Epidemiology and Management of Chickpea (*Cicer arietinum* L.) Dry Root Rot Induced by *Rhizoctonia bataticola* (Taub.) Butler {*Macrophomina phaseolina* (Tassi.) Goid.}

राइजोक्टोनियॉ बटाटीकोला (टॉब.) बटलर {मेक्रोफोमीना फेजियोलिना (टासी.) गोइड.} जनित चने के सूखा जड़ गलन रोग का जानपदिक एवं प्रबन्धन अध्ययन

OM PRAKASH SHARMA

THESIS

Doctor of Philosophy in Agriculture

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THESIS

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OM PRAKASH SHARMA

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

Gram *(Cicer arietinum* L.) is also known as chickpea or Bengal gram, the most important pulse crop grown in India. It is said to be one of the oldest pulse crop$ cultivated from ancient times both in Asia and Europe. Its origin lies in South West Asia. The crop is a member of family leguminosae. The chickpea plant is a small, much branched herb having well developed root system. It is a valuable crop for maintaining soil fertility having a capacity of fixing atmospheric nitrogen through *Rhizobium* nodules.

On global basis, chickpea is the third most important pulse crop after beans *(Phaseolus vulgaris L.)* and peas *(Pisum sativum L.).* It is being cultivated in 12.03 million hectares with a production of 9.24 million tonnes. (Anonymous, 2001). The major chickpea producing countries are India, Pakistan, Ethiopia, Burma, Turkey, Mexico and Australia. It is usually grown after rainy season on conserved soil moisture during winter in the tropics and in spring_, in the temperate and mediterranean regions. Chickpea is of two types *deshi* and *kabuli.* The seeds of *deshi* type are yellow to black in colour with a rough surface whereas seeds of *kabuli* type are light coloured having smooth surface.

Although, predominantly consumed as a pulse, dry chickpea is also used in preparing a variety of snack foods, sweets and condiments (Saxena, 1987). Green fresh chickpea is commonly consumed as a vegetable for a short period before the crop is matured. Straw of chickpea is an excellent fodder for cattle specially for camels. The grain contains 21.1 per cent

proteins, 61.3 per cent carbohydrates, 4.5 per cent fats and are also rich in calcium, iron and niacin (Singh, 1986).

In India, it contributes about 70 per cent in the hectareage of *rabi* pulses. It is cultivated in about 8.69 million hectares of land with a production of 6.97 million tonnes of grain per annum (Anonymous, 1999).

The major chickpea growing states in India are Madhya Pradesh, Rajasthan, Uttar Pradesh, Maharashtra, Harayana and Karnataka. Rajasthan occupies 2. 31 million hectares under chickpea cultivation and producing 1.74 million tonnes of grain (Anonymous, 1999).

The crop plays an important role in the economy of the state on account of low and static yield levels. Its production has been inadequate. Several environmental, agronomic and biotic factors are responsible for low productivity of chickpea. Drought is the major environmental constraint to low productivity in many areas of Indian subcontinent. Besides, other reasons such as a large number of pathogens attacking the crop are also responsible for inadequate yield of the crop. The most dreaded diseases in the state are *Ascochyta* blight, *(Ascochyta rabiei),* dry root rot *(Rhizoctonia bataticola)* and chickpea chlorotic dwarf virus. Ind state of Rajasthan, the crop is grown mainly on the receding soil where moisture is conserved from the rain received prior to the chickpea growing season. The soil moisture conservations practice is generally followed in Chum, Sriganganagar, Jhunjhunu, Bhilwara, Ajmer and Tonk districts.

Dry root rot incited by *Rhizoctonia bataticola (M. phaseolina)* has been found prevalent in such chickpea growing tracts of the State that is a serious threat to the chickpea growers. Sometimes association of other root pathogens like wilt *(Fusarium oxysporum f. sp. ciceri),* collar rot *(Sclerotium rolfsii),* root knot nematodes *(Meloidogyne incognita)* have also been found. However, no detailed work seems to have been done on dry root rot in Rajasthan hence, an attempt has been made to study the epidemiology and management of the disease.

OBJECTIVES

1. To know the disease status in the major chickpea growing districts in Rajasthan.
2. To estimate the actual loss caused by the disease.
3. To know the variability in the pathogen.
4. Effect of some environmental factors and quality of water on disease development.
5. To find out the role of macro and micro-nutrients on development of the disease.
6. To manage the disease by suitable chemical, cultural and biological means.

DISTRIBUTION

An association of *Fusarium sp.* and *Rhizoctonia sp.* with wilted plants of chickpea was first reported by Narsimhan (1929). Later, Dastur (1935) found *Rhizoctonia bataticola* producing wilted plants in chickpea in central province of India and called the disease, *Rhizoctonia* wilt. Subsequently, it was reported from Punjab by Luthra (1938), New Delhi (Anonymous, 1952), Madhya Pradesh (Sharma and Khare, 1969; Kotasthane *et al.,* 1979), West Bengal (Biswas and Gupta, 1981), Rajasthan (Siradhna *et* a1.,1982) and Haryana (Tripathi and Sharma, 1983). El Ahmad and Mouselli (1990) reported incidence of *M. phaseolina from* southern Syria. According to Beniwal *et al.* (1992) dry root rot and wilt were the most important diseases in Ethiopia.

SYMPTOMATOLOGY

Symptoms of the disease in field were described as drooping of leaves followed by pronounced wilting and necrosis of the tissues in the collar and main roots. Affected plants easily break away at the collar region when pulled out of the soil or the lateral roots may be broken and left behind (Narsimhan, 1929). According to Dastur (1935), only mature plants were affected, showing bronzing of the leaves on one or more of the lower branches. The colour, later, changed to yellow and then brown. The affected branches and leaf stalks of diseased plants are stiff and turned upwards, and leaflets stand more or less vertically and are shed prematurely. The terminal part of the tap root is black or brown and

shriveled. Nene *et al. (1991)* described the symptoms that disease generally appears around flowering and podding time in the form of scattered dried plants. The seedlings can also get infected. Drooping of petioles and leaflets is confined to those at the top of plant. Leaves and stems of

affected plants are usually straw coloured but in some cases the lower leaves and stem are brown. When the plant is uprooted, lower portion of the tap root remains in the soil and devoid of most of its lateral and finer roots. Dark minute sclerotial bodies can be seen on the roots exposed or inside the wood. Singh *et al. (1990)* reported that roots inoculated with *Rhizoctonia bataticola (M. phaseolina)* showed disintegration of cortical tissues while mycelium and sclerotial bodies plugging the xylem vessels.

PATHOGEN

Rhizoctonia bataticola (Taub.) Butler as a plant pathogen was recognised by Halsted *(1890).* In India, Shaw *(1912)* described a sterile fungus with black sclerotia causing seedling disease on jute, cowpea, groundnut and cotton. He identified it as *Rhizoctonia solani* Keuhn. Taubenhaus (1913) gave the name of the genus *Sclerotium* because of absence of spores and the species name as *bataticola* because it was pathogenic to *Ipomea batatas (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. phaseoli* as the pycnidial stage of *Rhizoctonia bataticola* on the basis that *Macrophomina phaseoli* was the earliest applicable binomial. He was not

aware that Tassi had earlier described *Macrophomina phaseolina.* Haigh (1930) suggested that *R. bataticola* be used for sclerotial isolate and pycnidial strains should be called *M phaseolina (R. bataticola).* Goidanich (1947) examined the original material of Tassi and compared it with *Macrophomina phaseoli, M corchori, M. cajani, M. sesami, M. philippinensis, Dothorela cajani* and *D. phaseoli* and found all of them identical. He correlated the mistake made by Ashby and according to the International Code of Botanical Nomenclature the binomial *Macrophomia phaseolina is* the valid name for the pycnidial stage of *R. bataticola.* Kulkarni and Patil (1966) did not adopt the new binomial because Ashby should be given in the priority due to the reasons that his observations were earlier to Goidanich.

YIELD LOSSES

Dry root rot caused by *Rhizoctonia bataticola is* a serious disease whenever the crop is exposed to temperatures more than 30°C. The disease development is 'influenced by dry soil conditions, specially at flowering, causing the plants to sudden drying (Singh and Mehrotra, 1982). The incidence of dry root rot on chickpea has been reported to be as high as 24.7 per cent in Madhya Pradesh by Sharma *et al.* (1983). Quaiser Ahmad and Abu Mohammed (1986) reported that if the plant get Infected at full podding stage, the loss in seed weight per plant was as high as 70.8 per cent. They also reported that the plant affected at pre harvest stage may cause 48.9 per cent loss in seed weight per plant. The reduction in 1000

seed weight at these two stages was noted to be 33.9 per cent at podding stage and 18. 4 per cent at pre harvest stage.

VARIABILITY AMONG ISOLATES

Sulaiman and Patil (1966) studied 19 isolates of *M. phaseoli* and on the basis of cultural characters and pathogenicity on cotton varieties, two isolates were distinguished. Similarly, Jain *et al.* (1972) reported variation among the isolates of *R. bataticola* isolated from various parts of *urid* plant. Dhingra and Sinclair (1973) noted variation in cultural characteristics and virulence. All the isolates of *M phaseoli* isolated from different plant parts of soybean varied in their growth rate and colony characteristics. Maximum growth in seven isolates was noted at 35°C and in two at 30°C. Hooda and Grover (1982) studied the isolates of *R. bataticola* obtained from different plant species and plant parts of the same host which differed in their morphological and cultural characteristics. Gupta and Kolte (1982) found differences in isolates of *M. phaseolina* isolated from root and leaf of groundnut plant. Byadgi and Hegde (1985) studied the isolates of R. *bataticola* obtained from six different plant species, differed in their cultural characters, growth and morphology of the sclerotia. They also reported that pycnidial production was recorded only on bean and bengal gram seedlings. Bean, bengal gram and cowpea isolates were the most virulent. Than *et al.* (1991) noticed that isolates from soybean and *Phaseolus vulgaris* were related to chickpea isolate. Sobti and Sharma (1992) noted that pathogen isolated from groundnut plant had no correlation between radial growth, virulence and pycnidial formation.

Ratnoo *et al. (1997)* indicated cultural and pathogenic variability among the isolates of *M. phaseolina* causing ashy grey stem blight of cowpea. Isolates were derived from root and stem parts of cowpea and found that stem isolate was proved to be more virulent and produce numerous distinct pycnidial bodies on dry stem than the root isolate.

HOST RANGE

Host range of the fungus is very extensive. Hooda and Grover *(1982)* isolated *Rhizoctonia bataticola* from mung bean, cowpea and groundnut and was tested for virulence on mung bean. It was found that mung bean root and leaf isolates were highly pathogenic to mung bean foliage, isolate from cowpea leaf was also pathogenic to foliage of mung bean. But groundnut isolate was the least virulent on the foliage. Singh and Nene *(1990)* studied cross inoculation of *Rhizoctonia bataticola* isolated from infected chickpea, pigeonpea, groundnut and sorghum plants. On inoculating different crops, it was observed that chickpea isolate was more pathogenic to safflower, sorghum, b- - .& bet end pigeonpea than to chickpea; the pigeonpea isolate was more pathogenic to safflower than to pigeonpea; the sorghum isolate was equally pathogenic on sorghum and groundnut and more pathogenic on all other crops tested; the groundnut isolate gave almost equal pathogenic reactions on groundnut, pigeonpea and -pearl * and was more pathogenic on chickpea and safflower. It was observed that the chickpea isolate was the most aggressive and safflower was the most susceptible crop to all the isolates. Umrani *et al. (1992)* reported that *Cicer arietinum* was more sustainable

under continuous cropping than sorghum and safflower which suffered from the increased incidence of R. *bataticola* Rotating sorghum and safflower with increased grain and seed yields

respectively

by 34 and 14 per cent compared with continuous cropping.

FACTORS AFFECTING PATHOGEN AND DISEASE DEVELOPMENT

EFFECT OF LIGHT

West and Stuckey (1931) observed that light has no effect on growth and sclerotia of *M. phaseoli* but direct sunlight can be detrimental to growth of the fungus. Johnson (1932) observed that exposure to visible light has no effect on vegetative growth and sclerotia formation of M. *phaseoli* in culture. Vasudeva (1937) also observed similar results. Michail *et al.* (1977) observed pycnidia formation on water agar leaf medium at 20°C under alternative cycles of 12 h. near ultra violet light and 12 h. darkness for 7-10 days.

EFFECT OF TEMPERATURE

Uppal (1934) found that soil temperature from 30°C to 34°C was most favourable for *M. phaseoli* to invade cotton plants, while in case of sorghum seedling blight, 35.5°C was most favourable and no disease developed at 30°C and below or at 40°C. Similarly, Norton (1953) reported that optimum temperature for the growth of *Sclerotium bataticola* in soil was 35°C, though growth also occurred at 30°C. Damage to the peanut plants occurred *by M phaseolina* between 21-32°C but at lower

temperature. fungus caused concealed damage (Gupta and Chouhan, 1970). Agarwal *et al.* (1973) reported that charcoal rot in soybean has been found to occur only at temperatures between 25 to 40°C. Cook (1955) observed that severity of the *M. phaseolina* on castor bean was greater during the extended hot and dry weather following by warm and moist spring. Ayanru and Green (1978) studied the germination of *M. phaseolina* sclerotia obtained from 3 to 20-day .Sold PDA cultures. It was being 98 - 25 per cent and 75 - 30 per cent, respectively incubated at 32°C and 24°C. Singh and Mehrotra (1980) reported that seed exudates increased when incubated at 35°C than at 15 and 25°C . They also presented that increased seed exudation is a major factor contributed to increase pre-emergence damping off of gram seedling by R. *bataticola* at high temperatures. Mukherjee *et al.* (1983) reported that at low temperature of 5°C, a large number of sclerotia were produced while the population was decreased with the rise

increase.

* temperature to 30°C. However, at 40°C, there was again __ in sclerotia production.

Banerjee et 9a (1983) reported that mycelium of M *phaseolina* lysed rapidly in natural soil and completely disappeared by twelfth day, temperature had little effect on lysis. The rate of decrease of sclerotial population was greater in natural soil than in sterile soil and greater at low temperature (5°C) combined with high soil moisture. Dwivedi and Dubey (1987) reported that in polythene sheeted soil in full sunlight when temperature reached to 54°C at a soil depth of 1 cm, survival *of M phaseolina* was greatly reduced. Byadgi and Hegde (1988) demonstrated the saprophytic activity of *Rhizoctonia bataticola* in soil and

found that it was maximum at soil temperature of 30°C .good at 35°C and -minimum at 15°C. Ratnoo *et al.* (1997 reported that the infection and development of ashy grey stem blight in cowpea caused by *M phaseolina* was most favoured by higher temperature 25-40°C. **It** was also observed that disease development was low in flooded soil compared to drier soil (40 - 60 per cent moisture).

EFFECT OF MOISTURE

For the development of *M phaseolina, soil* moisture is considered to be of prime importance. Ghaffar and Erwin (1969) observed that when cotton plants at soil temperatures of 20-40°C were subjected to soil water u stress and inoculated, the severity of *Macrophomina phaseoli was* much greater than those provided with sufficient soil water. Dhingra and Sinclair (1975) reported that sclerotia population of *M phaseolina* declined rapidly under high soil moisture. At soil moisture of 60-100 per cent water holding capacity, sclerotial population declined by 96-99 per cent as compared with populations in dry soil. Mukherjee *et al.* (1983) found that sclerotial population was stimulated by low soil moisture (10% WHC). None was produced at 30 and 70 per cent WHC in non amended soil. Zaki and Ghaffar (1988) observed that soil flooding reduced the sclerotia of M *phaseolina* by 95 per cent in fields without rice and 81 per cent with rice after 12 weeks. Taya *et al.* (1988) reported that low soil moisture was conducive to dry root rot (R. *bataticola)* disease development in chickpea. Colonization of *M phaseolina* on chickpea roots was higher when

subjected to moisture stress conditions compared with unstressed plants (Husain and Ghaffar, 1995).

EFFECT OF pH

Adam and Stockes (1942) observed good growth of R. *bataticola* occurred on media at pH range 5.0 to 8.0. Livingston (1945) also reported same range of pH best for the growth of *M. phaseoli* (charcoal rot of corn, sorghum). According to Singh *et al.* (1974) the optimum growth and

1014

sclerotial formation of R. *bataticola* was at^ .0, JA While, Singh and Kaiser (1994) in their studies reported that the pH 6.5 was the best for mycelial dry weight followed by pH of 5.0, 6.0 and 7.0. **EFFECT OF MACRO AND MICRO NUTRIENTS**

According to Dhingra and Sinclair (1975) soil amendment with sodium nitrate was found to decrease *M. phaseolina* sclerotial populations for 2-3 weeks after treatment and then increased until at seven weeks. Abdoul *et al.* (1980) observed that ammonium phosphate and ammonium nitrate induced the formation of immature sclerotia but ammonium chloride inhibited the sclerotial formation of *M. phaseolina* completely Sheikh and Ghaffar (1986) observed reduction in number of sclerotia by 18-100 per cent by N fertilizers. Mathur and Chandra (1987) reported a reduction in root mycoflora through foliar application of urea, ammonium sulphate and ammonium phosphate.

According to Taya *et al.* (1988), increased level of nitrogen caused increase in dry root rot incidence in chickpea. Similarly, when phosphate

levels were increased, disease intensity went down. When combination of both the nutrients was studied, the effect of nitrogen was found to be masked by phosphate levels. Dubey and Dwivedi (1988) demonstrated that population of *M. phaseolina* was declined in soil amended separately with Cd, Co, Ni, Zn, while, Cd proved to be most toxic, completely inhibiting the survival of the pathogen in soil after 20 days. Singh and Kaiser (1990) concluded that charcoal rot of maize induced by *M. phaseolina* enhanced by N application alone or in combination with P and K. Phosphorus and potash reduced the disease severity. Singh *et al.* (1990) found that combined doses of organic and inorganic forms of nitrogen; and urea along with farmyard manure significantly reduced the root rot of sesame caused by *M. phaseolina.*

INTERACTION WITH OTHER PATHOGENS

Synergistic relationship between *M phaseolina* and *Fusarium sp.* has been reported on beans. The symptoms of *Fusarium sp.* infection were dominated by more conspicuous symptoms of root rot caused by M. *phaseolina* (Miller *et al.,* 1947). In dual culture plate assts, *Rhizobium sp.* from pea, lucerne, and soybean inhibited the radial growth of M *phaseolina* obtained from cotton. A significant reduction in severity of *Macrophomina* root rot was noted by *Rhizobium* inoculation of mungbean, *okra* and sunflower in green house experiment by Zaki and Ghaffar (1987).

Combined inoculations of *Meloidogyne javanica* and *Macrophomina phaseolina* had caused significant reductions in plant growth and pod formation of lentil in pot experiments. The damaging effect was more

pronounced in simultaneous inoculation than in the sequential inoculation of pathogens at an interval of ten days. There was a negative interacting correlation between the organisms with the fungus being inhibitory to the nematode especially when inoculated ten days previously (Tiyagi *et al.,* 1988).

PL -!"-i& *bataticola (M. phaseolina)* and *Meloidogyne incognita* inoculated on *Cicer arietinum* either singly or concomitantly showed significant reduction in plant growth, in pot experiments Pandey and Singh (1990). Mohamed *et al.* (1990) reported that root rot of soybean caused by *M phaseolina* was increased in the presence of *Meloidogyne incognita.* Siddiqui and Husain (1991) observed that increase in the inoculum level of *M. phaseolina* progressively, decreased the nematode multiplication and root galling, while root rotting increased with the increase in the combined inocula of *M phaseolina* and *M incognita* in chickpea. Siddiqui and Husain (1992) examined the effect of *Meloidogyne incognita, Macrophomina phaseolina* and *Bradyrhizobium sp.* on root rot disease complex of chickpea and reported that *M incognita and M phaseolina* caused statistically equal damage to plant growth when inoculated singly but two pathogens together caused more damage than the sum total damage caused by both pathogens individually. Inoculation of *Bradyrhizobium, 10* days prior to the inoculation of the pathogens resulted in reduced damage. Inoculation of pathogens prior to *Bradyrhizobium* resulted in more damage than prior or simultaneous inoculation of *Bradyrhizobium,* had an adverse effect on nematode multiplication. In field test, *Rhizobium meliloti* seed

dressing reduced the infection *of M phaseolina* in soybean, mung bean, sunflower and *okra* (Haque and Ghaffar, 1993).

DISEASE MANAGEMENT

A. THROUGH CHEMICAL SEED TREATMENT

Varma and Vyas (1977) found carboxin and chloroneb effective against chickpea root rot caused by *Rhizoctoia bataticola,* ***(M.*** *phaseolina).* Taneja and Grover (1982) compared the efficacy of fungicides and found that benomyl and carbendazim were most inhibitory to ***M.*** *phaseolina.* Dwivedi and Dubey (1987) concluded that carbendazim inhibited the M.

phaseolina completely after 30 days of application in soil at only 250 ug/g

mancozeb and quintozene after 30 and 40 days, respectively. Rawat and Somani (1987) reported that seed treatment of chickpea with captan and chlorothalonil were the most effective in reducing root rot caused by *R. bataticola (M. phaseolina).* Vir (1987) reported that benomyl and carbendazim were effective against *M. phaseolina* in the soil to a depth of 4 cm. At 5 cm. depth, fungicides were inactive, possibly due to their absorption by soil particles.

Taya *et al.* (1990) showed that carbendazim alone or in combination with thiram as seed treatment plus drenching after sowing were found effective against *R. bataticola* of chickpea. Singh *et al.* (1992) reported that carbendazim plus thiram as seed treatment was effective against dry root rot of chickpea induced by *R. bataticola (M. phaseolina).* Ahmed *et al.*

(1992) found that thiophanate methyl was the best followed by thiobendazole in reducing *M phaseolina* stalk rot of maize. **B. THROUGH CULTURAL PRACTICES**

a) Date of sowing

Kotasthane *et al. (1979)* noted mortality of gram cultivars due to *Rhizoctonia bataticola* was not influenced by either planting date or spacing. More disease in chickpea susceptible variety JG-62 was observed in later stage. Tripathi and Sharma *(1983)* noted that the incidence of

Luring

chickpea dry root rot was higher during late October to mid November, it decreased in December and January and then increased again **in** FebruaryMarch. Echavez-Badel and Beaver *(1987)* concluded that ashy stem blight of bean caused by *M. phaseolina* infection was increased approximately by 40 per cent between pod set and physiological maturity. Singh *et al. (1990* reported that in chickpea, susceptibility to dry root rot *Rhizoctonia bataticola (M. phaseolina)* increased with plant age at the time of inoculation from *30* days onwards. Ratnoo and Bhatnagar *(1993)* reported that cowpea plants were more susceptible to ashy *grey* stem blight disease caused by *M. phaseolina* at younger age. The disease was most severe up to the age of 45 days. However, disease index gradually decreased with increase in the age of the plants.

b) Effect of soil amendments

Singh *et al.* (1981) found that *Rhizoctonia* root rot of chickpea was significantly controlled by the amendment of soil with wheat straw, maize

straw and sorghum straw. They also noted that amendment of soil with mustard straw was almost ineffective. Dwivedi and Chaube (1985) studied the effect of oil cakes on survival of *Macrophomina phaseolina* in soil and found margosa and cotton cakes as the best in minimizing the population. Singh and Neema (1987) observed a significant reduction in dry root rot disease of chickpea when soil was amended with wheat and oat residues. However, lentil and chickpea residues did not reduce the infection level significantly.

Singh *et al.* (1990) observed that urea along with farmyard manure proved best in reducing root rot disease incidence in sesame crop induced by *M. phaseolina.* Srivastava and Singh (1990) found reduction in *M. phaseolina* incidence in french bean when soil was amended with mustard cake. Ratnoo and Bhatnagar (1993) reported a reduction in disease index when soil was amended with wheat straw and among oil cakes neem cake was the best in reducing the disease index in cowpea incited by M. *phaseolina.* Sharma *et al.* (1995) reported a reduction in population density *of M. phaseolina* when amended with mustard cake and cauliflower residue. According to Hundeker *et al.* (1998), in pot culture experiment, neem, cotton, groundnut and safflower cakes were found to be effective in reducing the inoculum levels of *M phaseolina* of sorghum stalk rot.

C THROUGH ANTAGONISTIC BIOAGENTS

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Singh and Mehrotra (1980) showed that *Bacillus* and *Streptomyces* reduced the dry root rot incidence along with increased plant growth and dry matter in chickpea, while Parakhria and Vaishnav (1986) observed 1\

that gram seeds treated with *Trichoderma harzianum* were effective against *Rhizoctonia bataticola* root rot. Mukherjee and Sen (1992) reported that culture filtrate of *Aspergillus fumigatus* inhibited the fungal growth and sclerotial germination of *M. phaseolina. A* reduction in dry root rot of mung bean was noted when *Trichoderma viride* was applied in rows two days before sowing (Raghuchander *et al.,* 1993). Singh *et al.* (1993) reported antagonistic effect of *T. harzianum* and *T. viride* against *M. phaseolina* of mung bean. A reduction in stem blight disease of cowpea was noted when seeds were treated with *Trichoderma viride* (Mathur, 1995). Nautiyal *{1997)* reported *that Pseudomonas fluorescens* increased the germination of chickpea by 25 per cent and reduction in disease **incidence** (dry root rot, wilt and *Pythium* rot) by 45 per cent over control.

D) THROUGH HOST RESISTANCE

Haware *et al:* (1981) reported that nine lines of chickpea were resistant to wilt (F. *oxysporum f. sp. ciceris)* and dry root rot *[R. bataticola (M. phaseolina)].* According to Singh and Mehrotra (1982), chickpea cultivars BG-203, G-543 and Hare Chhole-1 had showed resistance to dry root rot (R. *bataticola).* Nene *et al.* (1989) evaluated two hundred twenty five genotypes of chickpea for broad based resistance to wilt (F. *oxysporum f. sp. ciceris)* dry root rot (R. *bataticola),* wet rot *(R. solani)* and charcoal rot (F. *solani)* at 24 locations. Few of the lines which were resistant to wilt and root rots were ICC-2862, ICC-9023, ICC-9032, ICC-10803, ICC-11550 and ICC-11551. On screening of two hundred eleven

1. SURVEY AND COLLECTION OF DISEASE SPECIMEN

1.1 DISTRIBUTION AND INCIDENCE OF THE DISEASE

Survey was undertaken to major chickpea growing districts of Rajasthan to know the prevalence of dry root rot. Observations on dry root rot incidence were. recorded. The selection of villages and fields was done randomly. To assess the disease incidence, five to seven fields were observed in each village and average incidence of the disease in each village was calculated. In each field, marked randomly, diseased and healthy plants were counted in one square meter area. In a field, five such spots were randomly selected and average incidence of field was calculated. The per cent disease incidence was calculated as per formula given below

$$\text{Per cent disease incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Survey was carried out in Jaipur, Sikar, Jhunjhunu, Bhilwara, Kota, Sriganganagar, Alwar and Tonk districts of Rajasthan. **1.2 ISOLATION AND PURIFICATION OF PATHOGEN**

Fungal isolations were made from the infected roots of chickpea plant. Infected roots were cut into 2 mm bits. Surface sterilization of the diseased bits was done in 0.1 per cent mercuric chloride solution for one minute followed by three subsequent washings with sterilized water. The

lines of chickpea seventeen lines were noted as resistant to wilt and root rots (Ahmed *et al.,* 1990).

Reddy *et al.* (1990) evaluated some 1283 accessions of chickpea collected from Madhya Pradesh, Rajasthan and Bangladesh during 19851989 against wilt and root rot. Out of them, ICC-14532, 14619, 14631, a& 14735, 15125 and 15233 were observed a source of resistance to both the resistant diseases. Reddy *et al.* (1991) Screened some wilt lx accessions of *Cicer sp.* and reported combined resistance to wilt and dry root rot in these species. Baker and Ahmed (1991) found only 12 out of 90 entries resistant to wilt and root rot. Of these, ICC-12263 was hi 4401.4-resistant. Hunde *et al.* (1992) evaluated forty five lines of chickpea at Ethiopia and the lines ICC-14400, 12241, 12245 showed resistance to wilt and dry root rot (R. *bataticola).* Gupta (1995) reported ICCV-89402, 90201, 9054, BG-209, H-88-2, GF88426 and RSG-180 as resistant to wilt and dry root rot of chickpea. Singh and Hari Chand (1996) reported 6 genotypes of chickpea viz., H-83-125, G-186012, GL-186143, H-90-22, H-91-35 and H-91-37 as resistant to wilt, dry root rot and *Ascochyta* blight.

MATERIALS AND METHODS

1. SURVEY AND COLLECTION OF DISEASE SPECIMEN 1.1

DISTRIBUTION AND INCIDENCE OF THE DISEASE

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bits were dried by placing on sterilized blotter paper and then transferred to potato dextrose agar (PDA) slants. These slants were incubated at 30±1°C. Mycelial growth started appearing after about 48 hours. Pure culture of the fungus was obtained by single hyphal tip method. For single hyphal tip

ed.

method, the fungus was inoculated on water agar plates and allowed to grow for 24 hours at 30±1°C. Growth thus obtained was extremely sparse. At this stage, it was easy to locate single hyphal tip. A cut was marked on single hyphal tip on agar plate with the help of sterilized dummy objective and transferred it onto PDA slants. Purified cultures of *Rhizoctonia bataticiola* were maintained by periodical transfers. On the basis of morphological characters, these cultures were grouped into four isolates, which were referred to as A-1, A-2, A-3 and A-4. The distinguishing characters were recorded as mentioned under: (Plate 1)

1.3 CHARACTERIZATION OF ISOLATES

Purified cultures of *Rhizoctonia bataticola* (Taub.) Butler *[Macrophomina phaseolina) (Tassi.)* Goid.] were grown on potato dextrose agar plates, incubated in BOD incubator at 30±1°C for 7-day. Then, these

cultures were observed for colour and shape of the colony; and distribution of sclerotia in the cultures. On the basis of morphological characters, all the isolates were grouped in 4 distinct types. Thereafter, their pathogenicity was tested using a susceptible variety (ICC-4951) of chickpea. After establishing their phatogenicity, detailed observations for morphological, cultural and pathogenic variability among the 4 isolates were undertaken.

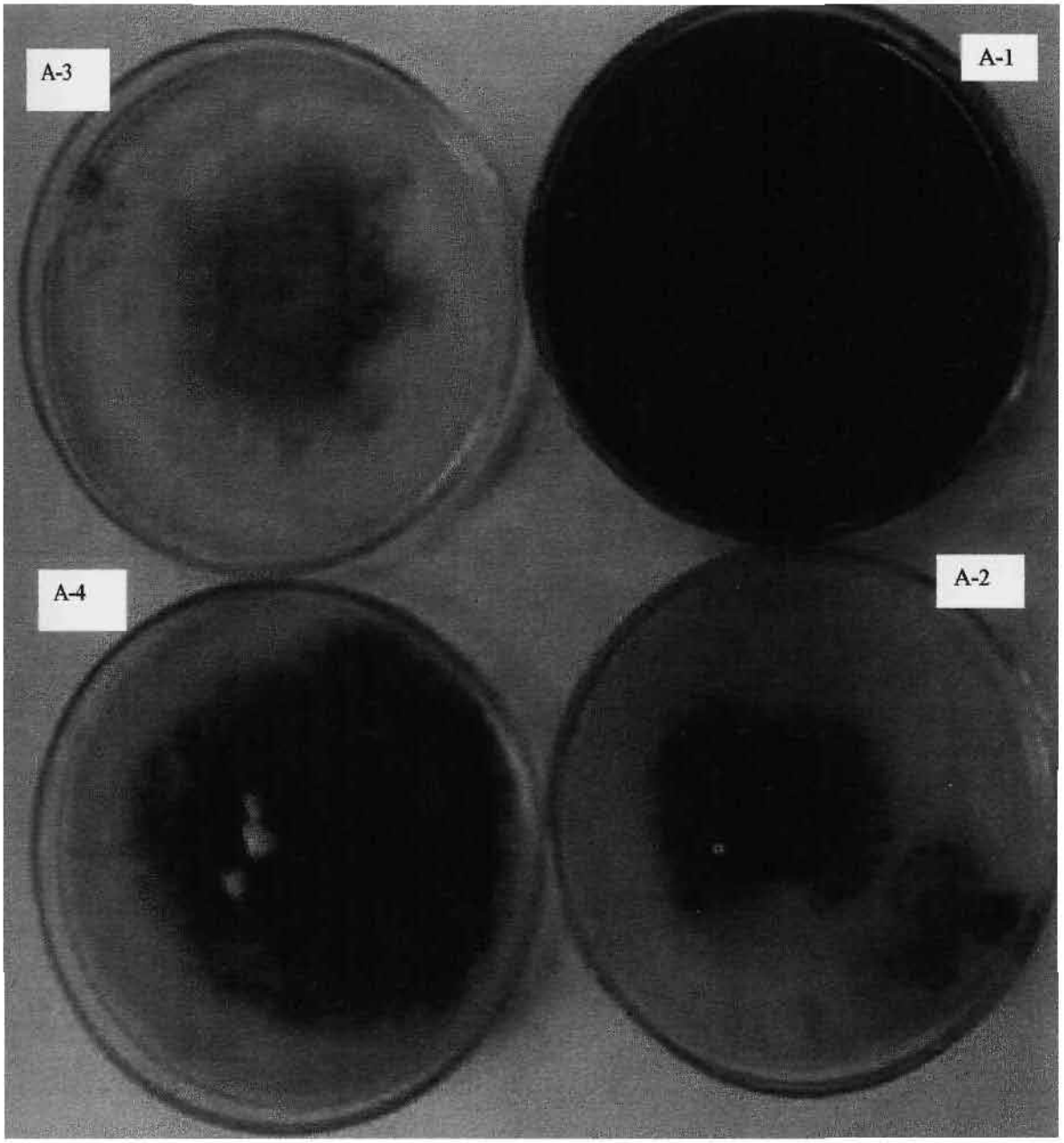

Plate 1 : Isolates of *Rhizoctonia bataticola* (Taub.) Butler [*M. phaseolina* (Tassi.) Goid.] A-1, A-2, A-3 and A-4

2. PATHOGENICITY

X2.1 PREPARATION OF INOCULUM

Rhizoctonia bataticola (M. phaseolina) was isolated from infected roots of chickpea plants collected from different parts of Rajasthan. Pure cultures of each isolate were obtained by single hyphal tip culture method. The inoculum of all four isolates was multiplied on sterilized maize meal soil medium 1:10 (Semenuk, 1944). For preparing sand maize meal mixture, 200 g riverbed sand, 20 g maize meal and 40 ml distilled water were placed in each 500 ml Erlenmeyer flask. The medium was autoclaved in the flasks at 1.05 kg/cm2 pressure for 20 minutes. On cooling, each flask was inoculated with a bit of 2 mm size actively growing mycelium. In each flask, 3 bits were placed. The inoculum for each isolate was obtained from periphery of 7-day-old culture growing actively on Richards agar medium in a Petri plate. Inoculated flasks were placed in a BOD incubator at 30±1°C for 15 days. Soil collected from the field was autoclaved at 1.05

kg/cm^2 for 30 minutes for 3 consecutive days. The inoculum prepared in the flasks was mixed uniformly with this sterilized soil @ 10 per cent (w/w) and filled in surface sterilized 30 cm earthen pots. The pots were surface sterilized by 2 per cent formaline solution before filling the soil inoculum mixture. After watering, @ 400 ml water per pot, the, same amount of water was applied at 6-day-interval, these pots were placed for 4 days for fungal multiplication. On the fifth day, fifteen chickpea seeds of variety ICC-4951, surface sterilized with 1 per cent sodium hypochlorite solution were sown in each pot. For each isolate ;' pots were used. The

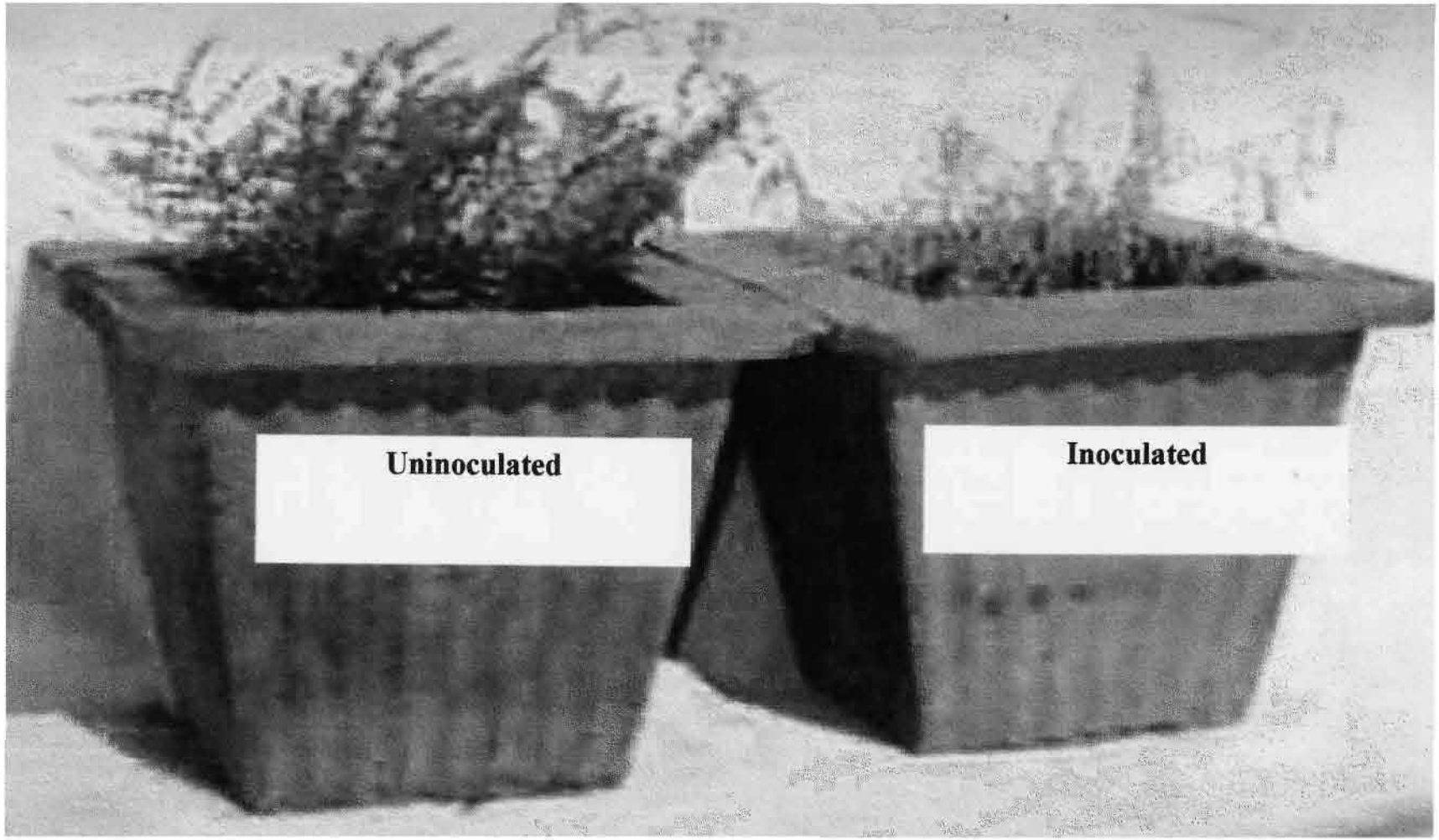

Plate 2 : Pathogenicity Test

pots without inoculum served as control. Observations on disease incidence in case of all the four isolates were recorded at 15 days after sowing. Plants showing disease (root rot) symptoms were collected and the pathogen was reisolated, and compared with the original cultures. (Plate 2)

2.2 INOCULATION METHOD

As mentioned above, inoculum was multiplied in 500 ml conical flasks containing sterilized sand maize meal medium and incubated at 30±1˚C for a period of 15 days. The inoculum so prepared was mixed in sterilized soil @ 10 per cent and distributed uniformly in each pot. Each pot of 30 cm dia containing 7 **kg** of soil was inoculated with inoculum @ 700 g per pot. After watering at 400 ml of water initially, the same amount of water was applied to each pot at an interval of 6-day. These pots were placed in cage house for 4 days and then surface sterilized seeds were sown for further test.

3.ASSESSMENT OF LOSSES

An experiment on loss evaluation in grain yield of chickpea due to dry root rot disease was under taken in sick soil condition. Fifteen-day-old culture, multiplied on sand maize meal medium was placed in furrows @ 100 g in each of the one meter row length to increase the disease pressure. Seeds of chickpea susceptible variety ICC-4951 were planted in 2m x 2.1 m plot. In each plot, 140 seeds were sown. Row to row and plant to plant spacing were 30 cm and 10 cm, respectively. Experiment was laid out in randomized block design (RBD) manner. Protected and unprotected block

(Treatments) each with fourteen replication sub-plots (as replications) were maintained.

Treatments

(i) **Unprotected block**

Plots inoculated with the virulent isolate A-land sown with untreated seeds of chickpea variety ICC-495 1.

(ii) **Protected block**

Plots inoculated with the virulent isolate A-land sown with seeds of chickpea variety ICC-4951 treated with carbendazim + thiram @ 3 g (1 g +2 g) kg' , seed.

Total number of germinated seeds were counted in each sub plot after 10 days of sowing. Total number of plants and number of infected plants in each plot were recorded before 15 days of harvesting and per cent disease incidence was determined. Likewise, grain yield per plot in both unprotected and protected blocks was noted after harvesting. Loss in grain yield was computed on the basis of the formula given below

$$\text{Per cent loss in yield} = \frac{\text{Average grain yield in protected block} - \text{Average grain yield in inoculated block}}{\text{Average grain yield in protected plot}} \times 100$$

In another set of experiment, fifty plants were selected randomly and tagged at two different crop growth stages where dry root rot incidence was observed on the basis of external symptoms appeared in the field.

Plants of the same variety were tagged in sick and non sick plots. The crop stages at which the symptoms noted were (i) flowering stage and (ii) podding stage. After harvest, grain yield per plant and then weight of 1000seeds was also recorded.

4. VARIABILITY AMONG ISOLATES 4.1

MORPHOLOGICAL CHARACTERS 4.1.1

Growth characters

The four isolates *viz.,* A-1, A-2, A-3 and A-4 collected from different chickpea growing areas of the state (Rajasthan) were further studied for their morphological and cultural behaviour. The radial growth, colour of the colony, character of mycelium; shape, size and development of sclerotia were studied of all the test isolates. Each isolate was grown on 25 ml of Richards' agar medium in Petri plates of 10 cm dia by inoculating with small disc of 2 mm in centre of each plate having four replications. The mycelial discs were cut using a sterilized metallic cork borer from the periphery of four-day-old actively growing culture on Richards' agar medium plates.

4.1.2 Mycelial characters

These plates were incubated at 30±1°C in BOD incubator. The shape and size of 40 mycelial cells for each isolate were measured after seven days of fungal growth with the help of calibrated microscope (eye piece 10 x, objective 40 x).

4.1.3 Sclerotial characters

The observations on sclerotia dimensions were also recorded for each isolate. The shape and size of 40 sclerotia of each isolate were determined. For recording extent of scierotial production, an uniform amount of fungal biomass (2 mm bit) was taken at random from ten different places in each Petri dish after 15 days of incubation at 30±1°C.

These bits were put into 25 ml of sterilized water in 100 ml conical flasks and shaked thoroughly on mechanical shaker for 15 minutes. A drop of the fungal biomass suspension was put on the slide and examined for scierotial count under low magnification. In each of the 3 drops, 5 microscopic fields were observed and mean number of sclerotia in each isolate was calculated. The degree of sclerotiaL production has been expressed as follows after calculating the average number of sclerotia per microscopic field (Hooda and Grover 1982).

Mean number of sclerotia per field of microscope	**Category**
0	Nil
1-20	Few
21-40	Several
Above 40	Abundant

4.1.4 Pycnidial production

For pycnidia production, Richards' agar medium was supplemented with host plant extract (30 g of host tissue containing leaf, stem and roots/litre of medium). After sterilization, 25 ml of this Richards' host extract agar medium was poured in each plate. Plates were inoculated with 2 mm mycelial bit taken from periphery of 4-day-old culture of each of the four isolates. Four replications of each isolate were maintained. Plates after inoculation of individual isolate were incubated in BOD incubator at 30±1°C for 15 days. Observations on pycnidia formation were recorded thereafter (Vishwa Dhar, 1986).

4.2 CULTURAL VARIABILITY 4.2.

1 Variability on agar media

All the four isolates were grown on ten different solid media for their growth and sclerotial production. The composition of each medium used is given as under:

1. **Czapek's medium**

   Sodium nitrate 2.0 g Potassium dihydrogen phosphate 1.0 g Potassium chloride 0.5 g Magnesium phosphate 0.5 g Ferrous sulphate 0.01 g Sucrose 309 Agar 20 g Distilled water 1000 ml

2. **Richards' medium**

Potassium nitrate log Potassium dihydrogen phosphate 5 g Magnesium sulphate 2.5 g Ferric chloride 0.02 g Sucrose 50 g Agar 20 g Distilled water 1000 ml

3. **Asthana and Hawkers's**

Glucose	5.0 g
Potassium nitrate	3.5 g
Potassium phosphate	1.75 g
Magnesium sulphate	0.75 g
Agar	20 g
Distilled water	1000 ml

4. Brown's medium

Glucose 2.0 g Asparagine 2.0 g Potassium dihydrogen phosphate 1.25 g Magnesium sulphate 0.72 g Agar 20g Distilled water 1000 ml

5. Potato dextrose agar (PDA)

Peeled potato	200 g
Dextrose	20 g
Agar	20 g
Distilled water	1000 ml

6. Oat meal agar

Oat meal 30 g Agar 20 g Distilled water 1000 ml

7. **Corn meal agar**

Corn meal 30g Agar 20 g Distilled water 1000 ml

8. Mung bean agar

Mung bean (crushed) 30 g Agar 20 g Distilled water 1000 ml

9. Martin's agar

Potassium dihydrogen phosphate 1.0 g Magnesium sulphate 0.5 g Peptone 5.0 g Dextrose 10.0 g Rose Bengal (1%) 3.3 ml Agar 20 g

Distilled water 1000 ml

10. Malt extract agar

Malt extract 20.0 g Dextrose 20.0 g Peptone 1.0 g Agar 25. 0 g Distilled water 1000 ml

Each of the above mentioned solid medium was prepared in 1000m] of water and sterilized at 1.05 kg per sq. cm. pressure for 20 minutes. Sterilization of glass Petri dishes (Borosil) was done at 180°C for 2 h in a hot air oven. In each Petri dish, 25 ml of respective medium was poured keeping quadruplicate for each treatment. Inoculation was done with each of the 4 isolates. An inoculum bit of 2 mm dia was inoculated in the centre of each plate and observations on mycelial growth and sclerotia production were recorded. Pycnidial production for each of the isolate was recorded on Richards' host extract agar medium.

4.2.2 Variability on broth media

All the ten media which were prepared using agar were also tried as broth media. After sterilization, 25 ml of each medium was poured into conical flask of 100 ml capacity, keeping quadruplicate for each treatment. The flasks were inoculated with 2 mm bit of the pathogen, and were incubated at in BOD incubator 30±1°C. After seven days of incubation, mycelial mat was harvested on oven dried whatman No. 1 filter paper. Mycelial mat along with filter paper was dried at 60°C for over night in hot air oven and weighment was done. For sclerotia production, 3 separate flasks were maintained. The each of the 4 isolates was cultured on each broth medium separately in Erlenmeyer flasks for 15 days at 30±1°C. The mycelial mat was fragmented in waring blender at low speed intermittently for a total time of 5 min. The homogeneous suspension so obtained was strained through the mushlin cloth and supernatants were received in a beaker. A drop of the suspension was taken on the slide and examined for sclerotia count under low magnification.

4.2.3 Variability on grain media

Wheat, barley, maize, sorghum, cluster bean, mung bean and chickpea grains were employed for the study. A 50 g whole grains of each type were cooked until just soft, air dried and filled in 250 ml conical flasks. Flasks containing cooked grains were sterilized at 1.05 kg/cm^2 pressure for 30 minutes twice with an interval of one-day, Then, the flasks were inoculated with 2 mm mycelial bit of each individual isolate i.e. A-1, A-2, A-3 and A-4 and incubated in BOD incubator at 30±1°C. Visual observations on fungal growth were recorded. Observations on sclerotia formation were recorded after 15 days of incubation, fungal biomass along with the grain substrate was removed from the flask in a surface sterilized tray and dried under laminar flow chamber for 24 h. Thereafter, the dried grains infested with the fungal biomass were mixed thoroughly and a uniform sample of 10 g was drawn from each flask. The sample so obtained was suspended in 100 ml sterilized water in 250 ml conical flask and shaked on mechanical shaker for 15 minutes. Then the shaked suspension was strained through the muslin cloth and supernatant was obtained in a beaker for estimating sclerotia production as done under 4.1.3.

4.3 PATHOGENIC VARIABILITY

Chickpea cultivar ICC-4951 was raised in 30 cm earthen pots. The pots were surface sterilized with 2 per cent formaline solution and after 24 h, filled with inoculum mixed soil @ 10 per cent w/w. In general, soil was

loamy sand, neutral, low in nitrogen and medium in phosphorus and potash. The pH, electric conductivity (EC) and organic carbon were being 8.2, 0.15 dsm^{-1} and 0.15 per cent, respectively. Five pots were sown with fifteen surface sterilized seeds in each pot which were treated as five replications for each of the 4 isolates (A-1, A-2, A-3 and A-4). Disease incidence was recorded regularly commencing after 15 days till 75 days of sowing and per cent incidence was calculated as under: (Plate 3)

$$\text{Per cent disease incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Observations on incubation period, pycnidia formation were also recorded. For pycnidia production the pathogen was grown on maize mealsand medium in' conical flasks at 30±1°C. After 7 days of incubation a portion of the medium along with pathogen biomass was placed on the surface of the soil in close contact with collar of the chickpea seedlings and covered completely with sterilized soil. The pots were watered as and when required and placed in a cage house. Roots of infected plants were examined under microscope for pycnidia formation at 4, 7, 10 and 15 day interval (Kulkarni *et al., 1962).*

5. HOST RANGE

The following seventeen plant species belonging to different angiospermic families were tested for their susceptibility to *Rhizoctonia bataticola (M. phaseolina)* of chickpea, in pots, using the most virulent isolate A_1.

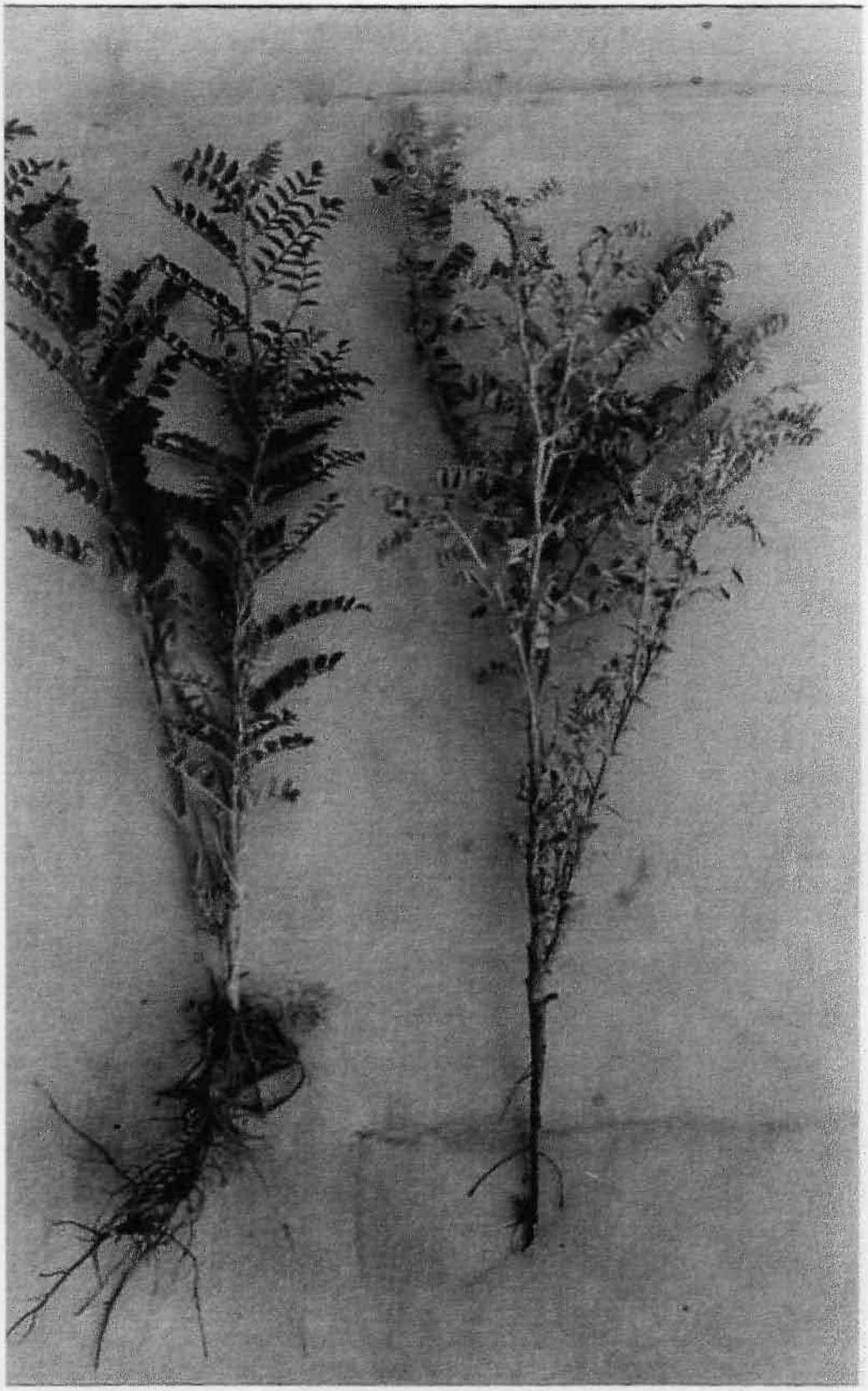

Plate 3 : Healthy and dry root rot infected plants of chickpea

Common name	Scientific name	Family
Black gram	*Vigna mungo (L.)*	Leguminosae
Chickpea	*Cicer arietinum (L.)*	Leguminosae
Clusterbean	*Cyamopsis tetragonoloba D.C.*	Leguminosae
Cowpea	*Vigna unguiculata (L.)* Walp.	Leguminosae
Groundnut	*Arachis hypogaea (L.)*	Leguminosae
Lentil	*Lens esculenta* Monech (E. Medit.)	Leguminosae
Linseed	*Linum usitatissimum (L.)*	Linaceae
Methi	*Trigonella foenumgraecum (L.)*	Leguminosae
Moth bean	*Vigna aconitifolia* (Jacq.) Marchel	Leguminosae
Mung bean	*Vigna radiata (L.)* Wilezek	Leguminosae
Mustard	*Brassica camper tris (L.)*	Cruciferae
Pea	*Pisum sativum (L.)*	Leguminosae
Pearl millet	*Pennisetum typhoids* (Burin. F.) Stapf. & Hubb.	Gramineae
Rajmash	*Phaseolus vulgaris (L.)*	Leguminosae
Red gram	*Cajanus cajan (L.)* Mill sp.	Leguminosae
Soybean	*Glycine max. Merr.*	Leguminosae
Wheat	*Triticum aestivum (L.)*	Gramineae

Surface sterilized seeds of each test species (15 seeds/p-ot) were sown in *Rabi* and *Kharif* seasons as they belong, in earthen pots of 30 cm size. In each pot, inoculum of *R. bataticola (M. phaseolina)* was added before sowing as mentioned under 2.2. After inoculation, pots were

watered @ 400 ml water / pot and ' kept for four days in cage house and then sowing was done. Subsequent watering was applied @ 400 ml water / pot at an interval of 6-day. Each treatment was replicated thrice. Observations on disease incidence and incubation period were recorded. The pathogen was re-isolated from the infected roots of test crops and identity was confirmed.

6. FACTORS AFFECTING THE PATHOGEN AND DISEASE DEVELOPMENT

6.1 EFFECT OF INOCULUM DOSES ON DISEASE

Sterilized soil was filled in 30 cm dia earthen pots. In each pot, 7 kg soil was filled. Inoculum was multiplied on maize meal sand medium as mentioned in (2.1) and incorporated to each pot in order to achieve five different doses viz., 175 g, 350 g, 525 g, 700 g, 875 g which provided 2.5, 5.0, 7.5, 10 and 12.5 per cent (w/w), respectively. After adding inoculum, pots were watered at 400 ml water/pot and kept in the cage house for 4

of the four replicatior

days. Then, sowing in each pot was done with 15 surface sterilized chickpea seeds cv. ICC 4951. Thereafter, pots were irrigated after every 6 days using 400 ml water / pot. Observations on disease incidence were

recorded after 15 days of sowing and continued up to 75 days and per cent disease incidence was calculated. Observation on incubation period for the disease was also recorded.

6.2 EFFECT OF TEMPERATURE

6.2.1 *In vitro*

Richards' broth medium broth was used as the basal medium. After inoculation, the flasks were incubated in BOD incubators maintained at 20, 25, 30, 35 and 40°C temperatures at which the growth was to be observed. Each conical flask (100 ml) containing 25 ml of Richards' broth was inoculated with 2 mm mycelial bit. Each treatment was taken in quadruplicate. Dry mycelial weight of fungal biomass and sclerotia production were recorded.

6.2.2 *In vivo*

Surface sterilized plastic pots of 10 cm dia containing 400 g sterilized soil in each pot were inoculated with inoculum of R. *bataticola. (M. phaseolina)* @ *10* per cent (w/w). Five surface sterilized seeds were sown and placed for respective temperature treatments in BOD incubators. Each treatment replicated 8 times. Pots were irrigated with 25 ml of water to each pot at an interval of 6-day. Observation on disease incidence was recorded at 7-day interval and continued until 40 days of sowing. For determining the population of pathogen propagules, soil samples were drawn from the pots and analyzed for propagule population using the medium described by Meyer *et al. (1973).* The rice agar (RA) was prepared by boiling 10 g of polished rice in 1 litre of distilled water for five minutes; filtering through cheese cloth; 20 g Difco agar was added to the filtrate and autoclaved. In one litre of rice agar (RA) *300* mg active ingredient of

chloroneb; 7 mg mercuric chloride; 90 mg rose bengal; 40 mg streptomycin sulfate and 60 mg potassium penicillin were added, whereas lactic acid was used to bring the pH 6.0.

For pathogen population soil samples were drawn from each pot 75 days 4k" sowing to case of 30 cm dia pots and 40 days after in 10 cm dia pots by removing 5 cm surface soil layer. From each pot, uniform amount of soil (50 g) was taken in a sterilized Petri dish, soils samples drawn from each replicate pot were mixed together and finally a 50 g of it was air dried under laminar flow and mixed thoroughly. Fifty mg of air dried soil was plated on each of the twenty Petri dishes containing 25 ml specific chloroneb mercury rose bengal agar medium (Meyer *et al.,* 1973). After 72 h of incubation at 30±1°C fungal colonies were counted by colony counter and population g^{-1} soil was determined.

6.3 EFFECT OF SOIL MOISTURE

For study of soil moisture regimes, earthen pots of 30 cm dia were used. Inoculum was added to each pot at the rate of 10 per cent (w/w). Pots after inoculation were watered and kept for 4 days. On fifth day fifteen surface sterilized seeds of cultivar ICC-4951 were sown in each pot. The pots were irrigated at the interval of 2, 3,4, 5 and 6 days to maintain different moisture regimes by applying equal amount of water to each pot (400 ml). Each treatment was replicated 6 times. Soil samples were drawn and population per gram of soil was recorded.

6.4 EFFECT OF TEMPERATURE AND SOIL MOISTURE INTERACTION ON DRY ROOT ROT

To study the temperature and soil moisture interaction, plastic pots of 10 cm dia were used. The pots were filled with sterilized soil after surface sterilization by 2 per cent formaline solution. Each pot was inoculated @ 10 per cent w/w inoculum as done in case of 2.2. Eight replications of each treatment were maintained. To maintain different moisture levels, amount of water required for saturation was measured and considered as 100 per cent moisture. Accordingly, the moisture levels were maintained. In the present investigation 12 per cent moisture was considered as saturation (mhc) point of the working soil. On this basis 3, 6 and 9 per cent moisture contents were treated as 25, 50 an 75 per cent of the moisture holding capacity of the soil (mhc). Initially, these three levels were maintained. Subsequently, water was added to each pot in order to maintain the respective level of moisture by computing the loss in weight of soil. Observation on disease incidence was recorded.

6.5 EFFECT OF DIFFERENT RELATIVE HUMIDITY (RH) LEVELS

Humidity levels were maintained by using sulphuric acid and distilled water in different proportions (Buxton and Mellanby, 1934). Petri dishes having 25 ml Richards' agar medium were inoculated with 2 mm bit of fungus and incubated in BOD incubator at 30±1˚C. Four replications of

each treatment were maintained. 'The inoculated surface was directly exposed to different humidity levels in a dessicator. The colony diameter and sclerotia formation were recorded after 7 days of inoculation.

Details of humidity levels

Humidity (%)	*stock solution (ml)	Distilled water ml.
40	539	306
50	514	420
60	374	396
70	348	510
80	294	640
90	161	712
100	0	Only distilled water

* Stock solution of sulphuric acid (50 per cent v/v)

6.6 EFFECT OF HYDROGEN ION CONCENTRATION (pH)

Citrate phosphate buffer solution was prepared as follows:

Stock solutions: Solution A and solution B were prepared. For solution `A', 19.21 g of citric acid was dissolved in one litre of distilled water to get 0.1 M solution of MW 192.7, while for solution `B', 58.78 g of dibasic sodium hydrogen phosphate was dissolved in one litre of distilled water to get 0.2 M solution of 293.9 MW. Stock solutions A and B were mixed in different proportions in order to achieve the desired level of pH as given below:

Solution A (ml) Solution B (ml) pH 158.9 41.1 3.0 143.0 57.

0 3.5 122.9 77.1 4.0 106.5 93.5 4.5 97.0 .103.0 5.0 84.0

116.0 5.5 73.7 126.0 6.0

54.5 145.5 6.5

35.3 164.7 7.0

12.7 187.3 7.5

5.5 194.5 8.0

To obtain pH 9.0, boric acid and borax buffer solutions were used. They were prepared as follows:

(i) Boric acid solution: In one litre of distilled water, 12.37 g of boric acid was dissolved to get 0.2 M solution. **(ii) Borax buffer solution:**
In one litre of distilled water 19.07 g of borax was dissolved to get 0.05 M solution. Now, 2.0 ml of solution of boric acid was mixed with 8.0 ml solution of borax buffer to obtain pH 9.0.

Thus, water of each pH was supplied as per the requirement of chickpea plants in pots. Earthen pots of 30 cm dia sown with 15 surface sterilized seeds of chickpea cv. ICC 4951 were employed. Inoculations

were done as per the procedure adopted under 2.2. Each treatment was kept quadruplicate and observations for disease incidence were commenced after 15 days of sowing. Mycelial propagules per gram of soil were also recorded.

6.7 EFFECT OF LIGHT

6.7.1 *In vitro*

The effect of different combinations of light and darkness on mycelial growth and sclerotial formation were studied. The following treatments were included.

1. 24 h continuous light.
2. 18 h light followed by 6 h darkness.
3. 12 h light followed by 12 h darkness.
4. 6 h light followed by 18 h darkness.
5. 24 h continuous darkness.

One hundred ml conical flasks, each containing 25 ml sterilized Richards' broth medium were inoculated with a 2 mm mycelial disc of isolate A-1 taken from the periphery of 4-day-old actively growing culture in the Petri plate. The inoculated flasks were exposed to different light regimes at the temperature of 30±1°C. Each treatment was replicated 4 times. On seventh day of exposure, dry mycelial weight of the fungal biomass and sclerotia formation were recorded, following the procedure mentioned under 4.2.2.

6.7.2 ***In*** *vivo*

For *in vivo* studies, small size plastic pots of 10 cm dia were used. These pots after surface sterilization by 2 per cent formaline solution were filled with sterilized soil mixed with inoculum *(R. bataticola).* Each pot was inoculated with the pathogen as under 6.2.2. Initially 25 ml of water was added to each pot, then they were irrigated at 6-day interval. Five surface sterilized seeds as done earlier (6. 2.2) were sown in each pot then exposed to respective light and dark treatments in the BOD incubator at a temperature of 30±1°C for 7 days. For darkness, pots were kept in the incubator where no illumination was provided. Each treatment was replicated eight times. Observation on disease incidence was recorded periodically commencing after 7 days of sowing. Mycelial propagules were counted as CFU g^{-1} of soil under each light treatment.

6.8 EFFECT OF HOST NUTRIENTS 6.8.1

(a & b) Effect of macro nutrient

In general, soil was loamy sand, neutral, low in nitrogen, and medium in phosphorus and potash. The pH, electric conductivity (EC) and organic carbon were being 8.2, 0.15 dsm^{-1} and 0.15 per cent, respectively. Soil mixed with *R. bataticola (M. phaseolina)* inoculum multiplied on maize-meal-sand medium at the rate of 10 per cent (w/w) was filled in earthen pots of 30 cm dia after lining the pots with polyethylene sheet of 40 µm gauge. Four nitrogen levels including 0, 15, 20 and 25 kg/ha and four

levels of phosphorus viz., 0, 30, 40 and 50 kg/ha were tried in sixteen

different combinations. Required quantity of urea and single super phosphate were added in soil in order to achieve the desired levels of nitrogen and phosphorus, respectively. Quantity of each fertilizer in each pot (7 kg soil) was calculated on the basis of weight of the soil. 0, 105.91, 141.19, 176.59 mg of urea whereas 0, 595.59, 795.34, and 994.31 mg SSP were added to supply the above mentioned levels of N and P, respectively. Four replications (4 pots) in each combination treatment were maintained. Fifteen surface sterilized seeds of chickpea cultivar ICC-4951 were sown in each pot. After sowing, 400 ml water was supplied to each pot, thereafter watering was done at an interval of 6 days. Disease incidence was recorded periodically commencing after 15 days of sowing and was continued upto 75 days. The pathogen population was also determined in terms of mycelial propagules g^{-1} of soil as mentioned under 6.2.2.

6.8.2 Effect of micro-nutrients

For study of micro-nutrients, plastic pots of 10 cm dia were used. Seven micro-nutrients *viz.,* zinc, manganese, calcium, copper, cobalt, iron and nickel were tried. Each element at the rate of 10 mg kg^{-1} of soil was applied in *R. bataticola (M phaseolina)* inoculated soil.. Nitrogen and phosphorus were applied at 20 kg N and 40 kg P2O5/ha as a general dose in all the treatments. Five surface sterilized seeds of chickpea cultivar ICC4951 were sown in each pot. Each treatment was replicated eight times. After sowing 25 ml water was supplied to each pot thereafter, watering was done at an interval of 6-day. Disease incidence was recorded after 7 days of sowing and continued till 40 days. Pathogen population and incubation

period were also recorded. Micronutrients were supplied in the form of chemicals as given below:

Micronutrient	Name of chemical	*Quantity kg' soil (in mg)
Zinc	Zinc sulphate	29.68
Manganese	Manganese sulphate	27.44
Calcium	Calcium sulphate	40.50
Copper	Copper sulphate	29.36
Cobalt	Cobalt chloride	25.58
Iron	Ferrous sulphate	32.50
Nickel	Nickel chloride	26.60

* To supply 10 mg kg^{-1} of each nutrients.

6.9 INTERACTION OF *R. BA TATICOLA WITH* OTHER SOIL ORGANISMS

Interaction of *R. bataticola (M. phaseolina)* with wilt causing organism *(Fusarium oxysporum f. sp. ciceris), Rhizobium* sp. and root knot nematode *(Meloidogyne incognita)* was studied in pots. In all, there were 5 treatments *viz., Rhizoctonia baiaticola* alone; *Rhizoctonia bataticola + Fusarium oxysporuft; Rhizoctonia bataticola + Rhizobium; Rhizoctonia bataticola + Meloidogyne incognita* and *Rhizoctonia bataticola + Fusarium oxysporum + Meloidogyne incognita.* Field soil inoculated with

R. bataticola (M. phaseolina) inoculum (multiplied on corn-meal-sand medium) at 10 per cent (w/w) was filled in 30 cm dia earthen pots. Twenty five pots were prepared. For wilt causing organism (F. *oxysporum),* inoculum multiplied on corn-meal-sand medium was applied at 10 per cent w/w in each of the ten pots. In case of *Rhizobium sp.,* seeds were treated with chickpea *Rhizobium* culture before sowing in five pots. Whereas for root knot nematode ten pots of neratode infested soil having 8 galls/g of soil were used. Five replications (5 pots) in each treatment were maintained. Initially, 400 ml of water was added in each pot then. they were irrigated at 6-day interval with the same quantity of water in each pot. Fifteen surface sterilized seeds were sown in each pot and observations on disease incidence and incubation period were recorded after 15 days of sowing and continued till 75 days. Mycelial propagules were counted as g_1 of soil from the samples drawn from each treatment as mentioned earlier in 6.2.

7. MANAGEMENT OF DRY ROOT ROT

Unless mentioned other wise, following methodology was used. The experiment was conducted in 30 cm dia earthen pots. Inoculum in each pot was mixed four days before sowing at 10 per cent w/w. Four replications (4 pots) of each treatment were maintained. Nitrogen and phosphorus were applied at 20 and 40 kg/ha, respectively. For this 20.17 mg of urea and 113.62 mg of single super phosphate kg' soil were incorporated. Irrigation to each pot was given at an interval of six days. In each pot, 15 surface sterilized seeds of the susceptible chickpea (ICC-4951) were sown. Disease

incidence observations were started after 15 days of sowing and continued up to 75 days and per cent disease incidence was calculated. 7.1 **THROUGH CHEMICALS**

7.1.1 Fungicidal seed treatment in pots

Seeds of chickpea variety ICC-4951 were treated with each of the six fungicides including Bavistin, Thiram, Vitavax, telest, Topsin-M and Kavach. Fifteen seeds treated with each fungicide were sown in each pot with four replications. Initially 400 ml of water was added to each pot, thereafter pots were irrigated at an interval of 6 days with same amount of water. Observation on disease incidence was commenced after 15 days of sowing and continued upto 75 days. The details of the fungicides used are mentioned as below:

Trade Name	Common Name	Chemical Name	Dose kg" seed (in g)
Bavistin	Carbendazim 50%	methyl-2-benzimidazole-2-carbamate	1.0
Thiram , Thiram		75% tetra methylthiuram disulphid	2.0
Vitavax	Oxycarboxin 75%	carboxine (5-6-dihydro-2-metyl 1, 4-oxathin-3carboxanidide) oxathein	1.0
Celest	Fluoxinyl	Phenylpyrrole	1.0
Topsin-M	Thiophanate-Methyl 75%	1,2,bis (3 ethoxycarbonyl-2-thioureido)	1.0
Kavach	Chlorothalonil Tetra ch: oroisophthalonitrite 75%		1.0

Pots without seed treatment were treated as control.

7.1.2 Fungicidal seed treatment in field

Similar set of treatments was also sown in field with plot size of 2 m x 2.1 m, under sick soil condition. Row to row and plant to plant spacing was 30 and 10 cm, respectively. Each plot had seven rows and sown with 140 seeds. Two irrigations were applied. After sowing, first at 45 days and second at 75-80 days. Fertilizer doses were applied as mentioned earlier. Observations on disease incidence were started recording after 15 days of sowing till harvest. Grain yield per plot was recorded. Each treatment was replicated four times and mycelial propagules were counted as g^{-1} soil through samples drawn from each plot.

7.2 THROUGH CULTURAL PRACTICES 7.2.1

Effect of date of sowing

Incidence of root rot disease was observed on chickpea plants sown at ten different dates. Sowing was done from 14th October to 16th December at an interval of 7 days. Fifteen surface sterilized seeds of chickpea variety ICC-4951 were sown in each of the 5 earthen pots (30 cm dia) under each treatment. The pots were filled with inoculated soil in the same proportion using the most virulent isolate (A-1) of R. *bataticola* as mentioned earlier (4.3). Five pots represented 5 replications for each date of sowing. The sowing dates were as follows:

(i) 14th October

(ii) 21St October

(iii) 28th October (iv) 4th

November (v) 11th

November (vi) 18th

November (vii) 25th

November (viii) 2nd

December (ix) 9th

December (x) 16th

December

In each pot 20.17 mg urea and 113.62 mg single super phosphate kg" soil were applied, in order to supply 20 kg N and 40 kg P_2O_5 per hectare, respectively. Pots were kept in cage house and watering was done with 400 ml of water per pot and thereafter at an interval of 6 days. Observations for occurrence of the disease were commenced after 15 days of sowing and continued up to 75 days. Mycelial population g" of soil were assessed as per procedure described under 6. 2.2.

7.2.2 Effect of soil amendments

Soil was amended with 6 types of organic materials including four crop straws, two oil cakes and farmyard manure (FYM). Straws and cakes each individually were thoroughly ground and mixed in the form of powder. Soil was amended 15 days earlier to sowing and then inoculated with the pathogen as done earlier. The pots were irrigated at an interval of 6 days with equal amount of water i.e. 400 ml/pot. The organic materials used for soil amendment are mentioned as below. Four replications of each treatment were maintained.

Organic material	Dose g kg'" soil
Wheat straw	20
Bajra straw	20
Mung bean straw	20
Chickpea straw	20
Mustard cake	5
Groundnut cake	5
Farm Yard Manure (FYM)	20

Observation on disease incidence was recorded. Pathogen population was estimated in terms of propagules (CFU) g"[1] of soil from the samples drawn from each treatment, as done earlier (6.2.).

7.3 THROUGH ANTAGONISTIC BIOAGENTS

Dust formulations of four bioagents were tried against dry root rot pathogen, in the form of seed treatment. Six replications (6 pots) of each bioagent treatment were maintained. Before applying bioagent on the surface of the seeds, seeds were moistened with 5 per cent gum solution applied at 10 ml kg'" of seed. The bioagent were used as seed treatments.

Size of the pots, methods of the sowing and watering were the same as mentioned under 7.1. The details of the bioagents are mentioned as under:

Bioagent	Dose g kg'' seed
Trichoderma vi ride	*4.0*
Trichoderma harzianum	*4.0*
Gliocladium virens	*0.5*
Bacillus subtilis	*6.0*

Observation on dry root rot incidence was recorded. Pathogen population in terms of mycelial propagules (CFU) g' of soil was counted.

7.4 THROUGH HOST RESISTANCE

One hundred genotypes of chickpea received from Senior Breeder Pulses, Agricultural Research Station, Durgapura and Chickpea, Coordinator, Kanpur were evaluated against chickpea dry root rot under sick soil condition, in field. Fifty seeds of each test entry were sown in a 5 m. row length. After every two lines of test entry, one susceptible line of ICC-4951 was planted. Inoculum multiplied on sand-maize-meal medium was placed in furrows at 10-12 cm depth at 500 g/5 cm row length to increase the disease pressure. The experiment was replicated twice. Of one hundred entries evaluated, *40* were of desi type, 20 of bold type, 17 of kabuli type, 3 of drought tolerant group and 20 were of state promising lines. Observations were recorded after 15 days of sowing. On the basis of disease incidence the entries were categorized as per criterion followed by Agarwal and Sarabhoy *(1976).*

Category	Per cent disease incidence
Free	0
Resistant	1-10
Moderately resistant	10.1-20
Susceptible	20.1-30
Highly susceptible	> 30 / plants killed

EXPERIMENTAL RESULTS

1. SURVEY

Survey for the occurrence of chickpea dry root rot was undertaken in Jaipur, Sikar, Jhunjhunu, Bhilwara, Kota, Sriganganagar, Alwar and Tonk districts of Rajasthan during 1996-97 and 1997-98. Extensive survey revealed that the disease was present in varying intensities in all the districts surveyed.

1.1 DISTRIBUTION AND INCIDENCE OF THE DISEASE

It is apparent from the data depicted in Table 1 that the dry root rot *(R. bataticola)* incidence in different districts varied from 4.98 to 18.99 per cent. In Tonk, it was maximum (18.99%), followed by Jaipur, Alwar and Bhilwara having incidence to the tune of 12.33, 11.24 and 11.04 per cent, respectively. Least dry root rot incidence was observed 4.98 per cent in Sriganganagar district. It was also observed that dry root rot incidence was more where the crop was cultivated as rainfed. Incidence of chickpea dry root rot was higher in the fields when chickpea itself was grown in the previous *Rabi* season and minimum when it was followed by mustard crop in the previous *Rabi* season. In general, disease symptoms were observed in all the fields with crop age between 70-95 days. However, per cent disease incidence was comparatively higher in the crop of 80-90 days than it was in 70-80 days old. The disease was observed on both timely sown and late sown crops of chickpea but the infection was higher on the crop sown later than 5th November (Table 1).

Table 1 : Per cent disease incidence* of dry root rot of chickpea induced *by Rizoctonia bataticola (M. phaseolina)* in different districts of Rajasthan.

District; Village	Stage of crop (days old)	Mean disease village	Mean disease in district	Mean disease % Irrigated	Mean disease % Rainfed	Mean disease % Previous crop chickpea	Mean disease % Previous crop mustard	Mean disease **Early sown	Mean disease ***Late sown
Jaipur			12.33					–	
Hingonia	75-80	15.80		-	-			9.20	1410
Itawa	75-80	12.75		-	-	13.75	8.75		
Kalakh	70-80	8.38		-	-				
Sikar			10.53						
Reengus	65-75	9.38		-	-				
Srimadhopur	ti)	11.68		7.26	16 10			7.50	11.50
Jhun.jhunu			7.80	--	-				
Navalgarh	85-90	9.69		-	-	10.64	8.38		
Mukundgarh	80-85	7.38		-	-				
Neemkathana	80-95	6.34		5.10	8.68				
Bhilwara			11.04						
Shahpura	85-9u	9.36		-	-				
Jahajpur	75-80	11.42		8.20	13.64				
Upreda	80-85	12.34		-	-				
Kota			7.45						
Deoli	80-85	6.38		-	-				
Sangod	75-80	9.64		-	-	11.46	7.40	6.50	10.50
Khadia	70-85	6.34		4.32	8.36	7.34	4.60		
Sriganganagar			4.98						
Suratgarh	85-90	5 69		-	-				
Sriganganagar	80-85	4.27		-	-				
lAhvar			11.24						
Navgaon	80-85	13.24		-	-	10.50	7.69		
Thanagaji	80-85	9.24		-	-				
Tonk			18.99						
Diggi	80-90	22.64		-	-			15.00	20.50
Todda	90-95	15 34		13.64	17.04				

Mean of two years data (1996-97 and 1997-98)

** Sowing done 15th October to 5th November

*** Sowing done later than 5th November

1.2 ISOLATION AND PURIFICATION OF PATHOGEN

Dry root rot infected chickpea plants were collected from different chickpea growing areas of the state. Isolations were made and purified.

1.3 CHARACTERIZATION OF ISOLATES

On the basis of the colony characters, cultures were grouped into four isolates.

A-1 - Colony entire, appraised, black mycelium, in colour distribution of sclerotia, mycelia barrel shaped.

uniform

A-2 - Irregular, light black in colour, uniform distribution of sclerotia.

A-3 - Entire, fungal growth dark brown in colour at centre and light towards periphery, sclerotia heavily concentrated at centre.

A-4 - Raised, cottony, greyish black in colour, sclerotia uniformly distributed.

2. PATHOGENICITY

All the four isolates of R. *bataticola* tested against chickpea variety ICC-4951 proved pathogenic. Symptoms of dry root rot started appearing after 19 days of inoculation. Infected plants were found slow in growth as compared with healthy ones. Affected seedlings later turned pale in colour and ultimately dried. Pathogen was re-isolated from these infected seedlings and purified on potato dextrose agar (PDA) medium. The identification of the pathogen was confirmed as R. *bataticola.* All the

four isolates caused dry root rot to chickpea. The incidence varied between 26.66 to 53.33 per cent (Table 2). (Plate 4)

3. **ASSESSMENT OF LOSSES**

Under sick plot condition, the incidence of dry root rot *(R, bataticola (M phaseolina)* was recorded during *Rabi* 1996-97 and 199798, which was rioted to the extent of 54.41 and 58.02 per cent, respectively. This resulted loss in grain yield by 55.77 per cent in *1996-97* and 56.86 per cent in 1997-98 over the protected plots. However, In the protected plots, the incidence *of* the disease was reduced to 19.37 and 19.63 in both the years, respectively (Table 3a).

In, another experiment, studies with regard to yield components affected by the dry root rot were taken up by tagging fifty plants of the test cultivar (ICC-495 1), under sick and non sick plots. Plants were randomly selected on the basis of external symptoms seen at flowering and podding stages of the crop separately. Results indicated that the losses in the grain weight per plant over healthy plant were recorded to be 60.90 and 42.27 per cent when plants got infected at flowering and podding stages, respectively. The per cent reduction in 1000-grain weight over healthy plant was also recorded and it was noted to be 36.25 per cent at flowering

stage and 22.93 per cent at podding stage. Reduction was more pronounced when infection occurred at flowering stage (Table 3 b).

Table 2 : **Per cent disease incidence caused due to four isolates of *Rhizoctonia bataticola* on chickpea**

Isolate	Per cent dry root rot incidence*	Incubation period (days)
A-I	53.33 (46.89)	19
A-2	35.99 (36.83)	25
A-3	26.66 (30.89)	24
A-4	38.66 (38.39)	22
Control	0.0	
SEm±	1.40	
CD (P=0.05)	4.15	

* Mean of five replications

- Figures in parentheses are angular transformed values

Table 3(a) : Grain yield loss due to dry root rot of chickpea induced by R. *bataticola (M. phaseolina).*

Treatment	Root rot incidence* (%)		Grain yield* (kg/ha)		Grain yield loss(%)	
	96-97	97-98	96-97	97-98	96-97	97-98
Unprotected plot: Plot inoculated with *R. bataticola* and sown with untreated chickpea seeds	54.41	58.02	310	289	55.77	56.86
Protected plot: Inoculated with R. *bataticola* and sown with seed treated with carbendazim + thiram (1 g + 2 g kg'' seed)	19.37	19.63	701	670	-	-

* Mean of 14 replications

Table 3(b) : Loss in grain yield due to dry root rot, *R bataticola (M. phaseolina)* of chickpea

Yield components	1996-97			1997-98			Mean (1996-97 and 1997-98)		
	Healthy	Infected at flowering stage	Infected at 'podding stage	Healthy	Infected at flowering stage	Infected at podding stage	Healthy	Infected at flowering stage	Infected at podding stage
Mean grain weight / plant (g)	26	10.0	15.0	29.0	11.50	14.0	27.50	10.75	14.50
Per cent loss in grain weight/plant	-	61.53	42.30	-	60.34	51.72	-	60.90	42.27
Mean 1000 grain weight (g)	145	95.0	111.0	151.20	93.70	117.10	148.00	94.35	114.05
Per cent reduction in 1000 grain weight	-	34.48	23.44	-	38.02	22.55	-	36.25	22.93

*Based on observations of 50 plants

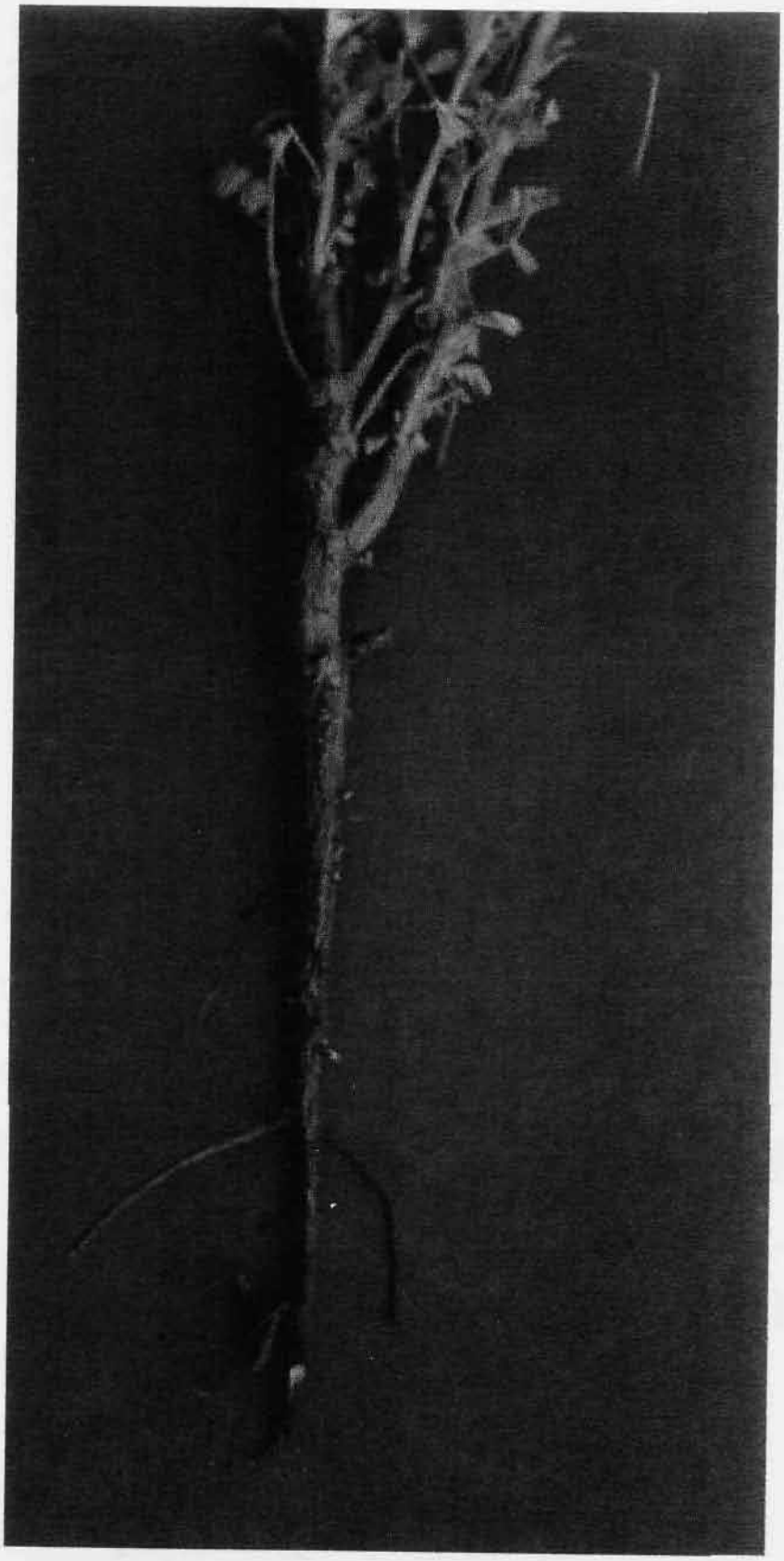

Plate 4: Symptoms of dry root rot on chickpea devoid of lateral roots

4. VARIABILITY AMONG ISOLATES OFR. *BA TATICOLA*

*(M. **PHASECLINA**)*

4.1 MORPHOLOGICAL CHARACTERS

The morphological variability such as shape and size of the hyphal cell, sclerotial formation and pycnidia formation were recorded in different isolates of R. *bataticola* by growing them or. to Richards' medium. These are described as under:

4.1.1 Growth characters

Colony was entire and appraised to substrate in isolate A-1, raised and cottony grey appearance in isolate A-4. As regards colour of the colony, it was light black to black in isolates A-2 and A-1 whereas isolate A-3 possess dark brown colour and A-4 having greyish black mycelium. Distribution of sclerotia was noted uniformly in case of A-1, A-2 and A-4 whereas sclerotia were heavily concentrated at centre in isolate A-3. Colony diameter of test isolates was ranged between 61.4 to 80.2 mm. The maximum colony dia (80.2 mm) was attained by isolate A-1, which was significantly higher over all other isolates, while the minimum growth was observed in isolate A-3. Isolate A-2 and A-3 were statistically at par with each other for growth. Isolate A-4 attained 69.8 mm colony diameter and ranked second for growth (Table 4).

4.1.2 Mycelial characters

It is evident from the data presented in Table 5 that only two types of mycelial cells were seen in four isolates studied. Barrel shaped mycelial cells were seen in isolate A-1 and A-4, while cylindrical cells in the

Table 4 : Growth and colony characters of different isolates of R. *bataticola (M. phaseolina)* grown on Richards' agar medium.

Isolate	Colony characters	Colony diameter* (mm)	Colour of colony
A-1	Entire, appraised mycelium of sclerotia uniformly distributed	80.20	Black
A-2	Irregular, mycelium of sclerotia uniformly distributed	63.60	Light black
A-3	Entire, mycelium at centre and light towards periphery, sclerotia heavily concentrated at centre	61.40	Dark brown
A-4	Raised, cottony, mycelium, sclerotia uniformly distributed	69.80	Greyish black
SEm±		1.80	
CD (P= 0.05)		5.38	

*Mean of four replications

isolates A-2. and A-3,. As regards size of mycelial cell, it was being 19.2 x 7.2 and 20. 2 x 6.4 urn in the isolates A-4 and A-1, respectively. On the other hand, the isolates A-2 and A-3 having cylindrical mycelial cells were measured as 24.0 x 5.4 and 15.6 x 6.4 µm, respectively (Table 5).

Constrictions at septation were also noted. -In A-1, A-3 and A-4 isolates, a prominent constriction was noted at the point of union, while in A-2 it was very slight.

4.1.3 Sclerotia characters

Oval and spherical types of sclerotia were seen in four isolates studied. Isolates A-I, A-2 and A-3 bore oval shaped sclerotia while spherical shaped sclerotia were noticed in isolate A-4. The colour of sclerotia was black in case of isolates A-1 and A-2, grey in isolate A-3, while dark brown coloured sclerotia were seen in isolate A-4. Mean sclerotial size in oval shape sclerotia of A-1, A-2 and A-3 were 64.4 x 47.2, 85.4 x 59.0 and 77.2 x 54.4 µm, respectively. Whereas isolate A-4 which

produced spherical shape sclerotia was measured as 93.2 x 90.8 µm. However, among the isolates studied, maximum sclerotia size was attained by the isolate A-4, followed by the isolates A-2, A-3 and A-1. Isolate A-1

had produced highest number of sclerotia on Richards' agar medium (Table 6).

4.1.4 Formation of pycnidia

was studied

Pycnidial production on Richards' host extract agar medium. Only one isolate, A-4 could produce pycnidia in culture. The shape of the pycnidia was being pear shaped and measuring to be 60.5 x 46.5 µm in

Table **5 : Shape and size of mycelial cells in different isolates of R. *bataticola (M. phaseolina)* when cultured on Richards' agar medium**

Isolate	Shape	Size of mycelial cell (µm)*	Constriction at septation
A-1	Barrel	20.2 x 6.4 (16-24 x 4-12)	At the point of union
A-2	Cylindrical	24.0 x 5.4 (16-28 x 4-8)	Very slight constriction at Union
A-3	Cylindrical	15.6 x 6.4 (8-24 x 4-16)	At the point of union
A-4	Barrel	19.2 x 7.2 (12-24 x 4-12)	At the point of union

*Mean of 40 cells

Figures in parentheses are the range of size of mycelial cells

Table 6 : Shape, colour, size and number of sclerotia in different isolates of R. *bataticola (M. phaseolina),* cultured on Richards' agar medium

Isolate	Shape	Colour	Size (µm)	**Sclerotia formation (Nos.)
A-1	Oval	Black	64.4 x 47.2 (28-108 x 32-68)	44
A-2	Oval	Black	85.4 x 59.0 (36-100 x 24-78)	41
A-3	Oval	Grey	77.2 x 54.4 (32-108 x 28-88)	42
A-4	Spherical	Dark brown	93.2 x 90.8 (32-116 x 48-110)	40

* Mean of 40 sclerotia

** 40x magnification

size. However, other isolates were failed to produce pycnidia in culture. (Table 7).

Table 7 : Formation of pycnidia in different isolates of *R. bataticola (M. phaseolina)* when cultured on Richards' host extract agar medium

Isolate	Shape	Size *	Formation**
A-1	-	-	-
A-2	-	-	-
A-3	-	-	-
A-4	Pear	60.5 x 46.5 (45.0 - 72.5 x 37.5-52.5)	+ *

Mean of 40 pycnidia

** + Pycnidia present

- Pycnidia absent

4.2 CULTURAL VARIABILITY 4.2.1

Variability on agar media

Growth and sclerotia formation were studied on ten different agar media. Results indicated that isolate A-I and A-4 had produced maximum mycelial growth of 82.0 mm and 81.2 mm, respectively on Richards' agar medium while isolate A-2 and A-3 had shown maximum mycelial growth on Potato dextrose agar i.e. 72.6 and 80.0 mm, respectively. In general, Richards' agar medium was found better for mycelial growth (78.68 mm) among all the media tested. Similarly, A-1 isolate could produce the

highest growth (60.80 mm). All the four isolates had produced abundant sclerotia (41-48) on Richards' agar medium. Potato dextrose agar ranked second in sclerotia production (Table 8 and Fig 1). The mean number of sclerotia on Richards' and potato dextrose agar media were 44 and 40, respectively (Table 8).

4.2.2 Variability on broth media

Broth media study indicated that Richards' broth medium was found significantly superior over all other media, producing 151.48 mg dry mean fungal biomass of the 4 isolates. Potato dextrose, oat meal, and malt extract were next to Richards' with biomass production of 137.30, 107.89 and 95.03 mg, respectively. Among the four isolates, A-1 had produced 98.75 mg of dry fungal biomass and found significantly superior over all other isolates. Isolates A-2, A-3 and A-4 were the next producing 90.71, 88.30 and 80.31 mg pathogen biomass, respectively. Interactions between isolates and media were found to be significant. However, maximum growth of 159.37 mg was obtained with isolate A-1 grown on Richards' broth. Isolate A-1, A-4 and A-2 on Richards' broth and A-1 on potato dextrose were statistically at par (Table 9a).

For sclerotia production, Richards', potato dextrose, malt extract and oat meal were found better in producing higher number of sclerotia. The mean number of sclerotia in these media was 42, 39 and 38, per microscopic field respectively (Table 9b).

4.2.3 Variability on grain media

Seven grain media were evaluated for growth and sclerotia production. Fastest growth of the isolate A-1 and A-4 was obtained on chickpea grain medium, where complete surface of the substrate was

Table 8 : ***Growth and sclerotia formation in isolates of R. bataticola (M. phaseolina) on different agar media***

Agar media	Colony diameter (mm)* in different isolates					Sclerotia formation (Nos.)** in different isoaltes				
	A-1	A-2	A-3	A-4	**Mean**	**A-1**	A-2	**A-3**	**A-4**	**Mean**
Czapek's	61.73	58.00	54.25	50.00	55.99	16	30	36	26	27.00
Richards'	82.00	7162	79.87	81.25	78.68	44	41	46	48	44.75
Asthana & Hawker's	55.25	40.46	43.46	45.42	46.14	36	30	34	28	32.00
Brown's	53.87	40.00	50.62	49.46	48.48	13	31	29	20	23.25
Potato dextrose	59.62	72.62	80.0	60.50	68.18	40	45	38	40	40.75
Oat meal	52.00	62.00	49.75	51.40	53.78	34	34	26	18	28.00
Corn meal	77.75	5187	56.25	66.75	63.15	11	32	28	31	25.50
Mung bean	73.62	66.25	49.75	40.25	57.46	18	38	41	32	32.25
Martin's	49.31	41.34	38.34	62.25	47.81	15	29	32	30	26.50
Malt extract	42.87	46.75	40.42	53.00	48.26	41	24	29	19	28.25
Mean	60.80	55.00	54.27	56.02		26.80	33.40	33.90	29.20	

* Mean of four replications

** Sclerotia per microscopic field

Few =(1-20 sclerotia);

Several = (21-40 sclerotia) and

Abundant = (> 40 sclerotia)

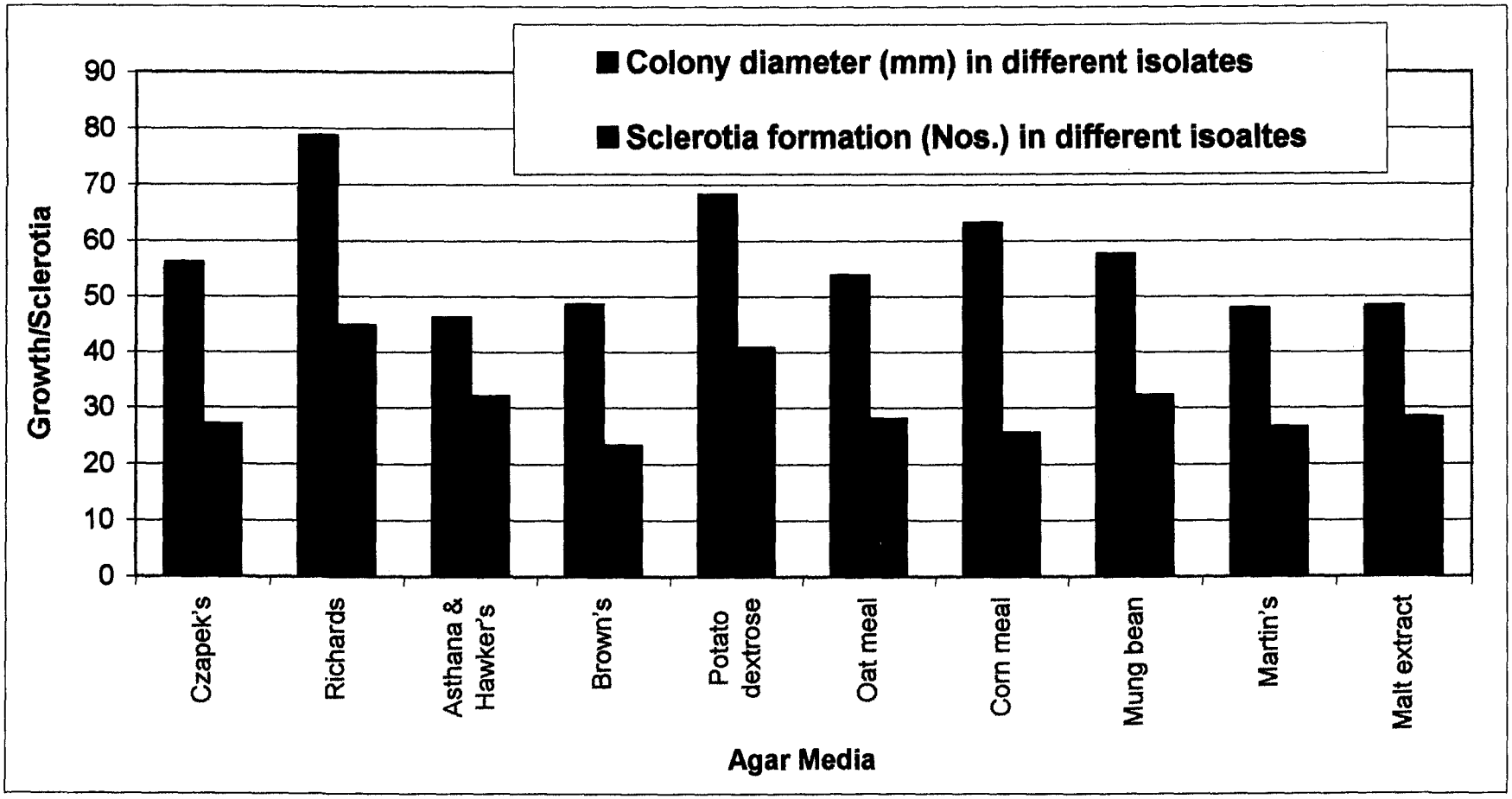

Fig. 1 : Growth and sclerotia formation in isolates of *R. bataticola* (*M. phaseolina*) on different agar media

Table 9a : Dry fungal biomass of. R. b*ataticola (M. phaseolina)* isolates on different broth media

Broth media	*Dry fungal biomass in 4 isolates (mg)				
	A-1	A-2	A-3	**A-4**	**Mean**
Czapek's	67.58	77.68	56.57	59.20	65.25
Richards'	159.37	155.25	135.25	156.06	151.48
Asthana & Hawker's	37.25	43.37	52.52	36.15	42.32
Brown's	51.62	58.91	66.90	54.75	58.04
Potato dextrose	153.62	127.31	140.97	127.30	137.30
Oat meal	133.12	109.20	91.75	97.51	107.89
Corn meal	86.50	90.35	94.95	86.31	89.52
Mung bean i	95.0	95.52	97.50	64.12	88.03
1 Martin's	60.12	67.26	58.90	50.01	60.30
Malt extract	143.27	82.27	87.78	66.71	95.03
Mean	98.75	90.71	88.30	80.31	

* Mean of four replications

	SEm±	**CD (P=0.05)**
Media	1.57	4.41
Isolates	0.99	2.79
Media x isolates	3.15	8.82

Table 9b : Sclerotia formation in *R. bataticola (M. phaseolina)* isolates on different broth media

Broth media	Mean sclerotia formation in 4 isolates* (Nos.)				
	A-1	A-2	A-3	**A-4**	**Mean**
Czapek's	32	28	32	31	30.75
Richards	48	41	40	42	42.75
Asthana & Hawker's	16	20	30	31	24.25
Brown's	32	28	34	29	30.75
Potato dextrose	44	41	39	39	40.75
Oat meal	44	38	32	38	27.00
Corn meal	36	32	26	36	32.50
Mung bean	17	24	41	28	27.50
Martin's	34	31	24	31	30.00
Malt extract	42	39	38	38	*39.25*
Mean	34.50	32.20	33.60	34.30	

* Mean of four replications

Few (1-20 sclerotia);

Several = (21-40 sclerotia) and

Abundant = (> 40 sclerotia)

covered within 6 and 9 days after inoculation. Maize grain medium was next to it for growth. Isolate A-2 produced fastest growth on maize grain medium covering entire surface of the substrate within 10 days of inoculation. Isolate A-3 grew quickly on mung bear. grain medium. In general, chickpea grain medium was found best for the rapid growth of all the four isolates requiring 9 days, whereas mung bean and maize grains media were second to it, which required 10.5 and 10.2 days to cover the entire surface of the substrate (Table 10).

Isolate A-1 had produced abundant (>40) sclerotia on chickpea and maize grain media, while isolate A-2 produced abundant (>40) sclerotia on mung bean. Isolate A-3 had produced maximum number of sclerotia on maize grain media. Highest number of sclerotia were produced by isolate A-4 on chickpea. In general, chickpea and maize grain media were found better for sclerotia production in all the isolates. Mean number of sclerotia on chickpea and maize grain media were being 36.7 and 37.2, respectively (Table 10).

4.3 PATHOGENIC VARIABILITY

All the four isolates of R. *bataticola* were tested for their pathogenic behaviour on a susceptible host plant (chickpea) variety ICC-4951. Isolate A-1 caused maximum disease incidence of 57.33 per cent which was significantly higher over all other isolates, followed by isolates A-4, A-2, and A-3 with root rot incidence of 39.99, 29.33 and 26.66 per cent, respectively. Incubation period of four isolates ranged between 18-26 days

Table 10 : Growth and sclerotia. formation in different isolates of R. *bataticola (M. phaseolina)* on grain media

Grain (media	Growth (surface of substrate covered in days*)					Sclerotia formation (Nos.)**				
	A1	A-2	A-3	A-4	**Mean**	**A-1**	A-2	**A-3**	**A-4**	**Mean**
Wheat	10	12	13	12	11.7	31	24	28	31	28.5
Barley	13	13	14	15	13.7	19	21	23	21	21.0
Maize		10	12	10	10.2	45	38	34	32	37.2
Sorghum	14	11	12	14	12.7	38	31	30	28	31.7
Cluster bean	15	14	13	13	13.7	18	19	20	24	20.2
Mung bean	12	11		10	10.5	40	42	22	28	33.0
Chickpea	6	12	10		9.2	47	38	24	38	36.7
Mean	11.28	1.85	11.85	**1.85**		4.00	0.42	5.85	8.85	

* Mean of four replications

** Sclerotia per microscopic field

Few = (1-20 sclerotia);

Several = (21-40 sclerotia) and

Abundant = (> 40 sclerotia)

after inoculation. Highly pathogenic isolate A-1 had the lowest incubation period.

The isolates A-2 and A-4 had produced pycnidia on host plant after 38 and 35 days of inoculation, while A-1 and A-3 isolates failed to produce any pycnidia on host plant. The isolate A-1 was recorded most virulent hence, selected for further studies. (Table 11).

5. HOST RANGE

Seventeen plant species belonging to various families were tested for their reaction to isolate *A-1 of R. bataticola (M. phaseolina) of* chickpea. All the plant species belonging to family leguminosae had showed positive reaction to *R. bataticola.* Maximum disease incidence, 51.0 per cent was recorded on chickpea plants which is significantly higher over all other plant species tested, followed *by Phaseolus vulgaris* and *Vigna aconitifolia* with the disease incidence of 31.1 and 24.4 per cent, respectively. However, *Pennisetum typhoids, Triticum aestivum, Brassica campestris* and *Linum usitatissimurn* showed negative reaction to the test *fungus, R. bataticola* (Table 12).

The incubation period for disease development in all the plant species tested, ranged between 21-38 days of inoculation. *Phaseolus vulgaris* has the lowest incubation period of 21 days whereas *Cajanus cajan* had the highest of 38 days.(Table 12).

Table 11 : Pathogenic variability amongst four isolates of R. *bataticola (M. phaseolina)* causing dry root rot of chickpea.

Isolate	Dry root rot incidence*	Incubation* period (days)	Pycnidia formation (days after sowing)
A-1	57.33 (49.23)	**18**	-
A-2	29.33 (32.62)	26	38
A-3	26.66 (30.89)	24	
A-4	39.99 (39.16)	22	35
SEm±	2.29		
CD (P=0.05)	6.14 *		

Mean of five replications (-)

Pycnidia absent

Figures in parentheses are angular transformed values

Table 12 : Dry root rot incidence and incubation period in different plant species caused due to *R. bataticola (M. phaseolina)*

Common name	**Scientific name**	Family	**Disease incidence*** (%)	**Incubation period (days)**
Black gram	*Vigna mungo (L.)*	Leguminosae	11.1 (19.22)	26
Chickpea	*Cicer arietinum (L.)*	Leguminosae	51.0 (51.10)	22
Cluster bean	*Cyamposis tetragonoloba* D.C.	Leguminosae	8.8 (17.05)	24
Cowpea	*Vigna unguiculate L.* wale.	Leguminosae	11.1 (19.22)	25
Groundnut	*Archis hypogaea L.*	Leguminosae	19.9 (26.33)	35
Lentil	*Lens esculenta* Monech (E. medit)	Leguminosae	22.2 (28.06)	34
Linseed	*Linum usitatissimum L.*	Linaceae	0.0 **(0.0)**	-
Methi	*Trigonella foenumgraecum L.*	Leguminosae	**11.1** **(18.18)**	29
Moth bean	*Vigna aconitifolia* (jacq.) Marchel	Leguminosae	24.4 (29.55)	24
Mung bean	*Vigna radiata (L.)* wilezek	Leguminosae	6.6 (14.89)	27
Mustard	*Brassica campestris L.*	Cruciferae	0.0 **(0.0)**	-
Pea	*Pisum sativum L.*	Leguminosae	8.88 (17.05)	28
Pearlmillet	*Pennisetum typhoids* (Burro. F.) stapf & Hubb.	Gramineae	0.0 **(0.0)**	-
Rajmash	*Phaseolus vulgaris L.*	Leguminosae	**31.1** (33.68)	21
Redgram	*Cajanus cajan* L. Mill. sp.	Leguminosae	17.7 (24.77)	38
Soybean	*Glycine max.* Merr.	Leguminosae	15.5 (23.10)	36
Wheat	*Triticum aestivum L.*	Gramineae	0.0 **(0.0)**	-
		N ti	1.19	
		CD (P=0.05)	5.73	

* Mean of three replications

-Figures in parentheses are angular transformed values

6. FACTORS AFFECTING THE PATHOGEN AND DISEASE DEVELOPMENT

6.1 EFFECT OF INOCULUM DOSES

Data depicted in Table 13 reveal that the incidence of root rot increased with the increase in dose of the inoculum. Disease incidence varied from 9.9 to 54. 99 per cent in different levels of inoculum. However, maximum disease incidence (54.99%) was obtained when plants were exposed to 12.5 per cent of (wow) inoculum in soil. A dose of 10 per cent

inoculum was statistically at par with 12.5 per cent dose, showing disease incidence of 53.33 per cent. On lower doses of inoculum beyond 10 per cent significantly lower disease incidence was recorded. Incubation period at different doses of inoculum varied from 19 to 36 days, the minimum being at 12.5 per cent. The period of incubation increased with the decrease of inoculum dose. (Table 13).

6.2 EFFECT OF TEMPERATURE

6.2.1 *In vitro*

The pathogen grew at a wide range of temperatures. However, the temperature of 30°C was recorded optimum showing maximum dry fungal biomass weight of 217.75 mg per 25 ml substrate. It was closely followed

by 35°C with 209.43 mg dry biomass of the fungus. Both the treatments (30 and 35°C) were statistically at par with each other and had abundant production (>40) of sclerotia. A progressive increase in dry fungal biomass was obtained with the increase in temperature from 20°C to 30°C.

Table 13: Effect of different inoculum levels on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina).*

Inoculum dose in soil w/w (%)	Dry root rot incidence* (%)	Incubation period (day)
2.5	9.99 (18.14)	36
5.0	19.99 (26.39)	32
7.5	28.33 (32.02)	32
10.0	53.33 (46.90)	19
12.5	54.99 (47.86)	21
SEm±	1.41	

* Mean of four replications

** Figures in parentheses are angular transformed values

CD (P=90.05) 4.21

However, a sharp decline in fungal growth as well as sclerotia formation was recorded at 40°C. Results showed that the optimum temperature for growth of R. *bataticola (M. phaseolina)* was 30-35°C (Table 14).

6.2.2 ***In vivo***

In vivo studies, effect of temperature on development of dry root rot was noted for two years 1996-97 and 1997-98. Results indicated that at 30°C maximum disease incidence was recorded during both the years, it was being to the tune of 67.5 and 70.0 per cent, respectively during 199697 and 1997-98. Disease incidence at this temperature was found significantly higher over all other treatments, followed by 35°C, exhibiting the root rot incidence to the extent of 52. 5 and 60.0 per cent in respective

years. Minimum disease incidence of 37.5 and 30.0 per cent in both the years was recorded at 20°C. Lowest incubation period of 18 days was observed at 30°C and the highest (35 days) was noted at 40°C. Maximum pathogen population was recorded 1.89 x 10^3 propagules g^{-1} soil at a temperature regime of 30°C and the minimum 1.62 x 10^3 propagules g -i soil at 40°C. (Table 15).

6.3 EFFECT OF SOIL MOISTURE

In vivo, effect of five soil moisture regimes on incidence of disease was studied. Irrigation was applied at an interval of 2, 3, 4, 5 and 6 days in separate treatments and observations on dry root rot incidence were recorded. An increasing trend of disease was observed with the increased

interval of irrigation during both the years of experimentation. Applying

Table 14 : Effect of different temperatures on development of fungal biomass and sclerotia formation of R. *bataticola (M. phaseolina)* on Richards' broth medium.

Temperature (°C)	Dry fungal biomass* (mg)	Sclerotia formation** (Nos)
20	152.37	17
25	190.37	29
30	217.75	45
35	209.43	42
40	103.06	19
SEm±	3.73	
CD (P=0.05)	11.24	

* Mean of four replications

** Few = (1-20 sclerotia);
Several = (21-40 sclerotia) and
Abundant = (> 40 sclerotia)

Table 15 : Effect of different temperatures on incidence of dry root rot disease induced by R. *bataticola (M. phaseolina).*

Temperatures (°C)	Per cent dry root rot incidence*		Incubation period	Pathogen Propagules g^{-1} soil
	1996-97	1997-98	(days)	
20	37.5 (37.3)	30.0 (32.2)	32	1.64×10^3
25	42.5 (40.3)	42.5 (40.3)	30	1.65×10^3
30	67.5 (55.6)	70.0 (58.9)	18	1.89×10^3
35	52.5 (46.7)	60.0 (50.9)	20	1.79×10^3
40	40.0 (38.9)	32.5 (34.4)	35	1.62×10^3
SEm±	2.75	2.77		
CD (P=0.05)	7.89	7.95		

* Mean of eight replications

** Figures in parentheses are angular transformed values

irrigation at 6-day interval, resulted maximum disease incidence of dry root rot in 1996-97 and 1997-98. The incidence were being 45.55 and 54.44 per cent in respective years, which were significantly higher over all other treatments. Minimum disease incidence was noted when watering in pots was done at an interval of 2 days, which was found statistically at par with 3-day interval of watering. As regards pathogen population, it was noted to be higher (1.92×10^3 propagules g^{-1} of soil) at lower moisture regime that is irrigation at 6-day interval and least (9.5×10^2 propagules g^{-1} of soil) at higher moisture regime when irrigation was applied at 2-day interval. Incubation period ranged between 20-35 days of inoculation (Table 16).

6.4 EFFECT OF TEMPERATURE AND SOIL MOISTURE INTERACTION ON DRY ROOT ROT

Combined effect of temperature and soil moisture levels was studied in pots, during 1996-97 and 1997-98. As regards temperature, the maximum mean disease incidence of 59.16 per cent was recorded at 30°C followed by 35°C having 45.8 per cent during 1996-97. In the present study the highest temperature of 40°C and lowest of 20°C exhibited significantly low incidence of root rot as compared to 30 and 35°C. Higher disease incidence of 58.0 per cent was noted at low soil moisture content (25 per cent mhc). The incidence of the disease decreased with the increase in moisture content of soil. It was being minimum of 19.0 per cent at 75 per cent moisture level in 1996-97 (Table 17 a).

Interaction between temperature and moisture was found to be non-significant. However, a combination of 30°C temperature with 25 per cent

Table 16 : Effect of different soil moisture regimes on dry root rot incidence of chickpea induced by *R. bataticola (M. phaseolina).*

Treatment (Irrigation interval, days)	Dry root rot incidence* (%)		Incubation period (days)	Pathogens Propagules g' soil
	1996-97	1997-98		
2	21.10 (27.20)	26.66 (30.95)	35	9.5×10^2
3	23.33 (28.81)	29.99 (33.14)	28	1.31×10^3
4	28.88 (32.39)	34.44 (36.20)	26	1.69×10^3
5	37.77 (37.87)	46.66 (43.39)	20	1.87×10^3
6	45.55 (42.41)	54.44 (47.54)	21	1.92×10^3
SEm±	1.28	1.29		
CD(P=0.05)	3.75	3.76		

* Mean of ' .suem replications

** Figures in parentheses are angular transformed values

soil moisture content (mhc) was found most congenial for development of the disease, exhibiting 82.5 per cent incidence. This was followed by interactions of 35°C temperature and 25 per cent soil moisture and 30°C and 50 per cent soil moisture (mhc) with the disease incidence of 65.0 and 65.0 per cent, respectively (Table 17a and Fig. 2).

During 1997-98, different combination of temperature and moisture had influenced the development of root rot in almost similar manner as that of during 1996-97. A temperature of 30°C along with 25 per cent soil moisture was found most suitable for causing maximum disease incidence of 85.0 per cent. This was followed by the treatments having temperature / moisture combination of 30°C / 50 per cent and 35°C / 25 per cent (Table 17b and Fig. 2).

6.5 EFFECT OF RELATIVE HUMIDITY (RH)

Growth of the pathogen ranged between 58.75 - 72.56 mm at 7 different RH levels on Richards' agar medium. Inoculated plates exposed to 50, 60, . 70, 80 and 90 per cent of RH had exhibited almost the same amount of fungal growth with no significant difference among them. However, the growths at 40 and 100 per cent RH were significantly poor over 50 and 60 per cent levels of RH (Table 18).

For sclerotia production, 60 per cent RH was found most conducive, followed by 50 and 70 per cent RH with sclerotia production of 42 (abundant), 32 and 29, respectively.

Table 17a : Effect of temperature and soil moisture interactions on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina)* during 1996-97.

Soil** moisture levels (%)	Mean dry root rot incidence (%)* Temperature ˚C					
	20	25	30	35	40	Mean
25	37.5 (37.5)	57.5 (49.4)	82.5 (68.4)	65.0 (53.9)	47.5 (43.5)	58.0 (50.54)
50	27.5 (31.3)	40.0 (39.0)	65.0 (54.0)	52.5 (46.4)	35.0 (36.0)	44.0 (41.34)
75	15.0 (19.9)	12.5 (16.6)	30.0 (32.9)	20.0 (24.8)	17.5 (21.5)	19.0 (23.14)
Mean	26.6 (29.5)	36.6 (35.0)	59.16 (51.7)	45.8 (41.7)	(33.66) 33.33	

Mean of eight replications

** Per cent moisture levels are based on mhc of the soil Figures in parentheses are angular transformed values

	SEm±	CD (P=0.05)
Temperature	1.95	5.47
Moisture	1.51	4.24
Temperature x moisture	NS	NS

Table 17b : Effect of temperature and soil moisture interactions on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina)* during 1997-98.

Soil** moisture levels (%)	Mean dry root rot incidence (%)* Temperature °C					
	20	**25**	**30**	**35**	**40**	**Mean**
25	35.0 (35.9)	52.5 (46.4)	85.0 (70.0)	67.5 (55.5)	42.5 (41.2)	56.5 (49.8)
50	25.0 (29.7)	35.0 (35.9)	*65.0* (54.0)	*47.5* (43.4)	30.0 (32.9)	40.5 (39.1)
75	12.5 (16.6)	10.0 (13.8)	32.5 (32.6)	17.5 (23.2)	15.0 (19.9)	(21.22) 17.5
Mean	24.1 (27.4)	32.5 (32.0)	60.8 (52.2)	44.1 (40.7)	(31.33) 29.1	

~` Mean of eight replications

** Per cent moisture levels are based on mhc of the soil Figures in parentheses are angular transformed values

	SEm±	CD (P=0.05)
Temperature	2.04	4.05
Moisture	1.58	4.44
Temperature x moisture	NS	NS

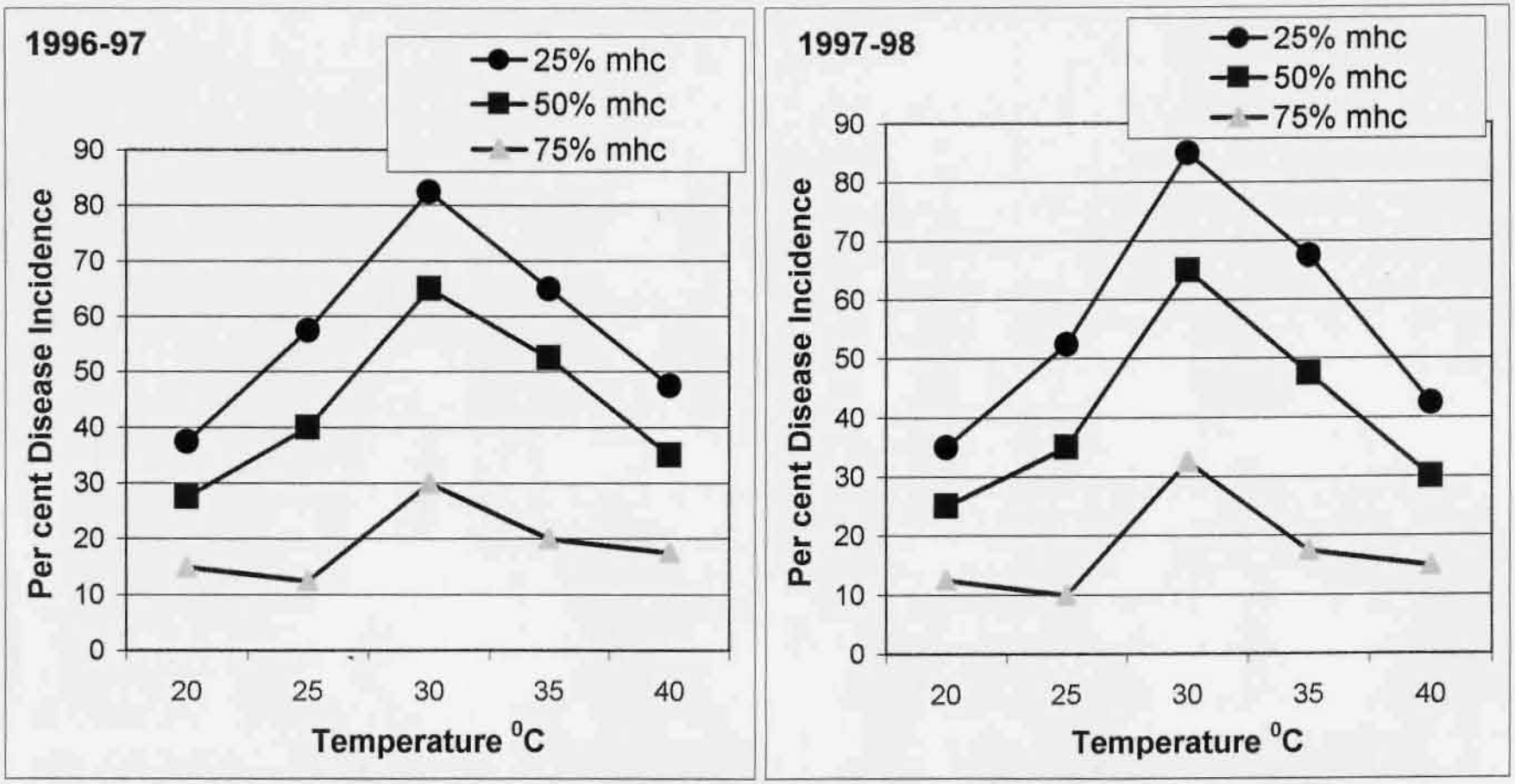

Fig. 2 : Effect of temperature and soil moisture interactions on dry root rot incidence of chickpea induced by *R. bataticola* (*M. phaseolina*) during 1996-97 and 1997-98.

Table 18 : Effect of different relative humidity (RH) levels on growth and sclerotia formation of *R. bataticola (M. phaseolina)* at 30±1°C

Relative humidity (RH)	Colony diameter* (mm)	Sclerotia formation* (Nos.)
40	58.75	15
50	70.25	32
60	72.56	42
70	68.87	29
80	67.12	16
90	67.37	19
100	64.00	18
SEm±	1.75	
CD (P=0.05)	5.15	

* Mean of four replications

Few = (1-20 sclerotia);

Several = (21-40 sclerotia) and

Abundant = (> 40 sclerotia)

6.6 EFFECT OF HYDROGEN ION CONCENTRATION (pH)

Irrigation water with five different pH was applied to chickpea plants at an interval of 6 days after sowing and incidence on dry root rot was noted. Disease incidence increased with the increase in the levels of pH of irrigation water, which continued up to the pH 8.0. Beyond this level, disease was found to be decreased. However, the maximum occurrence of disease was noted at pH 8.0. A similar trend for occurrence of disease was also recorded in respective years of experimentation. As regards pathogen propagules production, higher levels of pH (7.0 - 9.0) were found conducive showing more number of pathogen propagules as compared to the number of propagules produced at pH 5.0 and 6.0. The production of propagules at different pH levels ranged from 1.35 x 10^3 to 1.83 x 10^3 g ^{1} of soil (Table 19).

6.7 EFFECT OF LIGHT

6.7.1 *In vitro*

Of the five different light and darkness treatments, the pathogen R. *bataticola (M. phaseolina)* exposed for 24 h to continuous fluorescent light had exhibited maximum dry mycelial weight of 203.6 mg with abundant sclerotia formation and it was significantly superior oyer all other

treatments. Eighteen A exposure of continuous light and 6 h exposure to darkness ranked second resulting 169.8 mg dry mycelial weight with several sclerotia (32) formation. Sclerotia formation was also decreased

with the reducing exposure period to light. However, exposure to

Table 19 : Effect of pH of irrigation water on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina)*

pH of irrigation water	Per cent dry root rot incidence* (%)		Mean pathogen Propagules g-1 of soil
	1996-97	1997-98	
5.0	54.99 (47.87)	43.33 (41.14)	1.35 x 10^3
6.0	66.66 (54.76)	54.99 (47.88)	1.63 x 10^3
7.0	73.33 (58.97)	64.99 (53.71)	1.83 x 10^3
8.0	81.66 (64.70)	71.66 (57.93)	1.78 x 10^3
9.0	71.66 (57.93)	58.33 (49.82)	1.77 x 10^3
SEm±	1.69	1.92	
CD(P=102.05)	5.09	5.78	

* Mean of four replications

Figures in parentheses are angular transformed values

continuous darkness (24 h) had slightly improved the fungal growth aswell as sclerotia formation as compared to 6 h light and 18 h period of darkness. (Table 20). In general, growth of the pathogen was favoured on exposure to continuous light for 24 h.

6.7.2 ***In vivo***

Effect of five durations of light and darkness period was observed on dry root rot incidence. Though the effect of light was not apparent on development of dry root rot, yet the disease incidence was slightly favoured when the inoculated plants were exposed to long duration of light. Minimum incubation period of 24 'days was recorded at the exposure of 24 h light. The incubation period in other treatments was almost the same
varying from 24 to 26 days. As regards pathogen population, it was slightly higher in the pots exposed to 24 h light. (Table 21).

6.8 EFFECT OF HOST NUTRIENTS 6.8.1a

Effect of macro nutrients (1996-97)

Four levels each of nitrogen and phosphorus were tried in 16 different combinations. Data clearly indicates that increasing levels of nitrogen increased the mean disease incidence successively. Minimum disease incidence of 40.82 per cent was recorded when no (zero) nitrogen was applied to the plants in the years 1996-97. Whereas, the incidence of the disease was maximum (66.66%) when chickpea plants were supplied with the highest dose of nitrogen, @ 25 kg ha $^{-1}$ (Table 22a).

Table 20 : Effect of duration of light on dry fungal biomass and sclerotia formation of *R. bataticola (M. phaseolina)* at 30±1˚C

Duration of light (Light + Dark period)	Dry fungal biomass* weight (mg)	Sclerotia formation** (Nos.)
24 h + 0 h	203.60	49
18 h + 6 h	169.80	32
12h+12h	141.05	15
6 h + 18h	138.39	11
0h +24h	156.50	34
SEm±	2.49	
CD (P=0.05)	7.36	

* Mean of four replications

Few = (1-20 sclerotia);

Several = (21-40 sclerotia) and

Abundant = (> 40 sclerotia)

Table 21 : Effect of duration of light on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina)*

Duration of light	Dry root rot incidence (%)		Incubation period (days)	Mean pathogen propagules g" soil
Light +Dark	1996-97	1997-98		
24 h + 0 h	50.0 (45.0)	45.0 (42.1)	24	1.78 x 10^3
18 h + 6 h	*47.5* (43.5)	*42.5* (40.5)	26	1.75 x 10^3
12h+ 12h	47.5 (43.5)	45.0 (42.1)	25	1.74 x 10^3
6h+ 18h	45.0 (42.1)	42.5 (40.5)	26	1.74 x 10^3
0 h + 24 h	45.0 (42.1)	40.0 (39.0)	26	1.73 x 10^3

SEm± NS CD (P=0.05) NS *

Mean of eight replications

A reverse trend was noted in case of phosphorus. Incidence of dry root rot was decreased with the increasing levels of phosphorus. Minimum root rot incidence of 43.74 per cent was noted when the highest dose of phosphorus, 50 kg ha^{-1} was applied during 1996-97.

Interactions between nitrogen and phosphorus levels were found to be non-significant. However, the highest dose of phosphorus (50 kg ha^{-1}) with zero application of nitrogen had exhibited the lowest disease incidence of 34.99 per cent (Table 22a and Fig. 3).

6.8.1b Effect of macronutrients (1997-98)

Data depicted in Table 22b reveal that increasing levels of nitrogen increased the incidence of root rot significantly. The minimum incidence of 47.49 per cent was observed at zero application of nitrogen, which increased, progressively with the increasing levels of the nitrogen.

In contrast, increasing levels of phosphorus reduced the disease incidence significantly. The minimum disease incidence of 51.66 per cent was noted with the highest dose of phosphorus and vice-versa. Interaction between nitrogen and phosphorus were not found to be significant. However, application of 50 kg phosphorus ha^{-1} with zero level of nitrogen had reduced the disease I in cidence by 41.66 per cent as against 79.98 per cent -- -–ti. + plants .., ->„ supplied with 25 kg N and 0 level of P per hectare (Table 22b).

6.8.2 Effect of micronutrients

Soil was amended with seven micronutrients separately @ 10 mg kg^{1} of soil and incidence of dry root rot was noted. It appears from the

Table 22a : Effect of nitrogen and phosphorus levels on dry root rot incidence of chickpea induced by R *bataticola* *(M. phaseolina)* during 1996-97.

Nitrogen levels (kg ha^{-1})	Mean dry root rot incidence* (%)				
	Phosphorus levels (kg ha)				
	P_o	P_{30}	P40	P50	Mean
	46.66 (43.01)	41.66 (40.14)	39.99 (39.18)	34.99 (36.18)	40.82 (39.62)
N_{15}	44.99 (42.09)	43.33 (41.14)	39.99 (39.10)	36.66 (37.02)	41.24 (39.83)
N_{20}	54.99 (47.89)	48.32 (44.01)	43.33 (41.14)	41.66 (40.14)	47.07 (43.25)
N_{25}	73.33 (58.98)	68.32 (55.74)	63.33 (52.73)	61.66 (51.75)	66.66 **(54.80)**
Mean	54.99 (49.99)	50.40 (45.25)	46.66 (43.03)	43.74 (41.27)	

* Mean of four replications

- Figures in parentheses are angular transformed values

	SEm±	CD (P=0.05)
Nitrogen	0.95	2.71
Phosphorus	0.95	2.71
Nitrogen x Phosphorus	NS	NS

Table 22b : Effect of nitrogen and phosphorus levels on dry root rot incidence of chickpea induced by R. *bataticola (M. phaseolina)* during 1997-98.

Nitrogen levels (kg ha')	Mean dry root rot incidence* (%)				
	Phosphorus levels (kg ha')				
	P_o	P30	P40	P50	Mean
N_o	53.33 (46.90)	49.99 (44.97)	44.99 (42.09)	41.66 (40.18)	47.49 (43.53)
N15	56.66 (48.83)	53.33 (46.90)	46.66 (43.05)	44.99 (42.10)	50.41 (45.22)
N20	66.66 (54.76)	61.66 (51.75)	54.99 (47.87)	51.66 (45.96)	58.74 (50.08)
N_{25}	79.98 (63.58)	76.66 (61.16)	69.99 (56.79)	68.33 **(55.81)**	73.74 (59.33)
Mean	64.15 (53.51)	60.41 (51.19)	54.15 **(47.45)**	51.66 (46.01)	

* Mean of four replications
Figures in parentheses are angular transformed values

	SEm±	CD (P=0.05)
Nitrogen	0.84	2.38
Phosphorus	0.84	2.38
Nitrogen x Phosphorus	NS	NS

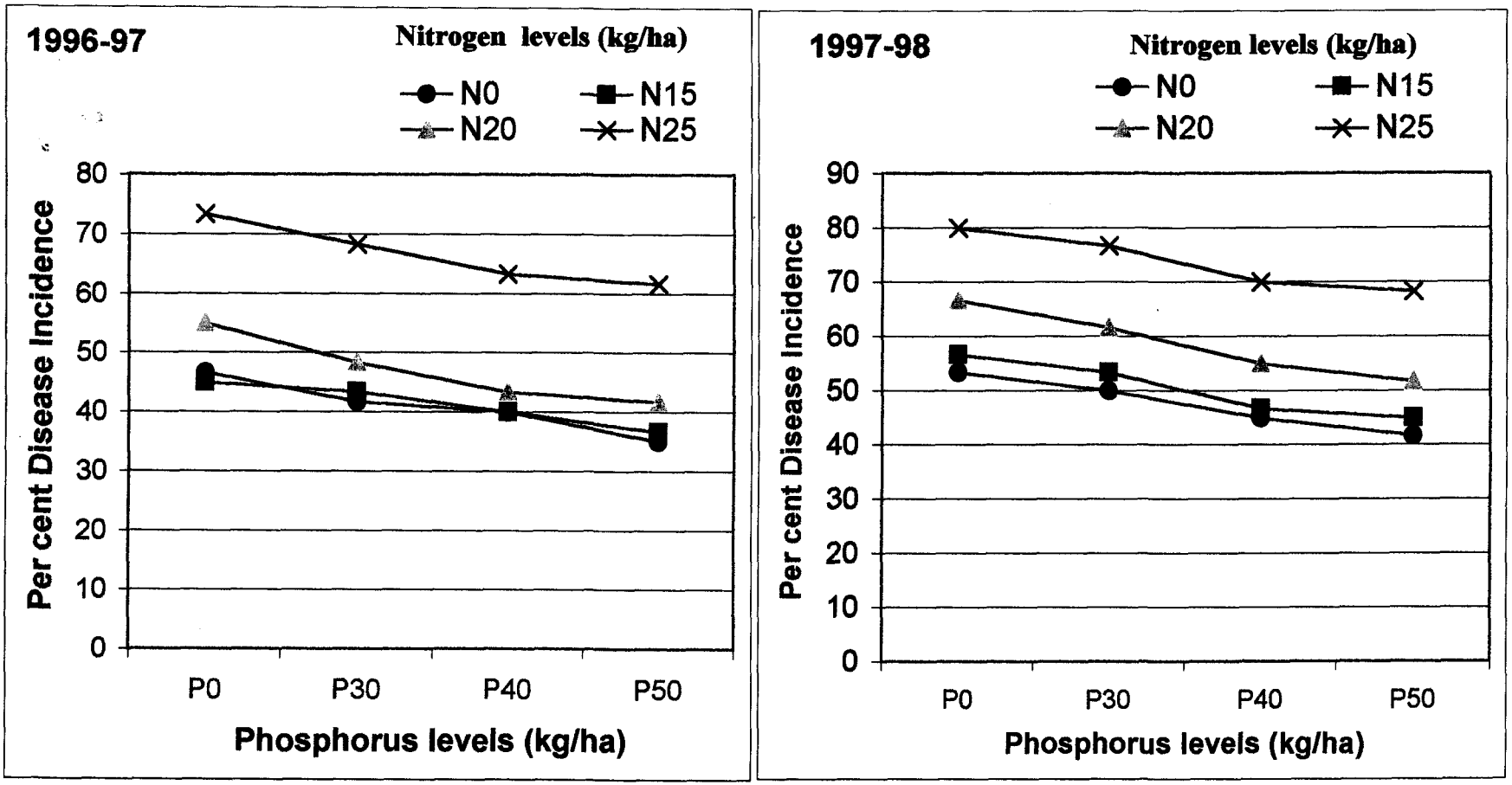

Fig. 3 : Effect of nitrogen and phosphorus on dry root rot incidence of chickpea induced by *R. bataticola* (*M. phaseolina*) during 1996-97 and 1997-98.

results that application of calcium and zinc reduced the dry root rot incidence significantly over check. Calcium was found to be most effective in minimizing the disease with incidence of 40.0 and 35.0 per cent in the year 1996-97 and 1997-98, respectively. This treatment was closely followed by zinc and found statistically at par with it. Apart from calcium and zinc, none of the micronutrients tested was found effective in minimizing the disease during both the years of experimentation. (Table 23). On determining the pathogen population, the lowest population was noted (1.46 x 10^3 propagules g' of soil) when soil was amended with calcium, followed by zinc having pathogen population of 1.56 x 10^3 propagules g' of soil. The highest population of 1.90 x 10^3 propagules was observed when the soil was amended with nickel. Minimum incubation period of 22 days was noted when soil was amended with calcium and zinc (Table 23 and Fig. 4).

6.9 INTERACTION OF *R. BATATICOLA* WITH OTHER SOIL ORGANISMS.

Incidence of root rot disease was found to be enhanced when the disease causing fungus *(R. bataticola)* was inoculated in combinations with *M. incognita,* and with *M. incognita* + *F. oxysporum* as compared with *R. bataticola* (as check) alone. In former treatment combinations disease incidence was being 62.66 and 65.33 per cent as against 53.33 per cent in *R. bataticola* (in check) during 1996-97. A similar trend with regards to effect of these combination treatments on disease incidence was observed during 1997-98. Integration of either *Rhizobium* or *F. oxysporum* alone with the root rot pathogen did not show any positive or negative effect on

Table 23 : Effect of micronutrient on dry root rot incidence of chickpea induced by R bataticola (M. phaseolina)

Micronutrients	Dose mg kg^{-1} soil	Dry root rot incidence* (%)		Incubation period (days)	Mean pathogen propagules g^{-1} soil
		1996-97	1997-98		
Zn	10	45.0 (42.4)	37.5 (37.64)	22	1.56×10^3
Cu	10	57.5 (49.0)	52.5 (46.44)	26	1.68×10^3
Co	10	60.0 (50.9)	55.0 (47.88)	25	1.70×10^3
Mn	10	57.5 (49.0)	52.5 (46.44)	26	1.66×10^3
Ca	10	40.0 (39.0)	35.0 (36.06)	22	1.46×10^3
Fe	10	55.0 (47.8)	50.0 (45.0)	25	1.60×10^3
Ni	10	62.5 (52.49)	60.0 (50.91)	26	1.90×10
Control (No micronutrient		60.0 (50.91)	57.5 (49.47)	23	1.78×10^3
SEm±		2.66	2.14		
CD (P=0.05)		7.54	6.05		

* Mean of eight replications

- Figures in parentheses are angular transformed values

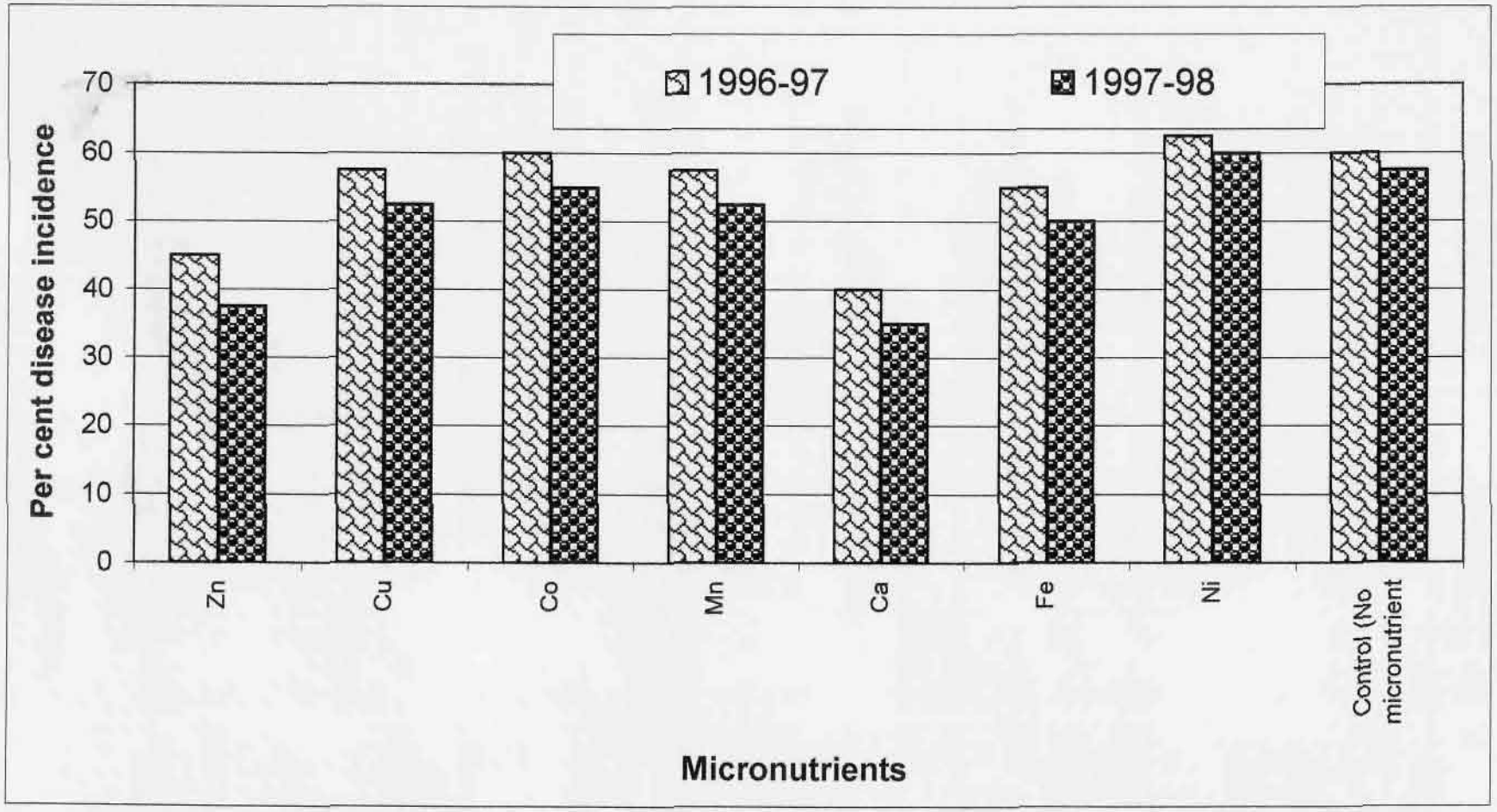

Fig.4 : Effect of micronutrient on dry root rot incidence of chickpea induced by *R. bataticola* (*M. phaseolina*)

disease development. The pathogen population determined after about 75 days of treatments showed that it was almost uniform in different treatments ranging from 1.43 x 10^3 to 1.47 x 10^3 propagules g' soil (Table 24)

7. MANAGEMENT OF DRY ROOT ROT 7.1 THROUGH CHEMICALS 7.1.1 Fungicidal seed treatments in pots

All the chemicals tested were found significantly superior over control in reducing the disease during both the years (1996-97 and 199798) of testing. However, seed treatment with carbendazim @ 1 g kg' seed was found most effective exhibiting the lowest disease incidence of 16.66 and 13.33 per cent in 1996-97 and 1997-98, respectively, This was closely followed by thiophanate methyl and TMTD with disease percentage of 19.99 and 23.33 in 1996-97; and 18.33 and 21.66 in 1997-98. Both of them were statistically at par in efficacy with that of the best treatment, carbendazim. Carboxin, phenyl pyrrole and chlorothalonil, were comparatively less effective in reducing the disease but significantly superior over check. As regards pathogen population, it was minimum, 5.3 x 10^2 propagules g ^{l} of soil when seeds were treated with carbendazim as against 1.34 x 10^3 propagules in control (without seed treatment) (Table 25).

7.1.2 Fungicidal seed treatments in field

All the chemical treatments reduced the root rot incidence significantly over untreated check during both the years of testing, in field.

Table 24 : Interaction of dry root rot pathogen R. *bataticola (M. phaseolina)* with other soil organisms associated with chickpea root system

Dry root rot pathogen + other organisms	Dry root rot incidence* (%).		Incubation period (days)	Mean pathogen propagules g^{-1} of soil
	1996-97	1997-98		
R. bataticola + Fusarium oxysporum	*54.66 (47.67)*	*41.33 (39.89)*	*27*	*1.47×10^3*
R. bataticola + Rhizobium sp.	*54.66 (47.69)*	*41.33 (39.87)*	*28*	*1.43×10^3*
R. bataticola + Meloidogyne incognita	*62.66 (52.34)*	*51.99 (46.22)*	*20*	*1.46×10^3*
R. bataticola + F. oxysporum + Meloidogyne incognita	*65.33 (53.96)*	*53.33 (46.89)*	*18*	*1.46×10^3*
R. bataticola (alone)	*53.33 (46.89)*	*39.99 (39.09)*	*22*	*1.47×10^3*
SEm± *1.54*	*1.97*	*CD(P=0.05) 4.55*	*5.79*	

* Mean of five replications

- Figures in parentheses are angular transformed values

Table 25 : Effect of fungicidal seed treatments on development of dry root rot on chickpea caused by R. *bataticola (M. phaseolina)* in pot

Fungicidal treatment	Dose g/kg seed	Dry root rot incidence* (%)		Propagules g ^{1} of soil
		1996-97	1997-98	
Carbendazim	1.0	16.66 (23.98)	13.33 (21.06)	5.3×10^2
TMTD	2.0	23.33 (28.44)	21.66 (27.51)	7.5×10^2
Carboxin	1.0	26.66 (30.97)	24.99 (29.85)	8.0×10^2
Phenylpyrrole	1.0	33.33 (35.19)	28.33 (32.02)	9.3×10^2
Thiophanate methyl	1.0	19.99 (26.39)	18.33 (25.27)	7.3×10^2
Chlorothalonil	1.0	34.99 (36.18)	29.99 (33.02)	8.8×10^2
Control (without seed treatment)		46.66 (43.05)	56.66 (48.85)	1.34×10^3
SEm± 2.16 2.23 CD(P=0.05)		6.34	6.57 *	

Mean of four replications

Figures in parentheses are angular transformed values

In different treatments disease incidence varied from 20.7 to 34.2 and 17.3 to 34. 4 as against 41.1 and 38.5 per cent in check in 1996-97 and 1997-98, respectively. However, seed treatment with carbendazim at 1 g/kg seed provided the minimum incidence (20.7 and 17.3 per cent) of the disease, closely followed by thiophanate-methyl and TMTD during both the years (Plate 5).

As regards grain yield, carbendazim provided highest grain yield among all the treatments in both the years. It was significantly higher over all other treatments including check during both the years of testing. Thiophanate-methyl, TMTDand carboxin were next to carbendazim for increase in yield. However, chlorothalonil and phenyl pyrrole were proved poorer for increasing the yield. The pathogen population in different chemical treatments ranged between 1.20 x 10^3 - 1.60 x 10^3 as against 2.1 x 10^3 mycelial propagules g^{-1} of soil in check, the lowest was being in carbendazim (Table 26).

7.2 THROUGH CULTURAL PRACTICES 7.2.1

Effect of date of sowing

Data on date of sowing experiments conducted during 1996-97 and 1997-98 indicate that the occurrence of the disease increased progressively as the sowing of chickpea was delayed. The incidence of dry root rot was lowest 22.66 and 27. 99 per cent in first date of sowing (14th October) while the highest was 46.66 and 55.99 per cent in the last sowing (16`^{h} December) during both the year of experimentation. The fungal population in soil was also noted to be minimum (1.3 x 103 $^{g-1}$ soil) in the early

Plate 5 : (1) A view of dry root infected chickpea crop
(2) A view of healthy chickpea crop

Table 26 : Effect of fungicidal seed treatments on development of dry root rot incidence on chickpea induced by R. *bataticola (M. phaseolina)* in field conditions.

Seed treatment (Chemical -" O- •,-ft)	Dose g kg -ı seed	Dry root rot incidence* (%)		Grain yield* (Kg ha^{-1})		Pathogen propagules g"^{1} soil
		1996-97	1997-98	1996-97	1997-98	
Carbendazim	1.0	20.70 (26.97)	17.31 (24.49)	1274	1324	1.20 x 10^{3}
TMTD	2.0	28.70 (32.46)	25.35 (30.19)	1116	1183	1.58 x 10^{3}
Carboxin	1.0	32.14 (34.49)	28.56 (32.26)	1025	1015	1.49 x 10^{3}
Phenylpyrrole	1.0	34.10 (35.69)	33.03 (35.04)	968	973	1.59 x 10^{3}
Thiophanate methyl	1.0	24.0 (29.34)	21.24 (27.51)	1175	1186	1.50 x 10^{3}
Chlorothalonil	1.0	34.28 (35.0)	34.46 (35.91)	976	974	1.60 x 10^{3}
Control (No tr$_{e}$atment	-	41.11 (39.84)	38.56 (38.36)	943	934	2.10 x 10^{3}
SEm±		0.95	0.83	10.82	10.72	
CD (P=0.05)		2.81	2.47	32.10	31.81	
Cv		5.68		5.20	4.81	

4.74 * Mean of four replications

planting and maximum (1.7 x 10^3 g'' soil) in late planting of crop, however population between planting dates of 28`h October to 25th November were almost the same, but higher as compared to 14 `h and 21 St October plantings (Table 27 and Fig. 5).

Planting dates on 11 `h November, 18th November and 25th November were statistically at par with each other for development of the disease. Also, same trend of disease was observed in further sowings done between 2''d- 16th December (Table 27).

7.2.2 Effect of soil amendments

Soil was amended with four crop straws, two oil cakes and farm yard manure. It is evident from the data presented in Table 28 that all the amendments provided significant reduction in disease incidence except chickpea and mung bean straws. Mustard cake amendment was found most effective in reducing the disease during both the years of testing. The incidence was noted to be 33.33 and 38.33 per cent as compared to 56.66 and 59.99 per cent in control (unamended soil) during 1996-97 and 199798, respectively. This treatment was followed by wheat straw, *bajra* straw and FYM, which were statistically at par with each other in efficacy (Table 28). Pathogen population was recorded to be minimum (1.1o x 103 propagules g'' soil) when soil was amended with mustard cake followed by wheat straw with population of 1.30x 10^3 propagules g'' of soil.

7.3 THROUGH BIOAGENTS

Four antagonistic bioagents were tested as seed inoculants in pots for their efficacy against dry root rot. All the bioagents were found

Table 27 : Effect of date of sowing on development of dry root rot on chickpea induced by R. *bataticola (M. phaseolina)*

Date of sowing	Dry root rot incidence*(%)		Mean propagules $_g$" soil
	1996-97	1997-98	
14`h October	22.66 (28.16)	27.99 (31.88)	1.30 x 10^3
21" October	23.99 (28.96)	29.33 (32.43)	1.34 x 10^3
28`h October	25.33 (29.89)	29.32 (32.72)	1.46 x 10^3
4`h November	25.32 (30.15)	30.66 (33.56)	1.48 x 10^3
11 `h November	35.99 (36.83)	34.66 (36.03)	1.50 x 10^3
18`h November	35.99 (36.83)	35.99 (36.83)	1.53 x 10^3
25`h November	38.66 (38.24)	37.33 (37.63)	1.50 x 10^3
2"d December	43.99 (41.52)	53.33 (47.08)	1.57 x 10^3
9[1h] December	46.66 (43.03)	54.66 (47.67)	1.67 x 10^3
16`h December	46.66 (43.05)	55.99 (48.53)	1.70 x 10^3
SEm±	1.12	1.54	
CD(P=0.05)	3.21	4.40	

* Mean of five replications

- Figures in parentheses are angular transformed values

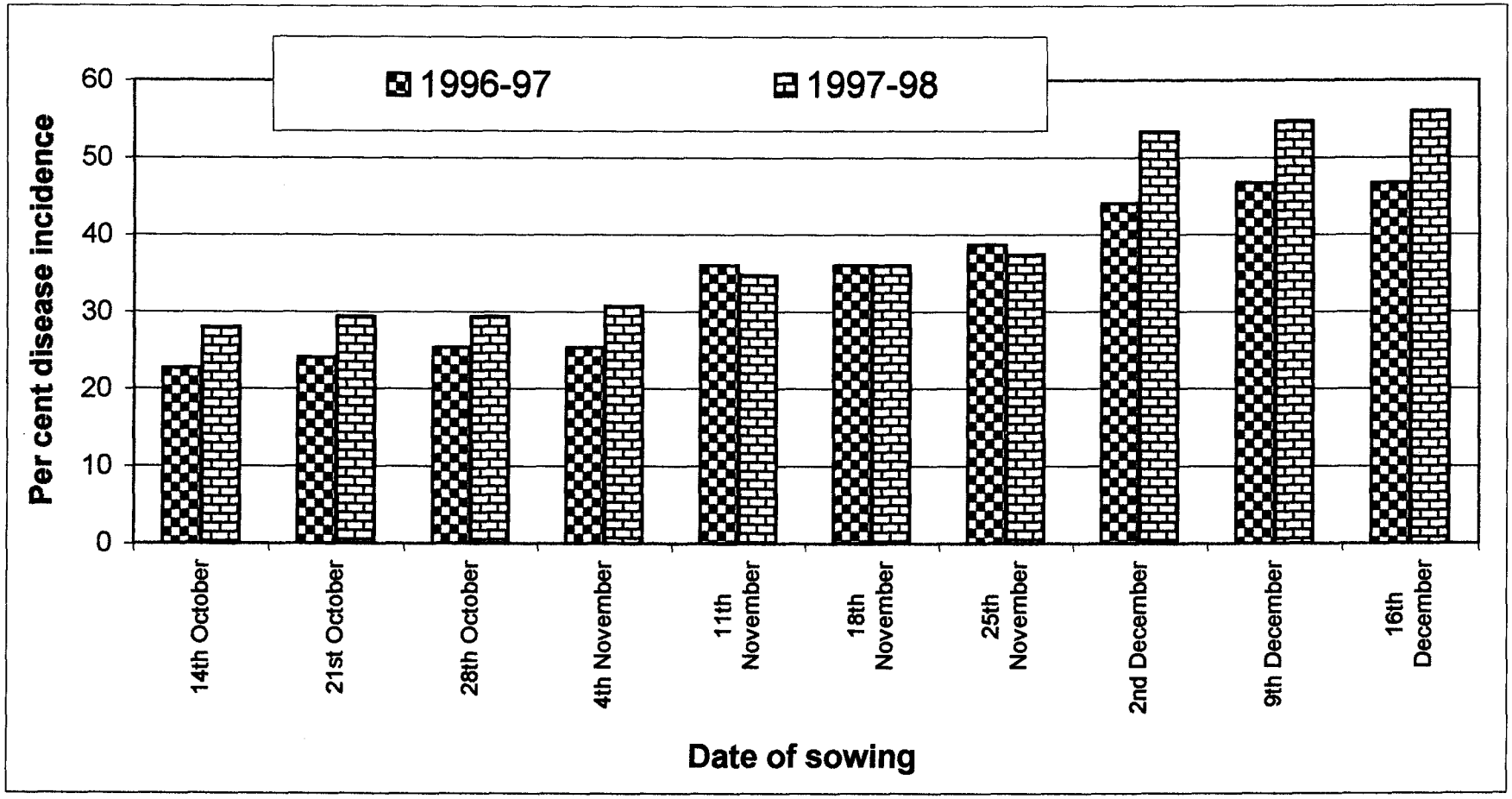

Fig. 5 : Effect of date of sowing on development on dry root rot of chickpea induced by *R. bataticola* (*M. phaseolina*)

Table 28 : Effect of different soil amendments on development of dry root rot of chickpea caused by *R. bataticola (M. phaseolina)*

Treatment	Dose g kg^{-1} soil	Dry root rot incidence*(%)		Mean propagules g^{-1} soil
		1996-97	1997-98	
Wheat straw	20	41.66 (40.14)	43.33 (41.49)	1.30×10^3
Bajra straw	20	43.33 (41.14)	44.99 (42.09)	1.40×10^3
Mung bean straw	20	53.33 (46.90)	56.66 (48.83)	1.54×10^3
Chickpea straw	20	54.99 (47.86)	58.33 (49.80)	1.54×10^3
Mustard cake	5	33.33 (35.19)	38.33 (39.18)	1.10×10^3
Groundnut cake	5	48.32 (44.01)	49.99 (44.97)	1.49×10^3
FYM	20	43.33 (41.14)	44.99 (42.05)	1.42×10^3
Control		56.66 (48.83)	59.99 (50.78)	1.60×10^3
SEm±		1.33	1.16	
CD(P=0.05)		3.90	3.40 *	

Mean of four replications

Figures in parentheses are angular transformed values

significantly superior in minimizing the disease over control. *Trichoderma viride* was found most effective, exhibiting the lowest disease incidence of 24.44 and *26.66* per cent as against 52.22 and 55.51 per cent in check during 1996-97 and 1997-98, respectively. This was closely followed by T. *harzianum* attaining root rot incidence of 32.21 and 33.33 per cent in both the years of testing. *T harzianum* was statistically at par with that of *T. viride,* in efficacy. Pathogen population was the least in *T. viride,* (1.16 x 10^3 propagules g^{-1} soil) followed by *T. harzianum* having population of *1.32 x* 10^3 propagules g^{-1} soil (Table 29).

7.4 THROUGH HOST RESISTANCE

On the basis of per cent dry root rot incidence, the chickpea genotypes were categorised as completely free, resistant, moderately resistant, susceptible and highly susceptible. Evaluation of 100 lines of chickpea under artificial inoculation condition revealed that none of the entries was found completely free from the disease. However, 10 entries viz., FG-348, BG-1043, FG-44, GPF-2, KGB-1175, Phule G-5, RSG-915, RSG-916, RSG-899 and RSG-803 were categorised as resistant showing disease incidence of 1-10 per cent, while 23 entries showed moderately resistant reaction (10.1 - 20%). Rest of the genotypes exhibited susceptible (20.1 - 30%) to highly susceptible (above 30%) reactions to the pathogen (Table 30).

Table 29 : Effect of antagonistic bioagents applied through seeds on development of dry root rot of chickpea caused by R. *bataticola (M. phaseolina)*

Treatment g / kg	Dose	Dry root rot incidence*		Mean pathogen
	seed	(%)		propagules
		1996-97	1997-98	g^{-1} of soil
Trichoderma viride	4	24.44 (29.34)	26.66 (30.75)	1.16×10^3
Trichoderma harzianum	4	32.21 (34.57)	33.33 (35.06)	1.32×10^3
Gliocladium virens	0.5	37.77 (37.87)	34.44 (35.79)	1.42×10^3
Bacillus subtilis	6	39.99 (38.19)	42.21 (40.48)	1.48×10^3
Control (without treatment)	-	52.22 (46.36)	55.51 (48.20)	1.54×10^3
SEm±		1.71	2.21	
CD(P=0.05)		5.0	6.44	

* Mean of six replications

Figures in parentheses are angular transformed values

Table 30: Screening of chickpea genotypes against dry root rot incited by *R. bataticola (M. phaseolina).*

Category	Type of genotypes	Name of genotypes
Completely free	-	None
Resistant (1-10%)	Desi	FG 348, BG-1043, FG-44, GPF-2
	Bold	KGB-1175, Phule G-5
	State	RSG-915, RSG-916,RSG-899 and RSG-803
Moderately resistant (10.1-20%)	Desi	GL-93014, KW-83, PBG-5, RSG-585, SAKI-9516, GNG-666, BG-1037, GCP-101, H 91-90, RSG-44
	Bold	WCG-3, Phule G-89204, BG-362, KW-104
	Kabuli	BG-227, L-550, RSG-628, KBK-12, GNG-1106
	State	RSG-859, RSG-860, RSG-861, RSG-807
Susceptible (20.1-30%)	Desi	GL-94019, GL-94023, GL-94057, GL 93011, PMG-1,GNG-97-8, Phule G-41, WCG-10, GCP-102, FG-22, BGD-82.
	Bold	PMG-12, Phule G-92004, BGD-86, BGD-87, BG-256
	Kabuli	BGD-80, BGD-81, KBK-12, GNG-1107, KBK-1, KBK-13
	State	RSG-854, RSG-855, RSG-858, RSG-862, RSG-863
Highly susceptible Above 30%)	Desi	IPC-9501, SAKI-9512, GCP-104, GCP 106, GL-94008, KPB-143-2, WCG-11, H 92-93, IG-412, KW-53, H 82-2, BG-1047, BGD-75, PBG-1, PBG-97-4, ICC-4951, KW-79, GL-94039
	Bold	GNG-1149, BG-390, BG-391, GL-94041, GL-94056, Phule G-920028, IPC 94-18, IPC 94-136, IPC 93-5, GNG-469, BGD-72
	Kabuli	BG-248, BG-267, BG-1050, BG-1053, CSG-9012, CSG-9027, HK-9294, BGD-80
	State	RSG-856, RSG-857, RSG-624

Dry root rot incited by *Rhizoctonia bataticola* (Taub.) Butler [*Macrophomina phaseolina* (Tassi.) Goid.] is one of the important diseases of chickpea causing considerable losses in Rajasthan. The major chickpea growing districts of Rajasthan viz., Jaipur, Sikar, Jhunjhunu, Bhilwara, Kota, Sriganganagar, Alwar and Tonk were surveyed during the year 199697 and 1997-98 for the occurrence of dry root rot. It was observed on both normal sown and late sown crops of chickpea but the in- da.tcewas higher on the late sown crop. This might be due to exposure of the crop to higher temperatures. Singh and Mehrotra (1982) mentioned that dry root rot caused by *R. bataticola is* a serious disease whenever the crop is exposed to temperatures > 30°C. In the present study, it was also observed that the crop grown under rainfed conditions at Srimadhopur, Neemkathana, Jhajpur, Khadia and Todda attained higher disease incidence as compared to the crop grown under irrigated conditions. Kotasthane *et al.* (1979) reported that the incidence of root rot was more in rainfed crop. Taya *et. al.* (1988) in their studies reported that low soil moisture was conducive to dry root rot of chickpea. Husain and Ghaffar (1995) also reported that colonization of *M phaseolina* on chickpea roots was higher when subjected to moisture stress.

A direct correlation was observed in disease incidence and reduction in yield. The grain yield of chickpea where the crop was protected with seed treatment of carbendazim plus TMTD was 701 and 670 kg ha $^{-1}$ in the year 1996-97 and 1997-98, respectively as compared to the yield of 310 kg and 289 kg ha^{-1} from unprotected plants in respective years. In

some cases pods were formed in diseased plants but diminutive. These observations clearly indicate the impact of disease on grain yield as also confirm the earlier reports emphasizing the serious losses in chickpea caused by dry root rot (Quaiser Ahmad and Abu Mohammad 1986). In the present study, loss in grain weight was 60.90 per cent at flowering stage

and 47.27 per cent at podding stage. Per cent reduction in 1000-grain weight was also recorded to the tume of 36.25 and 22.93 per cent when disease occurred at flowering and podding stage, respectively of the crop. Loss in 1000 *r9rw* weight due to the disease implies that seed quality was also affected adversely. What constituent(s) of the seed was affected by the disease need to be investigated.

Richards' medium was found to be significantly superior and best suited among all media in the present investigations for growth and sclerotial formation of the pathogen. This observation is in conformity with the earlier findings on media study of *M. phaseolina* reported by Shanmugam and Govindaswamy (1973) and Mishra and Sinha (1982).

In the present study, morphological and cultural variations existed among the four isolates (A-1, A-2, A-3 and A-4) of R. *bataticola (M. phaseolina)* when grown onto Richards' medium. All the isolates differ from each other in most of the morphological characters such as shape and colour of the colony, mycelial cells etc. However, A-1, A-2 and A-3 isolates had produced oval shaped sclerotia and differed from A-4, which produced spherical ones. In A-4 isolate, size of the sclerotia was also larger than A-1, A-2 and A-3. These sclerotia were found in different sizes and

smaller than 120 µm. Based on sclerotial diameter, all the four isolates fell in to Heigh's `C' group (Heigh, 1930). Various workers (Dhingra and Sinclair, 1973; Anil Kumar and Sastry, 1980; Gupta and Kolte, 1982; Byadgi and Hegde, 1985 recorded variation in size and shape of sclerotia of different isolates. For growth, A-1 and A-4 which produced higher growth were distinct from A-2 and A-3. Hooda and Grover (1982) reported isolates of *Rhizoctonia* on mung bean differed in mycelial dry weight as well as sclerotial production. Least growth was noted in isolates from mung bean stem, mung bean pod whereas three ming bean leaf isolates

and mung bean seed isolate showed significantly higher growth than others. No correlation was observed in shape of mycelial cell and sclerotia and pycnidia formation. The isolate A-4 and A-1 having barrel shaped mycelial cell but only isolate A-4 could produce pycnidia was identified as *M. phaseolina,* while remaining as R. *bataticola.* Further, formation of pycnidia did not have any relationship with virulence of the isolate. Isolate A-1 which was found best in mycelial growth and produced abundant

number of sclerotia on Richards' agar and broth media was found most virulent but failed to produce pycnidia on Richards' host extract culture medium. On the other hand, the isolate A-4 which was second best in mycelial growth with several sclerotia formation ranked second in virulence. Ratnoo *et al.* (1997) also reported variation in virulence of two isolates of *M phaseolina* on cowpea. Variation in virulence of isolates of

M. phaseolina on black gram and green gram was reported by Prameela Devi and Singh (1998).

followed by 52.5 and 60.0% incidence at 35°C. A reduction in incubation period was also noted at 30 and 35°C. Mayer *et al.* (1974) observed that seedling blight in soybean *(M. phaseolina)* was highest h at 30 and 35°C, while least infection occurred at 20 and 25°C. Ratnoo *et al.* (199 Q mentioned that ashy grey stem blight of cowpea was most favoured by high temperature regimes of 25-40°C. Uppal (1934) found that soil temperature of 30-34°C was most favourable for *M phaseolina* to invade cotton plants while in case of sorghum seedling blight, 35.5°C was the optimum. Maximum disease incidence of dry root rot in chickpea at 30°C may be attributed to the highest survival of the pathogen at this temperature as evident by the data on pathogen population g'" of soil in this study.

Study conducted on the effect of relative humidity(RH) reveals that maximum growth of *R. bataticola (M. phaseolina)* and sclerotia formation occurred at 60 per cent RH *in vitro.* Besides, soil moisture plays an important role in the development of soil borne diseases, for dry root rot in particular. In the present investigation, comparatively low soil moisture created by irrigating the potted inoculated plants at an interval of 6 days showed maximum incidence of root rot together with the highest pathogen propagules g' soil. Root rot incidence was significantly reduced with the increase in soil moisture. Chandra *et al.* (1980) also observed that survival of *R. bataticola* was adversely affected at high moisture. Gaffar and Erwin (1969) concluded that water stress prior to inoculation produced severe symptoms in cotton *by M phaseoli,* considering as one of the predisposing

survey, it was also observed that crop cultivated under rainfed conditions, the incidence of dry root rot was higher than irrigated crop. Singh and Mehrotra (1982) also reported that percentage of infection due to *R. bataticola* was much higher at 25 per cent moisture holding capacity (mhc) of the soil than at 50 and 75 per cent mhc. Rao and Mukherjee(1972) have also noted that less moisture favoured luxuriant growth of R. *bataticola* and hence it caused more damage to crops under moisture stress conditions. Low soil moisture was congenial for high incidence of the disease as this situation has been most favourable for survival of the pathogen too, in the present study.

Interactions between soil moisture and temperatures were non significant with regard to development of the disease. However, at a soil moisture of 25 per cent and 30°C temperature, maximum incidence of dry root rot was recorded, followed by at 50 per cent soil moisture and 30°C and 25 per cent soil moisture and 35°C. It confirms the earlier findings of temperature, moisture and their combined effects on different crops (Mathur and Sackston, 1963; Edmunds, 1964; Ghaffar and Erwin, 1969; Chang and Tu, 1972; Mayer *et al.,* 1974 and Taya *et al.,* 1988).

It is well established that hydrogen ion concentration (pH) plays an important role in the growth of fungi. In the present study, dry root rot, *R. bataticola (M phaseolina)* incidence was found maximum when crop was irrigated with 8.0 pH water, followed by pH 7.0. Though, an increasing trend of disease was observed with the increase in pH of irrigation water up to 8.0. However, occurrence of disease was found to be restricted at pH

5.0. Pathogen population was also noted to be higher at pH 7.0. This suggests that the development of the disease was favoured by application of alkaline water and adversely affected by acidic or low pH (5.0) water.

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This may probably due to poor survival of the pathogen *(R. bataticola)* at lower pH and vice-versa. Livingston (1945) also found the same range of pH for better growth of *M phaseoli* causing charcoal rot of corn and sorghum. According to Singh *et al.* (1974), the maximum growth and sclerotial formation of *R. bataticola* was at 7.0 pH. Singh and Kaiser (1994), reported that mycelial dry weight was excellent at pH 6.5, good at 5.0, 6.0 and 7.0.

As evident from the present study, fungal growth (dry weight of mycelium) of *R. bataticola* was reduced with the decreasing period (from 24 to 6 h) of exposure to light. Exposure to visible light had no effect on the growth and sclerotial formation of *M phaseoli,* in culture (Johnson,1932). Also in study, there was no significant difference on dry root rot development nor the pathogen population was affected in different treatments of light.

Increased levels of nitrogen resulted into increase in dry root rot incidence. However, when phosphorus levels were increased from 0 to 50 kg ha $^{-1}$, disease incidence had gone down. In general, it has been observed that when nitrogen and phosphorus were applied in combinations, the effect of nitrogen was suppressed by increasing levels of phosphorus. Similar observations have been recorded by Ghosh and Sen (1973), Thakurji (1974) and Taya *et al.* (1988). Shivaparakasham *et al.* (1975), Ramasami

and Shanmugam *(1976)* and Taya *et al. (1988)* studied the combined application of nitrogen and phosphorus on dry root rot development. The phosphorus neutralized the effect of nitrogen. These findings are in agreement with the results of N and P on *R. bataticola* in the present study.

In the present investigation, soil application of calcium and zinc

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reduced the dry root incidence. Similarly, a marked reduction in pathogen population of *R. bataticola (M phaseolina)* was also observed when soil was amended by calcium and zinc. On the contrary, an increase in disease incidence as well as pathogen population were noted when the soil was amended by nickel. Application of calcium is reported to control *Rhizoctonia* root rot in some crops. The role of calcium in disease resistance is probably to form insoluble pectates in plant cell wall, which

are resistant to hydrolysis by *Rhizoctonia* polygalacturonases (Batman, *1970).* Colonization of *M phaseoli* was depressed with soil application of zinc as reported by Radha *(1956).*

A significant increase in dry root rot incidence was noted when *Meloidogyne incognita* and *Fusarium oxysporum* were incorporated in to soil concomitantly, followed by inoculation with *R. bataticola (M.*

phaseolina). An enhancement in dry root rot incidence was also observed when the pathogen *(R. bataticola)* was introduced in soil already infested with root knot nematode *(M incognita)* alone. Application of either of the

F. oxysporum and *Rhizobium* with *R. bataticola* did not show any significant role to increase or decrease of dry root rot incidence. Siddique and Hussain *(1991)* reported that increase in the inoculum levels of *M*

phaseolina, progressively decreased the nematode multiplication and root galling while root rotting increased with the increase in the combined inocula of *M phaseolina* and *Meloidogyne incognita.* Combined infection

R. solani and root knot nematode was more severe on cotton seedlings than either of the two Carter *(1975).* Siddique and Hussain (1992) observed that *Meloidogyne incognita* and *M. phaseolina* caused equal damage to plant when inoculated singly but two pathogens together caused more damage than the sum total damage caused by both pathogens individually. Results of the present studies corroborates the findings of the other workers

reported earlier.

Seed treatment with carbendazim was noted most effective in reducing dry root rot incidence of chickpea as well as minimizing the pathogen population. This was closely followed by thiophanate-methyl and TMTD. However, Taya *et al.* (1990) in their study reported that

carbendazim alone or in combination with thiram performed better as seed treatment, pre sowing soil drench and seed treatment + drenching after sowing for the control of dry root rot of chickpea. Chauhan (1988) also reported maximum root rot control of cotton when seed treatment was done with carbendazim followed by quintozene. Thiram was reported to be the best fungicide by earlier workers (Lewis and Natrajan, 1971 and

Shanmugam and Govindaswamy, 1973) as seed dresser against M *phaseolina.* Ahmed *et. al.* (1992) reported that thiophanate methyl was the best in reducing the *M phaseolina* stalk rot of maize. Carbendazim is well known to have direct action on the pathogen through inhibition of spindle

formation during mitosis. Increase in phenolic compounds have also been observed earlier in mustard and chickpea plants with the application of bavistin (carbendazim) and carboxin (Kotasthane and Vyas, 1992 and Singh and Sindhan, 1998). In the present study, the effectiveness of carbendazim against R. *bataticola* may probably be attributed to the increasing levels of phenols, which provided resistance to the chickpea plants against the pathogen.

Data on dates of sowing indicated that the incidence of chickpea dry root rot increased progressively as the sowing of chickpea was delayed. Least disease incidence of 22.66 and 27.99 per cent in both the year of testing and reduced pathogen population was recorded in 14th October planting. While, highest disease incidence of 46.66 and 55.99 per cent with correspondingly high population of the pathogen was noted in 16`h December planting. Kotasthane (1979) observed that higher dry root rot incidence occurred in later stages of chickpea crop. Tripathi and Sharma (1983) reported that incidence of chickpea dry root rot was higher when sowing was done from late October to mid November, it decreased in December and January and increased again in February-March. Singh *et al.* (19901 indicated that susceptibility of chickpea crop to dry root rot increased with age from 30 days onwards.

Effect of certain organic substrates applied in to soil was observed on disease development. All the soil amendments significantly reduced the occurrence of root rot incidence of chickpea except mung bean and chickpea straw. Mustard cake amendment was found to be most effective

in reducing the disease followed by wheat straw, *bajra* straw and farm yard manure. The 1e-wit. number of pathogen propagules were recovered when soil was amended with mustard cake followed by wheat straw. Snyder *et al. (1959),* Davey and Papavizas *(1960)* reported that R. *bataticola* root rot of beans was suppressed substantially by soil amendment with mature barley straw, wheat straw and by mature crops of soybean, maize and oats.

Ratnoo and Bhatnagar *(1993)* reported a reduction in disease incidence of cowpea *(M phaseolina)* by wheat straw amendment. While Sharma *et. al. (1995)* re~ci.kaa reduction in population density of *M phaseolina* by mustard cake and cauliflower residues. Hundekar *et al. (1998)* found neem cake, cotton cake, groundnut cake and safflower cake effective in reducing

disease intensity of sorghum stalk rot induced by *M phaseolina.* They also observed that wheat straw and paddy straw could reduce the disease to some extent. The effect of organic amendments on the activity of pathogenic fungi could be attributed to CO2 accumulation and non availability of nitrogen. Volatile compounds present in oil cakes and increase of saprophytic mycoflora which were inhibitory to the pathogen in

amended soil (Stover, *1962).* In the present studies, significant reduction in disease due to soil amendments with mustard cake and wheat straw, are in accordance with the earlier findings of Synder *et al. (1959),* Dave and

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amendments with chickpea and mung bean straws could be attributed to increase availability of nitrogen to the pathogen (Singh *et al.,* 1981).

All the four bioagents tested were found significantly superior in reducing dry root rot incidence. *Trichoderma viride* was found most effective in inhibiting the *Rhizoctonia* population and consequently reducing the disease incidence, followed by *T. harzianum.* Prakhaia and Vaishnav (1986) found that *T. harzianum* w os

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effective against R. *bataticola* root rot,, A reduction in stem blight incidence of cowpea induced by *M. phaseolina* was noted by *T. viride.* While in black gram, seed treatment with *T viride* @ *4* g kg' of seed was sufficient to reduce the population of root rot pathogen and its incidence. (Raghuchandra *et al.,* 1995). The present studies are in conformity of the findings reported as above.

Use of host resistance is the most economic and convenient method for managing the disease. A number of workers (Haware *et. al. ,* 1981; Singh and Mehrotra, 1982; Nene *et. al.,* 1989; Ahmed *et. al.,* 1990 and Ready *et. al.,* 1990; Ready *et. al.* 1991 and Kraft *et. al.,* 1994) have made efforts to locate the source of resistance in chickpea against R. *bataticola (M phaseolina)* root rot. In the present case, the entries *viz.,* GF-348, BG1043, FG-44, GPF-2, KGB-1175, Phule G-5, RSG-915, RSG-916, RSG899 and RSG-803 were found to be resistant having less than 10 per cent disease incidence under artificial inoculation conditions in field.

Dry root rot of chickpea *(Cicer arietinum)* induced by *Rhizoctonia bataticola* (Taub.) Butler *[M. phaseolina* (Tassi.) Goid.] was found to be prevalent in all districts of Rajasthan surveyed. The disease varied from mild to severe form. In Tonk district, it was maximum (18.99%) whereas minimum disease incidence was noted in Sriganganagar district (4.98%). The average disease incidence of the surveyed area was 10.54 per cent. Incidence of chickpea dry root rot was recorded higher in rainfed cultivation and on late sown chickpea crop later than 5`h November. Data also indicates that its incidence was higher where during *Rabi* season, chickpea followed by chickpea and lower, where chickpea followed by mustard crop.

All the four isolates of R. *bataticola (M phaseolina),* the casual agents incitent of dry root rot, proved to be pathogenic to chickpea crop. On inoculation, symptoms started appearing after 19 days.

The losses in grain yield caused due to dry root rot of chickpea were estimated up to 55.77 and 56.86 per cent under sick plot condition during 1996-97 and 1997-98, respectively. Loss in grain weight per plant was recorded up to 60.90 per cent and 42.27 per cent when plants got infected at flowering and podding stages, respectively. A reduction in 1000-grain weight was noted by 36.25 per cent at flowering stage and 22.93 per cent at podding stage. Reduction was more pronounced when infection occurred at flowering stage.

Colony was entire and appraised to substrate in isolate A-1 and A-3, irregular in isolate A-2, raised and cottony appearance was seen in isolate

A-4. Light black to black colour mycelium was seen in isolate A-2 and A-1 dark brown in A-3 and greyish black in isolate A-4. Maximum colony diameter was recorded (80.2 mm) and (69.80 mm) in isolate A-1 and A-4, on Richards' agar medium. The shape of mycelial cells was barAl and cylindrical, bearing oval shaped sclerotia except isolate A-4, which

produced spherical shaped sclerotia. On Richards' host extract medium only, isolate could produce pycnidia. Richards' medium (agar and broth) was found to be most suitable for growth and sclerotia formation of *R. bataticola (M. phaseolina).* Fastest growth of *R. bataticola* was

3ulohort -tftchickpea grain medium, followed by maize grain medium.

Isolate A-1 caused significantly higher disease incidence and was found to be more aggressive than rest of the three isolates. Incubation period of four isolates ranged between 18-26 days after inoculation. Highly pathogenic isolate A-1 had the least incubation period.

Out of seventeen plant species tested, thirteen were found to be susceptible to the dry root rot pathogen, *R. bataticola (M phaseolina).* The species which expressed negative reaction to the pathogen were *Pennisetum typhoids, Triticum aestivum, Brassica campestris* and *Linum usitatissimum.*

Incidence of chickpea dry root rot increased with the increase in the

dose of the inoculum. the maximum disease incidence 54.99 per cent was to obtained when plants were exposed, 12.5 per cent of (w/w) inoculum in

soil.

The pathogen, *R. bataticola (M. phaseolina)* had exhibited an excellent growth at 30°C with abundant production of sclerotia, closely followed by the growth and sclerotia production at 35°C. However, a sharp decline in fungal growth as well as sclerotia formation was recorded at 40°C. In *in vivo* studies, highest disease incidence (67.5 and 70.0 per cent)

was recorded at 30°C during both the years of testing, followed by 35°C. Pathogen propagules (1.89 x 103 $^{g-1}$ of soil) were also noted higher at 30°C. Minimum disease incidence was noted at 20°C.

in in vivo studies, five moisture regimes were tried. An increasing trend of disease incidence was observed with the increasing interval of irrigation during both the years of experimentation. Applying irrigation at 6-day-interval had resulted maximum disease incidence (45.5 and 54.4 per cent) during respective years with high pathogen population (1.92 x 103 $_{g^{-1}}$ of soil). Minimum disease incidence and pathogen population (at 2-dayinterval) were recorded when irrigation was applied more frequently.

Interactions between temperature and soil moisture were found to be non-significant. However, the highest disease incidence 82.5 per cent was expressed at 30° C and 25 per cent mhc of the soil followed by 30°C and 50

per cent mhc. During 1997-98, the temperature and soil moisture conditions had influenced the development of dry root rot in almost similar manner.

Highest mycelial growth with abundant sclerotia formation was obtained at 60 per cent RH level. This was closely followed by 50 and 70 per cent RH together with formation of several sclerotia.

Summary

Irrigation water of five di: effect on dry root rot. Highest di was recorded at pH 8.0 during 19 an increasing expression of disea level of irrigation water up to assessed at pH 7.0, while minimu soil).

An exposure to 24 hour maximum dry mycelial weight wi hour exposure to light and six hoi best treatment for mycelial gi exposure to continuous darknes growth as well as sclerotia form;

copper, manganese and nickel did not show any reduction in disease incidence. On the contrary, nickel had increased the susceptibility of chickpea plants to dry root rot. Minimum pathogen population was assessed when soil was amended with calcium followed by zinc.

A significant increase in dry root rot incidence was observed when *Meloidogyne incognita* and *Fusarium oxysporum f. sp. ciceris* infested soil was inoculated with R. *bataticola.* An enhancement in disease incidence was also noted when the pathogen was introduced in soil infested with M *incognita.* Pathogen population in all the treatments was more or less similar.

Carbendazim was proved to be most effective in checking the dry root rot incidence (16.66 and 13.33 per cent) in the pots when used as seed dresser followed by thiophanate-methyl and thiram during both the years of experimentation. Pathogen population was also reduced when the seeds were treated with carbendazim followed by thiophanate-methyl. Similar trends were also observed in field experiment. Also, carbendazim treatment was found significantly superior in enhancing the grain yield of chickpea. Thiophanate-methyl and thiram treatments were at par next to carbendazim and with each other in yield enhancement of grain yield.

Incidence of root rot increased progressively as the planting of chickpea was delayed, the lowest disease incidence (22.66 and 27.99 per cent) being in the plants sown on 14th October during 1996-97 and 199798, respectively. As regards pathogen population, it was the least (1.30 x 10^{19} of soil) in early planting and highest in late planting (1.70 x 10^{3} g'

of soil). However, populations recovered from the soil between planting dates of 28`h October to 25th November did not show marked difference.

Soil amendment with chickpea straw and mung bean straw had no caused any significant difference in minimizing the dry root rot incidence While amendment with mustard cake resulted significant reduction in dr, root rot, followed by wheat straw, *bajra* straw and farm yard manure. Th(least pathogen population was recovered when soil was amended witl mustard cake followed by wheat straw.

Out of four bioagents, seed treatment with *Trichoderma viride* dus formulation @ 4 g kg $^{-1}$ seed gave maximum disease control followed b3 *Trichoderma harzianum.*

On evaluating 100 genotypes of chickpea against dry root rot under artificial inoculation conditions only 10 genotypes exhibited resistan· reaction having disease incidence of 1-10%. These were FG-348, BG• 1043, FG-44, GPF-2, KGB-1175, Phule G-5, RSG-915, RSG-916, RSG. 899 and RSG-803. Twenty three lines expressed as moderately resistant reaction and rest were either susceptible or highly susceptible.

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***Original not seen**

"Epidemiology and Management of Chickpea *(Cicer arietinum* L.) Dry Root Rot Induced by *Rhizoctonia bataticola* (Taub.) Butler *[Macrophomina phaseolina* (Tassi.) Goid.]"

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ABSTRACT"

Dry root rot of chickpea induced by *Rhizoctonia bataticola (M. phaseolina)* was found to be prevalent in eight districts of Rajasthan. Disease incidence varied from 4.98 to 18.99 per cent. It was more severe in the rainfed as well as in the crop sown later than 5`h November. Losses in grain yield were higher (60.9%) when infection occurred at flowering than at podding stage.

All the four isolates of the pathogen referred to as A-1, A-2, A-3 and A-4 caused dry root rot symptoms on chickpea. Among these isolates A-1 was found to be more aggressive. Isolate Al produced highest mycelial growth irrespective ocany medium. Richards' agar and liquid medium was found to be most suitable for growth and sclerotia formation.

Of the seventeen plant species evaluated except *Pennisetum typhoids*, *Triticum aestivum, Brassica campestris* and *Linum usitatissimum* showed positive reaction to dry root rot pathogen. Apart from chickpea, rajmash and moth bean had expressed comparatively high incidence of disease. Incidence of disease increased with the increase in dose of inoculum 10-12.5 per cent inoculum dose was found optimal for disease development in chickpea. Pathogen displayed maximum growth and root rot incidence at 30°C followed by at 35°C. Highest mycelial growth was harvested at 60 per cent RH followed by 50 per cent RH. Incidence of dry root rot was higher under moisture stress condition or when plants were irrigated at 6 days of interval.

A temperature of 30°C and moisture of 25 per cent mhc was found to be more favourable for disease development. Pathogen displayed maximum disease incidence and highest population of the pathogen *(R. bataticola)* at pH 8.0. Effect of light had no significant role on the disease development and on pathogen population in the soil.

Increasing levels of nitrogen successively increased the disease incidence while reverse trend was noted in case of phosphorus application. Soil application of calcium and zinc had reduced the disease incidence and pathogen population. On the contrary, nickel had increased the susceptibility of chickpea, to dry root rot pathogen.

Root rot incidence in chickpea was found to be enhanced when *R. bataticola* was inoculated in soil in combination with root knot nematode *(Meloidogyne incognita)* and a wilt causing fungus *(Fusarium oxysporum f. sp. ciceri)* as compared to the d..isease incidence caused due to inoculation of *R. bataticola* alone. However, the pathogen population recovered from soil was more or less uniform in all the treatments. Carbendazim seed treatment of chickpea was proved most effective in minimizing the disease as well as pathogen population in soil. 6n___ increase in disease incidence was expressed when planting of chickpea was delayed later than 4u' November. As regards pathogen population, it was least in early (14`h October) plantings. Soil amendment with mustard cake gave maximum disease control and minimum pathogen population as compared to chickpea and mung bean straws used as soil amendment.

Of the 4 bioagents, seed treatment with *Trichoderma viride* was found to be most effective in reducing the disease development and pathogen population, followed by *T. harzianum.*

Chickpea entries FG-348, BG-1043, FG-44, GPF2, KGB-1175, Phule G-5, RSG-915, RSG-916, RSG-899 and RSG-803 were found to be resistant against dry root rot under sick soil condition.

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राइजोक्टोनियाँ बटाटीकोला (टॉब.) बटलर {मेक्रोफोमीना फेजियोलिना (टासी.) गोइड.} जनित चने के सूखा जड़ गलन रोग का जानपदिक एवं प्रबन्धन अध्ययन

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अनुसंधानकर्त्ता

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सारांश[++]

राजस्थान मे चने की फसल मे लगने वाला सूखा जड़ गलन रोग राइजोक्टोनियाँ बटाटीकोला (मेक्रोफेमिना फेजियोलिना) कवक द्वारा होता है । राज्य के आठ जिलों में, रोग की मात्रा 4.98 से 18.99 प्रतिशत तक देखी गई । इसका प्रभाव सिंचित फसल की अपेक्षा बारानी खेती मे तथा अपेक्षाकृत देरी से बोई गई चने की फसल में अधिक पाया गया । यदि रोग का प्रकोप फूल बनने के समय हो तो विलम्ब से होने वाले (फली बनने के समय) रोग प्रकोप की तुलना में, चने के उत्पादन में अधिक हानि (60.9 ´/.) होती है ।

राईजोक्टोनियाम बटाटीकोला के चार प्रभेद (ए-1, ए-2, ए-3, व ए-4) चने मे सूखा जड गलन रोग उत्पन्न करने के लिए उत्तरदायी पाये गये । इनमे से प्रभेद "ए-1" अधिक उग्र पाया गया तथा अपेक्षाकृत तीव्र गति से कवक वृद्धि होते पाई गई । रिचर्ड का तरल एवं ठोस माध्यम, दोनो ही इसकी वृद्धि एवं स्कलरोशिया उत्पन्न करने मे सर्वाधिक उपयुक्त पाये गये । इसके कवक की वृद्धि चने के दानों के माध्यम मे सबसे जल्दी व अधिक पाई गई ।

सत्रह प्रकार के पौधों की प्रजातियों के परीक्षण मे बाजरा, गेहूँ, सरसों व अलसी के पौधे को छोड़कर अन्य सभी पौधो की प्रजातियों में (राईजोक्टोनिया बटाटीकोला) सूखा जड़ गलन रोग उत्पन्न करने में सफल पाया गया । चने के अतिरिक्त मोंठ, राजमा पौधों पर अधिक प्रकोप देखा गया । भूमि मे, रोग जनक कवक की मात्रा बढ़ाने पर रोग की उग्रता भी बढ़ती हुई पाई गई, 10 से 12.5 प्रतिशत की दर से कवक मिश्रण (रोग कारक) मिट्टी मे मिलाने पर, सूखा जड़ गलन रोग अधिक पाया गया । तापक्रम 30-35 डिग्री सेल्सियस, सापेक्ष आद्रता 60 प्रतिशत, पी.एच. मान 8.0 के पानी से पौधो को सिंचित करने तथा भूमि में नमी की कम मात्रा यानि पानी की सोखने की क्षमता का मात्र 25 प्रतिशत, (राइजोक्टोनियाँ बटाटीकोला) कवक वृद्धि, स्कलेरोशिया उत्पादन एवं रोग उत्पदन करने की क्षमता के लिए, सर्वाधिक अनुकूल पाये गये । छः दिन के अन्तराल पर चने के पौधों को सिचित करना 2, 3, 4 व 5 दिन के अन्तराल पर सिंचाई की अपेक्षा रोग का प्रकोप अधिक मात्रा में पाया गया ।

नत्रजन की मात्रा बढ़ाने से इस रोग की मात्रा अधिक हो जाती है एवं फास्फोरस की मात्रा बढ़ाने से कम होती आंकी गई । मिट्टी मे कैलशियम एवं जिंक नामक सूक्ष्म तत्व मिलाने से इस रोग की उग्रता भी कम पाई गई एवं रोग जनक की संख्या मे कम पाई गई । इसके विपरित निकल नामक तत्व मिलाने पर मिट्टी में रोग कारक कवक की मात्रा बढ गई जिसके फलस्वरुप चने मे जड़ गलन रोग का प्रतिशत भी अधिक हो गया ।

सूखा जड़ गलन रोग की उग्रता तुलनात्मक रुप से अधिक पाई गई जब इसके रोग जनक कवक (राइजोक्टोनिया) के साथ फ्यूजेरीयम ओक्सीस्पोरम कवक व मिलोइडोगाइनी नामक सूत्रकृमी को मिट्टी में मिलाया गया । हालाँकि इसके रोग जनक की संख्या लगभग समान थी । चने के बीज को कारबेण्डाजिम नामक कवकनाशी द्वारा 1 ग्राम प्रतिकिलो बीज से उपचारित करके बौने पर रोग की उग्रता एवं रोग जनक की संख्या अत्यधिक कम पाई गई । चने की फसल की बुवाई विलम्ब से करने पर (नवम्बर) रोग की उग्रता एवं रोग जनक की संख्या अधिक पाई गई । रोग जनक की संख्या जल्दी बुवाई (14 नवम्बर) करने पर सबसे कम आंकी गई । रोगग्रस्त मिट्टी मे सरसों की खली मिलाने पर रोग की तीव्रता एवं रोग जनक की संख्या कम पाई गई ।

ट्राईकोडर्मा विरिडे नामक जैविक कवकनाशी के द्वारा बीजोपचार रोग की मात्रा एवं रोग जनक संख्या कम करने मे उपयुक्त पाया गया । ट्राईकोडर्मा हारजियानम द्वारा बीजोउपचार भी उपयुक्त पाया गया । रोगग्रस्त भूमि मे परीक्षण करने पर चने की दस प्रजातियाँ क्रमशः एफ.जी.-348, बी.जी.-1043, एफ.जी.-44, जी.पी.एफ.-2, के.जी.बी. -1175, फूले जी.-5, आर.एस.जी.-915, 916, 899 एवं 803 रोग रोधी पाई गई ।

[+] सहायक आचार्य, पौध व्याधि विभाग, राजस्थान कृषि विश्वविद्यालय, कृषि अनुसंधान केन्द्र, दुर्गापुरा, जयपुर

[++] कृषि संकाय, राजस्थान कृषि विश्वविद्यालय के पौध व्याधि विषय मे विद्यावाचस्पति उपाधि की आवश्यकता की सम्पूर्ण पूर्ति हेतु शोध प्रबन्ध, जो कि डा.आर.बी.एल.गुप्ता, आचार्य, पौध व्याधि विभाग, कृषि अनुसंधान केन्द्र, दुर्गापुरा, जयपुर के निर्देशन में प्रस्तुत की गई।

LIST OF ACRONYMS

µm	Micrometre	mm	Milimeter
@	at the rate of	mhc	Moisture holding capacity
°C	Degree celsius	mg	Miligram
C.D.	Critical difference	ml	Mililitre
Ca	Calcium	Mn	Manganese
cm	Centimetre	Nos.	Numbers
Co	Cobalt	N	Nitrogen
Cu	Copper	Ni	Nickel
CV	Co-efficient of variation	pH	Negative logarithm of hydrogen ion
Ca	Calcium	P/P205	Phosphorus
Dia	Diameter	RH	Relative humidity
ds/m	desi ciman per metre	Sq	Square
EC	Electrical conductivity	SEm±	Standard error of mean
et al	(et alibi) and else where	SSP	Single Super phosphate
Fe	Iron	Sp	Species
Fig.	Figure	v/v	volume/volume
g	Gram	w/w	weight/weight
ha	Hectare	Zn	Zinc kg Kilogram