Pigeonpea Diseases in the Rain fed Semi-Arid Tropics (SAT). In: *5th International Food Legumes Research Conference (IFLRC V) & 7th European Conference on Grain Legumes (AEP VII) April 26-30, 2010*. Antalya, Turkey.

Pandey, P., Kumar, R., & Mishra, P. (2011). Integrated approach for the management of *Sclerotinia sclerotiorum* (Lib.) de Barry, causing stem rot of chickpea. *Indian Phytopathology*, **64**(1), 37.

Pathak, D. M., & Patel, R. R. (2019). *In vitro* evaluation of fungicides and organic extracts against *Macrophomina phaseolina (Tassi) Goid.* isolated from pigeonpea *[Cajanus cajan L.*]. *International Journal of Plant Protection*, **12**(2), 147-151.

Peshney, N. L., Gades, R. M. and Thakur, K. G. (1992). Sensitivity and adaptability of *Rhizoctonia bataticola* to different fungicides. *Journal of Soil Science and Crops.* **2**: 35-38.

Podile, A. R. Laxmi, V. D. V. (1998). Seed bacterization with *Bacillus subtilis* AF 1 increase phenylalanine ammonia- lyase and reduce the incidence of fusarium wilt in pigeon pea. *Journal of Phytopathology*. **146**: 255 – 259.

Rajeevpant and mukhopadhyay, A. N. (2001). Integrated management of seed and seedling rot complex of soybean. *Indian phytopathology,* **54**: 346-350.

Ravichandran, S. and Hegde, RY. (2017). Management of dry root rot of chickpea caused by *Rhizoctonia bataticola* through fungicides. *International Journal of Current Microbiology and Applied Sciences*, **6**(7), 1994-1600.

Reichert, I and Hellinger, E. (1947). On the occurrence, morphology and parasitismof *Sclerotium bataticola.Palestine Journal of Botany.* **6**:107-147.

Sanjeevkumar, K., Balabaskar, P., Sivakumar, T., & Renganathan, P. (2019). Effect of bacterial antagonists against root rot of cowpea caused by *Macrophomina phaseolina (Tassi.)* Goid. *Plant Archives*, **19**(2), 2430-2435.

Savaliya, V. A., Bhaliya, C. M., Marviya, P. B., & Akbari, L. F. (2015). Evaluation of phytoextracts against *Macrophomina phaseolina (Tassi)* Goid causing root rot of sesame. *Journal of Biopesticides*, **8**(2), 116.

Savaliya, V., Akbari, L., Talaviya, J., & Lathiya, S. (2020). Effect of different fungicides on growth and sclerotial formation of *Macrophomina phaseolina (Tassi)* Goid causing root rot of sesame. *International Research Journal of Chemistry*, **32**, 1-13.

Sharma, M., and Ghosh, R., and Pande, S. (2016). Dry root rot (*Rhizoctonia bataticola (Taub*.) Butler): an emerging disease of chickpea – where do we stand? *Archives of Phytopathology and Plant Protection*, **48**, 13-16, 797-812.

Sharma, M., and Pande, S. (2013). Unravelling Effects of Temperature and Soil Moisture Stress Response on Development of Dry Root Rot [*Rhizoctonia bataticola* (Taub.)] Butler in Chickpea. *American Journal of Plant Sciences*, **4,** 584-589.

Sharma, M., Ghosh, R., Sharma, T.R and Pande, S. (2012). Intra population diversity in *Rhizocotonia bataticola* causing dry root rot of chickpea (*Cicer arietinum* L.) in India. *African Journal of Microbiology Research*. **6**(37): 6653-6660.

Sharma, O. P., Mohan, G., Pruthi, S., Kaur, M., & Kumari, M. (2020). Effect of different soil amendments and bio agents on development of dry root rot diseases of chickpea caused by *Rhizoctonia bataticola. Journal of Entomology and Zoology Studies,* **8**(5): 637-639.

Short, G.E and Wyllie, T.D. (1978). Inoculum potential of *Macrophomina phaseolina. Phytopathology*.**68**: 742-746.

Sindhan, G. S. Hooda, I. and Karwasra, S. S. (2002). Biological control of dry root rot of chickpea caused by *Rhizoctonia bataticola*. *Plant disease research,* **17**(1): 68- 71.

Singh, N., Pandey, P. and Dubey, R. C. (2008). Biological control of root rot fungus *Macrophomina phaseolina* and growth enhancement *Pinus roxburghii (Sarg.)* by rhizosphere competent *Bacillus subtilis* BN1. *World Journal of Microbiology and Biotechnology*, **24**(9): 1669-1679.

Singh, R. and Sindhan, G. S. (1998). Effect of fungicides on the incidence of dry root rot and biochemical status of chickpea plants. *Plant Disease Research,* **13,** 14-17.

Singh, S. K., Nene, Y. L, and Reddy, M. V. (1990). Some histo-pathological observations of chickpea roots infected by *Rhizoctonia bataticola*.*International News Letter*, **23**:24-25.

Singh., R. D. N. and Kaiser, S. A. K. (1995). Evaluation of some systemic and non- systemic fungicides against charcoal rot of maize (*Macrophomina phaseolina*). *Journal of Tropical Agriculture*, **33**: 54-58.

Singhai, B., & Shrivastava, S. K. (2006). Nutritive value of new chickpea (*Cicer arietinum*) varieties. *Journal of Food Agriculture and Environment*, **4**(1): 48.

Smitha, K. P., Rajeswari, E., Alice, C. D., & Raguchander, T. (2017). Evaluation of Bacillus subtilis for the management of dry root rot and vascular wilt of chickpea. *Journal of Pharmacognosy and Phytochemistry*, **6**(6), 967-970.

Tatya, R. S., Tripathi, N. N. and Panwar, M. S. (1990). Influence of texture and nutritional status of soil on the efficacy of fungicides for the control of dry root rot of chickpea (*Cicer arietinum* L.). *Indian Journal of Mycology and Plant Pathology,* **20** (1): 14-20.

Tetali, S., lakshman, P. and bharat chardra, P. (2016**).** Efficacy of bio control agents and organic amendments against root rot disease in black gram. *International Journal of Plant Protection.* **9**(1): 279-282.

Uikey. D., Gupta. VR., and Uikey. KW., (2018). Efficacy of fungicides and bioagents against *Rhizoctonia bataticola*. *International Journal of Chemical Studies*, **6**(5), 744-747.

Van Loon, L. C., Bakker, P. A. H. M., Pieterse, C. M. J. (1998). Systemic resistance induced by rhizosphere bacteria. *Annual Rev Phytopathol.* **36**:453– 483.

Veena, G. A. and Reddy, N. P. E. (2016). Integrated disease management of dry root rot of chickpea. *International journal of applied biology and pharmaceuticals technology*, **7** (2): 578-581.

Veena, G. A., Reddy, N. E., Reddy, B. B., & Prasanthi, L. (2014). Pathogenicity tests and evaluation of efficacy of fungicides against *Rhizoctonia bataticola*, the causal agent of dry root rot of chickpea. *International Journal of Applied Biology and Pharmaceutical Technology*, **5**(1), 0976-4550.

Vinod Kumar, Anuj Kumar and Khadarwar, R. N. (2007). Antagonistc potential of *Pseudomonas florescence* and control of charcoal rot of chickpea caused by *Macrophomina phaseolina. J. Environ. Biol.,* **28** (1): 15-20.

APPENDIX

❖ ANOVA TABLE

IN VITRO EVALUATION OF SOME BIOLOGICAL AGENTS/BOTANICAL AGAINST *RHIZOCTONIA BATATICOLA* (TAUB.)

Appendix 1- ANOVA for *In vitro* evaluation of some biological agents/botanical against *Rhizoctonia bataticola* (Taub.) at 24 hours

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	4	1585.847	396.462	658.100	0.00000
Error	10	6.024	0.602		
Total	14				

Appendix 2 - ANOVA for *In-vitro* evaluation of some biological agents/botanical against *Rhizoctonia bataticola* (Taub.) at 48 hours

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	4	5330.209	1332.552	1486.75	0.00000
Error	10	8.963	0.896		
Total	14				

Appendix 3 - ANOVA for *In-vitro* evaluation of some biological agents/botanical against *Rhizoctonia bataticola* (Taub.) at 72 hours

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	4	8689.220	2172.305	4203.376	0.00000
Error	10	5.168	0.517		
Total	14				

IN-VITRO EVALUATION OF SOME FUNGICIDES AGAINST *RHIZOCTONIA BATATICOLA* (TAUB.)

Appendix 4 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 24 hours @ 0.005%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	3465.329	495.047	1601.036	0.00000
Error	16	4.947	0.309		
Total	23				

Appendix 5 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 48 hours @ 0.005%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	9279.987	1325.712	1513.075	0.00000

Error	16	14.019	0.876		
Total	23				

Appendix 6 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 48 hours @ 0.005%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	15141.567	2163.081	1794.623	0.00000
Error	16	19.285	1.205		
Total	23				

Appendix 7 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 72 hours @ 0.005%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	15141.567	2163.081	1794.623	0.00000
Error	16	19.285	1.205		
Total	23				

Appendix 8 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 24 hours @ 0.010%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	3256.486	465.212	802.667	0.00000
Error	16	9.273	0.580		
Total	23				

Appendix 9- ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 48 hours @ 0.010%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	9549.032	1364.147	1480.717	0.00000
Error	16	14.740	0.921		
Total	23				

Appendix 10- ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 72 hours @ 0.010%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	15660.879	2237.268	1903.849	0.00000
Error	16	18.802	1.175		
Total	23				

Appendix 11- ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 24 hours @ 0.015%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	3654.613	522.088	2471.421	0.00000
Error	16	3.380	0.211		
Total	23				

Appendix 12- ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 48 hours @ 0.015%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	9923.221	1417.603	1449.832	0.00000
Error	16	15.644	0.978		
Total	23				

Appendix 13 - ANOVA for *In-vitro* evaluation of some fungicides against *Rhizoctonia bataticola* (Taub.) at 72 hours @ 0.015%

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Treatment	7	16005.958	2286.565	2090.574	0.00000
Error	16	17.500	1.094		
Total	23				

INTEGRATED MANAGEMENT OF DISEASE IN EXPERIMENTAL FIELD.

Appendix 14- ANOVA for percentage disease incidence

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Replication	2	0.103			
Treatment	9	3206.017	356.224	1876.616	0.00000
Error	18	3.417	0.190		
Total	29				

Appendix 15 - ANOVA for Yield

Source	D.F.	S. S.	M. S.	F-Cal	Significance
Replication	2	0.331			
Treatment	9	152915	16.991	54.382	0.00000
Error	18	5.624	0.312		
Total	29				

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ABSTRACT

Chickpea (*Cicer arietinum L.)* is the world's leading pulse crop. It is an important pulse crop with a wide distribution across the tropics, sub tropics and temperate region. It is rich in dietary proteins and good for human consumption; moreover, its ability to form nitrogen fixing nodules via interaction with rhizobia adds to its uniqueness. Chickpea crop is prone to many pest and diseases. Among them dry root rot of chickpea caused by *Rhizoctonia bataticola* is a serious emerging threat to chickpea. *Rhizoctonia bataticola* is a genus of anamorphic fungi in order Cantharellales and family Ceratobasidiaceace. Rhizoctonia species do not produce spores, but are composed of hyphae and sclerotia. Rhizoctonia species are saprophytic, but some act as facultative plant pathogens causing commercially important crop diseases. The characteristics symptoms include yellowing of leaves, dark lesion on the stem at ground level; sclerotial bodies are seen beneath of bark of affected portion (root) of plant. The present study was conducted with the objectives on the *in vitro* evaluation of some bio agents/botanical and fungicides against *Rhizoctonia bataticola* (Taub.) Butler and integrated management of disease in experimental field. Among all tested antagonists *in vitro*, maximum mycelial growth inhibition was recorded with Garlic clove extract @ 5% (76.06%) after 72 hours, followed by *Pseudomonas florescence* (67.25%) and *Bacillus subtilis* (60%). The cent per cent mycelial growth inhibition of *Rhizoctonia bataticola* was recorded with fungicides carbendazim at all concentration i.e. 0.005%, 0.010% and 0.015%. While tebuconazole inhibited the mycelial growth of pathogen 88.15 % at 0.015% concentration, followed by 87.22% and 83.89% at 0.010% and 0.005% concentrations after 72 hours of inoculation respectively. During field experiment lowest percent disease incidence (10.11%) was recorded in (T_1) seed bio-priming with *Pseudomonas florescence* @10 g/kg seed, followed by (13.90%) in (T_8) seed treatment with carbendazim @2g/kg seed and (15.10%) and also maximum yield were obtained from same treatments respectively. Hence, we can say garlic clove extract @5% are highly effective against pathogen and seed bio-priming have synergetic effect on reducing disease incidence increasing yield as well.

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