The old world genus *Cicer* to which the chickpea or gram belongs contains some 40 species of annual or perennial herb, or small perennial shrub; one species (*C. cuneatum* Hochst. Ex Rich.) bears tendrils and is a semi-climber. Nine annual species are recognized *C. chorassanicum* (Bge) M Pop. and *C. yamashitae* Kitan, are native to Afghanistan; *C. judaicum* Baiss, *C. pinnatifidum* Jaub. & Spach, and *C. bijugum* K.H. Rech. are wild in the Middle East; *C. cuneatum* is endemic to Ethiopia and the Sudan; and the two species *C. echinospermum* Davis and *C. reticulatum* Lad. have been described from South-Eastern Turkey.

Chickpeas are widespread in seasonally arid regions as a rainfed crop on poor soil. They are notably tolerant of drought and low management and have apparently not become adapted to conditions very different from their original habitat. Yet within the crop range, there is considerable local adaptation among land races of which the crop principally consists. Although these adaptive responses are yet to be fully quantified, it is probable that different gene constellations have been fixed by selection in different environments.

India is the largest producer, accounting for 80 per cent of the world's crop; other countries producing significant quantities are in order of importance, Pakistan, Mexico, Turkey and Ethiopia. Kabuli types contribute some 10 - 15 per cent of the total production. In India chickpeas are most commonly either intercropped or grown in rotation with wheat, as winter ('rabi') crops following millet or sorghum. In Ethiopia, as in India, chickpeas are the most important legume; the crop is sown at the end of September after the main rains, usually as sole crop in rotation with wheat or tef (*Eragrostis tef*), but occasionally also in association with sorghum or safflower (*Carthamus tinctorius*). In Western Asia and the Mediterranean chickpeas are grown in monoculture, traditionally as spring sown crop.

During the past five decades there has been an intensification of research into chickpea improvement, beginning with establishment of the Regional Pulse Improvement Project (RPIP) in India and Iran in 1962. In 1973 work on the crop began at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Meanwhile, the Arid Lands Agricultural Development Program (ALAD) in the Middle East and North Africa had set up a food legume project which embraced chickpea, and this observed by the International Centre for Agricultural Research in the Dry Areas (ICRDA) in 1977.
Although *C. arietinum* is susceptible to a relatively large numbers of pathogens, few diseases are currently recognized as economic restraints to chickpea production. Predominant among the pathogen of *Cicer* are certain soilborne fungi which, in India, have long been associated with diseases of the root system and collar region of the plant. While little is known of the interactions that may occur between the various pathogens during disease development, it has been established that the 'wilt complex' comprises a number of effectively distinct diseases. A vascular wilt, caused by *Fusarium oxysporum* f. sp. *ciceris* and an aerial blight, caused by *Ascochyta rabiei*, are the most important chickpea diseases. Few viruses have been identified from natural infections of chickpea, the most important of which is pea leaf roll virus, the cause of stunt.

Chickpea wilt, has its origins in India where the disease was first mentioned in 1918. Since that time, an often bewildering array of agents have been claimed as the cause of 'wilt' including various soil fungi of the genera *Fusarium*, *Verticillium*, *Rhizoctonia*, *Sclerotium*, *Ozonium*, and *Acrophialaphora*. *Fusarium* wilt is reported, outside India, from Burma, Pakistan, Russia, Ethiopia, Malawi, Tunisia, Spain, USA, Mexico, and Peru. In India wilt responsible for substantial crop loss; an annual loss of 10-20 per cent is often quoted. Disease incidence, which is generally higher on light, sandy and alkaline soils than in heavier acid soils, is influenced by sowing date which reflects changes in soil moisture and temperature.

In view of the above mentioned facts, the present study attempts to assess the interaction between below ground organisms associated with chickpea plants, effect of the soil moisture, pH, and below ground interaction have been investigated. The present research work is summarized in four chapters:

**CHAPTER FIRST** as usual starts with introduction of the subject, which includes the information about the belowground microorganisms, i.e. fungal, bacterial and vesicular arbuscular mycorrhizal (VAM) fungi particularly their morphology and functional diversity, and their role with host plant. The general introduction also deals with nature of work that has been chosen for the present study.

**CHAPTER SECOND** of the thesis deals with the review of literature, as it is very important part of work. This gives an overview of belowground interaction throughout the world. Through this chapter it is possible to disseminate all the information available for the benefit of future workers. Attempts have been made to include the references of earlier workers from 19th century and survey has been extended upto the recent
references of 2007. This review of work gives a historical evidence of early belowground interactions research and progress along with the literature how belowground research gained worldwide attention.

CHAPTER THIRD deals with materials and methods, which also included the study of area. In this chapter a complete methodology is discussed right from the study area, mycological methods, methods of sampling, analysis of soil chemical and physical properties, and various techniques of mycorrhizal assessment i.e. isolation, enumeration, identification of fungi, bacteria and VAM fungal spores; and root processing and assessment of colonization; VAM fungal culture techniques, and different chemical substances used. Here, it is worth mentioning that chemical substances used during the study were of high grade. The chemicals include HCl, KOH, Lacto phenol, NaOH, Cotton blue etc.

CHAPTER FOURTH result and discussion of present work is divided into four subchapters.

CHAPTER 4.1 deals with isolation and identification of rhizospheric microflora of chickpea varieties and growth of Foc and Trichoderma isolates. Total 42 belowground microorganisms were isolated from the rhizosphere of the chickpea. Among them 22 fungal, 10 bacterial and 10 AM fungi species were identified. Out of 22 fungal species maximum four species each Fusarium, and Aspergillus, three species of Trichoderma, two species of each Rhizopus, Mucor, Penicillium, Mycelia; and single species of each Gliocladium virens, Rhizoctonia solani, and Phytophthora parasitica represents the rhizosphere of test chickpea varieties. Among the bacteria, Bacillus species dominant with four species, two isolate of each Rhizobium and Pseudomonas species, and one species of E. coli and one bacterial isolate could not be identified. Ten arbuscular mycorrhizal fungal (AMF) species were isolated and identified. Among the 10 AM fungi 7 species belong to Glomus, 2 from Acaulospora and one from Gigaspora was identified.

The growth of both the organisms Foc and BCA (Trichoderma isolates) was calculated on the basis of biomass production under in vitro condition in the various physiological and environmental conditions. The results suggest that Foc and Trichoderma isolates produced maximum dry weight in Potato Dextrose except TvSV-21 which produces maximum dry weight in Czapek's Dox. Rose Bengal does not suits to either Foc or Trichoderma isolates hence poor growth and lesser dry weight was recorded. Sucrose favours production of dry weight in Foc and Trichoderma isolates. Maximum
biomass of Foc and all the Trichoderma isolates was produced at sugar level 30.0 g/l. The results showed that maximum biomass produced by both Foc and Trichoderma isolates on NH$_4$NO$_3$. Maximum biomass production in Foc and Trichoderma isolates was recorded in 3.0 g/l nitrate level. It was observed that among amino acids tested, maximum dry biomass was produced by both Foc and Trichoderma isolates in glutamic acid. 35 °C temperature was optimum for production of maximum biomass in Foc and Trichoderma isolates. Alkaline (pH 8.0) favours the greater production of biomass in Foc whereas acidic (pH 6.5) favours the growth and resultant biomass production in Trichoderma isolates.

CHAPTER 4.2 deals with the interaction between Foc and BCA (Trichoderma isolates) in different physiological and environmental conditions. Maximum 85.0 per cent inhibition of Foc was recorded in Potato Dextrose by TvSV-11, maximum 84.3 per cent inhibition of Foc in sucrose by TvSV-11. 30.0 g/l of sucrose produces best results and shows maximum 82.0 per cent inhibition by TvSV-11 and 3.0 g/l NH$_4$NO$_3$ produces 85.0 per cent inhibition of Foc. ThSV-221 and ThSV-235 show maximum inhibitory effect when grown in medium containing 3 g/l of nitrate and TvSV-11 was able to inhibit growth of Foc up to 70% even at 0.25 g/l. Maximum 84.0 per cent inhibition of Foc was recorded in glutamic acid. Maximum 79.0 per cent inhibition of Foc was observed in at 35 °C by TvSV-11. pH 6.5 showed maximum inhibitory potential of Trichoderma isolates against Foc and minimum in pH 3.5.

CHAPTER 4.3 deals the multiple interaction among Trichoderma isolates, Rhizobium, Foc and AM Fungi in sterilize and unsterilize soils. The result depicted in the chapter three provides some interesting information. First thing which was observed confirm the validity of test varieties *viz.* ICC 4951 wilt susceptible, ICC 11322 and JG 74 wilt resistant varieties. In all the experiment conducted during study the incidence of wilt in susceptible variety was much severs then any other test varieties. It was also observed recorded that either Trichoderma isolates, AM fungi and Rhizobium showed good amount of phytoprotectant role. Combination either AM fungi + Trichoderma, AM fungi + Rhizobium or Trichoderma + Rhizobium was found to be major consoria of belowground organism which shows a considerable amount of positive impact on test variety. However, it is also come out the experiments and assumed that no single biological control agent couldn't manage the spread of disease. Therefore, number of beneficial organisms and their synergistic approach could get us some relief and a feel for achieving something. However, we still felt that their should be other organisms.
which could haven’t taken consideration to get the maximum benefit of these
belowground interactions. Nevertheless, it can be concluded here suitable Trichoderma
isolate preferable AM fungi and Rhizobium spp. should be used to prevent Foc induced
wilt in chickpea.

CHAPTER 4.4 deals with phytoprotectant role of AM Fungi, and Rhizobium, with
or without Trichoderma isolates, against the Foc in susceptible variety ICC 4951. Best
combination was TvSV-11 + Gl. mosseae, whereas TvSV-11 + G. albidu found to be weak
combination in controlling Foc under the experimental conditions on the germination of
chickpea. Chickpea plants pre-inoculated by different Trichoderma isolates when further
treated with AM fungi, Rhizobium sp. or Foc shows differential response for their per
cent germination. TvSV-11, AM fungi and Rhizobium pre-inoculated chickpea plant
shows greater per cent germination. TvSV-11 inoculated plants reduce the influence of
Foc more efficiently in comparison to AM fungi and Rhizobium. AM fungi and Rhizobium
together shows no significant effect on germination of the test chickpea variety.

Best result was recorded with TvSV-11 in test chickpea variety ICC 4951. Gl.
mosseae, Gl. fasciculatum and A. spinosa, produces synergistic effect on the height of the
chickpea. Chickpea plants pre-inoculated by different Trichoderma isolates when further
treated with AM fungi, Rhizobium sp. or Foc shows differential response for their height.
TvSV-11 pre-inoculated chickpea plant shows greater height with AM fungi. AM fungi
and Rhizobium combination with TvSV-11 pre-inoculated plants show maximum 31.4 cm
height of chickpea plants. Foc is introduced control without pre-inoculated with
Trichoderma isolates showed 15.0 cm height of chickpea plants. Chickpea plants first
treated with AMF then Foc it was observed that consoria of AMF played an important
role to control the damage caused by Foc. Greater height of chickpea plants treated with
AMF or Rhizobium was obtained with TvSV-11. Combined effect of AMF and Rhizobium
on Foc did show significant difference, however, growth promoting role of AMF or
Rhizobium, yield better results than used individually or in combinations against Foc.

Foc reduces the yield of chickpea plants inspite of presence of Trichoderma
isolates, however Trichoderma isolate TvSV-11 produce good phytoprotectant role. AM
fungal species in the presence Trichoderma isolates also shows phytoprotectant properties
against Foc. Best combination was observed with TvSV-11 + Gl. mosseae. TvSV-11 pre-
inoculated chickpea plant shows greater yield with AM fungi. AM fungi and Rhizobium
combination with TvSV-11 pre-inoculation 265.0 g which was maximum yield of
chickpea plants. AM fungi, *Rhizobium* and Foc shows significant synergistic effect of bioprotection or biocontrol mechanism on Foc.

Plants treated with Foc alone shows greater disease severity index but in the presence of *Glomus mosseae* decreases severity index and maximum reduction was recorded. Plants which shows maximum disease severity index (As- Foc+) shows lesser amount of shoot dry weight 0.45±0.01 g/plant and maximum shoot dry weight 1.52±0.12 g/plant recorded with *Gl. mosseae*. Without Foc treated plants showed greater per cent root colonization in comparison to with Foc inoculated chickpea plants. *Gl. mosseae* found colonizes to 96.4 per cent without Foc and 54.4 per cent with Foc. *Gl. mosseae*+ Foc- plants showed greater formation of vesicles. Plants treated with *G. albida* do not produce any type of vesicle like structures. *Gl. mosseae* inoculated and without Foc plants could able to develop greater per cent of arbuscules 32.1±5.2 and with Foc shows 14.5±4.2 per cent.

As such on the whole it may be summarized that:

- The present study reveals important aspects of bio-diversity of belowground microorganisms associated with chickpea plants.
- Almost 42 belowground microorganisms screened with chickpea which included 22 soil fungi, 10 AM fungi and 10 bacterial isolates.
- Among the 22 fungal isolates five *Trichoderma* isolates were selected which are TvSV-11, TvSV-21, ThSV-215, ThSV-221 and ThSV-235 for further studied because their good biocontrol ability to control the wilt disease.
- JG 74 and ICC 11322 shows greater resistance and ICC 4951 shows susceptible against *Fusarium* wilt.
- Environmental factors influence the biocontrol ability of *Trichoderma* isolates of the test plants.
- Among the selected AM fungi *Gl. fasciculatum* was found much effective for the growth and protection of the test plants.

Finally, it can be concluded that *Gl. fasciculatum* can be used an efficient AM fungi species for inoculation of chickpea as it greater diversity, biomass production, and bio-protection activity.