Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir

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THESIS

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MASTER OF SCIENCE IN AGRICULTURE
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2007

Dedicated
to my beloved Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Plant Pathology, Shalimar Campus, Srinagar
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Certificate – I

This is to certify that the thesis entitled **“Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir”** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology)**, to the Faculty of Postgraduate Studies, Sher-e-Kahsmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by **Mr. Fayaz Ahmad Wani (Regd. No. 2004-A-747-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

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Certificate – II

We, the members of the Advisory committee of **Mr. Fayaz Ahmad Wani (Regd. No. 2004-A-747-M)**, a candidate for the degree of **Master of Science in Agriculture (Plant Pathology)**, have gone through the manuscript of the thesis entitled, **"Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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This is to certify that the thesis, **"Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir"** submitted by **Mr. Fayaz Ahmad Wani (Regd. No. 2004-A-747-M)** to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology)** was examined and approved by his Advisory Committee and external examiner on ………………..

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Title of the Thesis	:	**"Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir"**

ABSTRACT

Studies were carried out on "Integrated Management of Chilli Wilt [*F. pallidoroseum* (Cooke) Sacc.] in Kashmir" during 2005-2006 at SKUAST-K, Shalimar, Srinagar. Under *in vitro* conditions, the culture filtrate of *T. viride* at 60 per cent concentration caused 87.59 per cent mycelial growth inhibition of *F. pallidoroseum*. Among the individual applications tested under *in vivo* conditions, carbendazim recorded minimum wilt incidence of 2.00, 13.12 and 33.56 per cent at flowering, fruit formation and ripening stages of chilli crop, respectively, with 72.35 q ha^{-1} per cent increase in fruit yield as compared to control (42.50 q ha^{-1}). Dual application of carbendazim + decomposed FYM recorded minimum wilt incidence of 1.08, 9.00 and 27.53 per cent at above respective stages with 80.80 q ha^{-1} per cent increase in fruit yield as compared to control. Combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM recorded significantly least wilt incidence of 0.62, 6.25 and 18.15 per cent at flowering, fruit formation and ripening stages respectively, with 98.23 q ha^{-1} per cent increase in fruit yield as compared to control. The highest wilt incidence of 10.20, 46.36 and 68.75 per cent at flowering, fruit formation and ripening stages of chilli crop, respectively, was recorded in control. The application of all treatments and their combinations also resulted in overall improvement of plant height, fruit number and fruit yield.

Key words : Integrated management, Chilli wilt (*F. pallidoroseum*), *T. viride*, Carbendazim, Delayed irrigation, FYM

Signature of Student	Signature of Major Advisor
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Fayaz Ahmad Wani

Place : Shalimar, Srinagar
Dated :

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Indu Jalali, Senior Scientist, HAU, Hissar during Viva-Voce examination held on 28.06.2007 have been incorporated in the manuscript entitled **"Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir"** submitted by **Mr. Fayaz Ahmad Wani (Regd. No. 2004-A-747-M)**.

Dr. A.G. Najar
Chairman
Advisory Committee

Chapter – 1

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important Solanaceous vegetable crop grown for its unripe green and ripe-red fruit which, in whole or powdered form, is an indispensable condiment, digestive stimulant as well as flavouring and colouring agent in sauces, *chitnies*, pickles and other forms of food. Its economic importance lies in pungency of its fruit due to an alkaloid capsaicin or capsicutin ($C_{18}H_{27}NO_3$). Besides vitamin A and C, the green fruit is known to contain vitamin P in appreciable proportion (Muthukrishnan *et al.*, 2002). Its cultivation is spread throughout India over an area of about 0.908 million hectares with an annual dry chilli production of 0.970 million tonnes (Anonymous, 2005). In Jammu and Kashmir state, chilli is cultivated over an area of 2700 hectares with an annual production of 4050 metric tonnes (Anonymous, 2004), which is quite low as compared to other states like Andhra Pradesh, Karnataka, Tamil Nadu, Punjab, Bihar and Gujarat.

Inspite of quite favourable edaphic and environmental conditions for chilli cultivation in the valley, the yields have not been so encouraging. In attempts to boost production by way of fresh introduction, hybridisation, intensive and extensive cultivation, a number of diseases incident upon the crop, which take heavy toll of the produce annually. Of the many impediments in increasing the chilli production, the occurrence of diseases such as damping off (*Pythium* spp.), leaf and fruit blight (*Phytophthora capsici*), anthracnose and dieback

(*Colletotrichum capsici*), root rot (*Rhizoctonia solani*), leaf spots (*Alternaria solani*, *Cercospora capsici*) and wilt (*Fusarium* spp.) are the most important as they considerably reduce the yield of the crop (Anonymous, 1993). Out of these major chilli diseases, chilli wilt complex has become an important disease in the valley during last decade and has caused epiphytotics in several chilli-growing areas of the valley resulting in about 48.81 per cent losses in fruit yield (Najar, 2001). The disease is characterised by withering and chlorosis of older leaves followed by young upper leaves, petioles and stem, which often results in wilting and outright killing of the whole plant within a few days due to *Fusarium pallidoroseum* (Cooke) Saccardo Syn. *Fusarium semitectum* Berk and Ravz. (Wani, 1994; Dar and Mir, 1995a; Najar, 2001).

Many attempts have been made so far, to manage the disease through chemicals in India and elsewhere, with little or some considerable success. Vascular Fusarial wilts have long been controlled by soil disinfection with methyl bromide (Jones and Overman, 1978) or diazomet (Nikolaeva, 1978). Seed treatment with fungicides like carbendazim or carboxin has also eradicated *F. oxysporum* from chilli seeds and reduced Fusarium wilt incidence significantly (Vidhyasekaran and Thiagarajan, 1981). Management of soil-borne plant diseases by manipulating cultural practices viz., crop rotation, fallowing, field sanitation, deep ploughing, irrigation, time and method of planting have been advocated by many workers (Kannaiyan and Nene, 1979; Sen, 1986; Café-Filho and Duniway, 1995). Of late, an economical and eco-friendly biological disease management has been also exploited against soil-borne pathogens.

A successful disease control programme depends upon crop production system which is closely aligned with the goals of disease management. Different disease management strategies, which, including host resistance, cultural control, chemical control and biological control have been taken into consideration. These strategies, when applied individually have been reported to reduce the effect of disease to some extent (Masoodi, 2000; Najar, 2001). Owing to the destructive nature of the disease, integration of various management components has become imperative to reduce resulting losses of the disease. Integrated disease management involving all the strategies available to the grower such as cultural, biological and chemical are expected to provide acceptable yield and quality at the minimum cost and is compatible with the tenets of environmental stewardship and normal crop production schedule. Integration of thiram (seed protectant) and soil application of antagonist (*Trichoderma harzianum*) were found synergistic in relation to chilli wilt (Patibanda *et al.*, 2002).

Keeping in view the increasing incidence of chilli wilt (*F. pallidoroseum*) and the prospects of its control through integrated disease management, the present study was undertaken with the following objective:

- To study the effect of some disease management practices and their combinations on chilli wilt disease.

Chapter – 2
REVIEW OF LITERATURE

The wilt of chilli (Capsicum *annuum* L.) is known to be caused by different fungal pathogens in different parts of the world, and different strategies for management of the disease have, therefore, been suggested (Satyaprasad *et al.*, 1998; Najar, 2001). Relevant literature relating to integrated management of the disease is reviewed as under :

2.1 Status of disease

The wilt disease was reported for the first time as early as 1908 in New Mexico (Chupp and Sherf, 1960). It has also been reported from West Indies (Ciferri, 1926), India (McRae, 1932), Brazil (Chaves, 1947), Chile (Fernandez, 1983), Iraq (Sarhan and Sharif, 1986), Cuba (Camino *et al.*, 1987), Tunisia (Moens and Benaicha, 1990) and China (Liping, *et al.*, 2001).

The disease has attained global status and causes significant economic losses vis-a-vis production of the crop. Severe incidence of the disease in some genotypes with 100 per cent crop loss has been reported from Punjab state of India (Thind and Jhooty, 1985; Kaur, 1993). In Himachal Pradesh, the disease incidence in all cultivated varieties except few with 20-90 per cent crop loss has been reported (Singh and Singh, 2004). However, in Kashmir valley the disease inflicted heavy loss of 48.81 per cent with disease incidence of 54.22 per cent (Najar, 2001).

2.2 Etiology

2.2.1 Causal organism

A number of pathogens are associated with the wilt of chilli in different parts of the world. Many workers ascribed the wilt, to various species of Fusarium viz., *F. oxysporum* Schl. (Vidhyasekaran and Thiagarajan, 1981). *F. oxysporum* f.sp. *redolens* (Sarhan and Sharif, 1986), *F. equisti* (Moens and Benaicha, 1990), *F. oxysporum* and *F. solani* (Hashmi, 1989) and *F. pallidoroseum* (Thind and Jhooty, 1985; Kaur, 1993; Wani, 1994; Najar, 2001). In Kashmir valley, *Phytophthora capsici*, *Rhizoctonia solani* and *F. pallidoroseum* have been reported to be associated with chilli wilt complex, *F. pallidoroseum* being quite predominant (Dar and Mir, 1995a; Najar, 2001).

2.2.2 Symptomatology

The symptoms of the disease manifest as chlorosis of older leaves of chilli plants followed by younger leaves, petioles and stem of plants (Doolittle, 2005). Roots of affected plants remain stunted, turn pale brown with root and shoot showing vascular browning. Moreover, infection of chilli plants with *F. pallidoroseum* was characterised by tan-brown to brownish-black stems, withering of leaves and ultimate death of infected plants (Kaur, 1993; Thind and Jhooty, 1985). Wani (1994) and Najar (2001) reported sudden wilting of leaves with loss of green colour, vein clearing and epinasty of older leaves progressing to younger leaves often at flowering stage due to root infection with *F. pallidoroseum*. Furthermore, they reported that the infected roots turned brown. Reports reveal that wilt infection of chilli crop at flowering stage resulted in complete crop failure before fruit ripening stage (McRae, 1932; Sango, 2003; Singh and Singh, 2004).

2.2.3 Predisposition

The disease is soil-borne in nature and practice of monoculture together with susceptible cultivars make the crop prone to disease. The other predisposing factors such as frequent irrigation and use of higher levels of nitrogenous fertilizers give fillip to the development and spread of the disease (Dar and Mir, 1995a; Najar, 2001).

2.3 Perpetuation of pathogen

Seed-borne nature and soil transmission of wilt causing *Fusarium* spp. have been duly reported (Nedumaran and Vidhyasekaran, 1982; Vijaylakshmi and Rao, 2003).

2.3.1 Perpetuation in/on seed

Many workers have established the seed-borne nature of *Fusarium* spp. causing wilt in chilli and other Solanaceous crops. Baby and Shakhnubaryan (1969) frequently isolated *F. oxysporum* from chilli seed and infection reduced seed germination, growth rate, fruit yield and induced wilting in transplanted crop. Basak *et al.* (1998) and Vijaylakshmi and Rao (2003) detected highest percentage of chilli seed and fruit infection with *Fusarium* spp.

2.3.2 Perpetuation through soil

Fusarium spp. being facultative saprophytes inhabiting the soil (Beckman, 1987). Chlamydospores of the fungus remain embedded in humus or plant debris (Nash *et al.*, 1961) and get transmitted to the transplanted crop (Vidhyasekaran and Thiagarajan, 1981). The soil-borne nature of the fungus has also been reported by other researchers (Nedumaran and Vidhyasekaran, 1982; Nasreen *et al.*, 1988; Kim *et al.*, 1990).

2.4 Disease management

The wilt disease being monocylic, management measures have been carried out by reducing inoculum load in/on seed or in soil.

2.4.1 Cultural methods

Management of soil-borne nature of the disease have been attempted by many researchers through manipulation of cultural practices viz., crop rotation, fallowing, field sanitation, deep ploughing, irrigation and time and method of planting (Kannaiyan and Nene, 1979; Sen, 1986; Café-Filho and Duniway, 1995; Najar, 2001). Though these practices are labour intensive, but have been found quite sustainable in management of the disease (Thurston, 1990).

2.4.2 Irrigation and method of planting

Restricted irrigation and planting on raised beds or ridges have been found to reduce wilt incidence (Dar and Mir, 1995b). A significant reduction was found in chilli wilt incidence by planting seedlings on raised beds or ridges and with less irrigation (Najar, 2001). Heavy rainfall or frequent irrigation has been found to favour phytophthora crown and root rot of bell pepper (Ristaino, 1991). Planting on 20-40 cm high ridges, where plants receive gravity water alone, help to reduce *P. capsici* infection of chilli plants compared to 10 cm ridge height (Vitanov, 1989). Irrigating the alternate furrows at longer intervals have been reported to reduce phytophthora root rot of bell pepper in California (Café-Filho and Duniway, 1995). Soil moisture, rainfall and flooding have been found to exert significant influence on inoculum build up in soil and disease severity (Bowers and Mitchell, 1990). Xie *et al.* (1999). conducted studies to determine the effects of different irrigation regimes on the development of soil-borne pathogens and their disease incidence. They found a positive relationship between disease incidence and irrigation. Influence of the furrow irrigation frequency and duration on the development of phytophthora root rot in tomatoes and bell pepper was also reported (Ristaino *et al.,* 1988; Ristaino *et al.*, 1991).

2.4.3 Soil amendments

Biological management of plant disease aims at reduction in inoculum density or pathogen activity. Among several biocontrol methods of soil-borne plant pathogens, soil amendments are one of the effective methods (Naik and Sen, 1994). Soil amendment in the form of plant debris, green manure, farmyard manure (FYM), compost, oil cakes and fertilizers are known to improve crop productivity by improving nutrient status and soil tilth, besides increasing the microbial population and activity in soil (Sivaprakasham, 1991). Augmentation of soil organic matter elucidate mechanism of biocontrol, enhance efficacy of antagonists, serve as substrate for antibiotic or toxic products by antagonists and produce inhibitory volatile substances (Papavizas and Lumsden, 1980; Lewis and Papavizas, 1985). Considerable success in the management of wilt and root rots have been achieved with cow dung and chick manure as soil amendments. The population of *F. solani* and *F. oxysporum* f.sp. *coglutinans* in soil were considerably reduced by incorporating organic matter by admixing sun dried cow dung and chopped Dhaincha leaves in soil (Chattopadhyay and Mustafee, 1978). The Fusarium wilt (*F. pallidoroseum*) of chilli was reduced by using different soil amendments viz. cow dung, sawdust, dull weed and lime. Among these soil amendments, decomposed cow dung @ 2 kg m^{-2} proved superior to other amendments in exhibiting minimum wilt incidence with increased yield (Najar *et al.*, 2006). Sweet pepper wilt (*F. oxysporum* f.sp. *vasinfectum*) was significantly managed by pig, horse and cow manure by enhancing defence against pathogens through nutritional effect (Liping *et al.*, 2002).

Padmodaya (2003) found a significant reduction in Fusarium wilt of tomato (*F. oxysporum* f.sp. *lycopersici*) under pot and field condition studies by different soil amendments viz., plant debris, green manures, farmyard manure (FYM), compost, neem cakes, pongamia cake and fertilizers. Among these soil amendments, he found a significant reduction in Fusarium wilt incidence of tomato with neem cake, farmyard manure (FYM) and pongamia cake with concomitant increase in yield.

Ashraf *et al.* (2005) found that application of organic amendments like farmyard manure and press mud in combination with seed and soil application of *T. viride* was most effective and significantly reduced root rot by improving plant growth and flower yield of African marigold plants. Lolpuri (2002) successfully managed the fungal wilt complex of eggplant (*Solanum melongena* L.) by decomposed cowdung.

2.4.4 Chemical management

Since Fusarium wilt is soil- and seed-borne, treatment of soil with fungitoxicants have yielded encouraging results. Prior to 1970s, some gaseous fumigants such as methyl bromide and cholorpicrin were the only commercially available method of vascular wilt control. Methyl bromide has proved most effective as compared to ethylene dibromide and propane-propene mixture in controlling Fusarium wilt disease (Wensley, 1953). Pepper wilt complex (*F. solani*, *R. solani* and *P. capsici*) was also controlled by application of diazomet (70 g m^{-2}) or drenching with metalaxyl @ 0.1 g m^{-2} (Ahmed *et al.*, 2000). Kapoor and Sharma (1988) obtained less wilt incidence of eggplant (*F. solani*) under field conditions with chlorothalonil root dip at transplanting and fortnightly rhizosphere drench. Carbendazim and captan rhizosphere drench completely checked *F. oxysporum* f.sp. *lycopersici* in tomato (Dwivedi and Pathak, 1981). Fusarium wilt of tomato and chilli was successfully reduced by soil drench with benomyl or MBC @ 200 mg kg^{-1} soil (Biehn and Diamond, 1970; Sen and Kapoor, 1974; Black, 2003). Moens and Ben-Aicha (1990) significantly reduced wilt incidence of pepper caused by a complex of fungi (*P. capsici*, *R. solani* and *F. solani*) by soil drenches with methan-NA, diazomet, metalaxyl and carbendazim. Singh *et al.* (1993) managed chickpea wilt (*F. oxysporum* f.sp. *ciceris*) through seed treatment with carbendazim at 2 g kg^{-1} seed. Shugha *et al.* (1995) evaluated twelve fungicides against chickpea wilt (*F. oxysporum* f.sp. *ciceris*) under *in vitro* and *in vivo* conditions. Carbendazim and thiram alone and in combination were highly effective in inhibiting mycelial growth *in vitro* and reducing wilt incidence under greenhouse and field conditions. Sharma *et al.* (2002) evaluated several fungicides against linseed wilt caused by *F. oxysporum* f.sp. *lini*) under *in vitro* conditions. The growth and sporulation of *F. oxysporum* f.sp. *lini* was completely inhibited by carbendazim in comparison with thiram. Wilt diseases of banana, guava, crossandra, carnation, gladiolus, cumin, coriander, ginger and Bengal gram caused by *Fusarium* spp. were significantly reduced by chemicals like carbendazim, benomyl, copper oxychloride (Singh and Singh, 1988; Dwivedi, 1995). A significant reduction in chilli and brinjal wilt incidence was recorded by seedling dipping and rhizosphere drench with carbendazim (Najar, 2001; Najar *et al*., 2006).

2.5 Biological management

Biological control of soil-borne plant pathogens has received tremendous attention on global level on account of the growing public concern about the health hazardous and pollutant effects of the pesticides (Ooijkass *et al.*, 1998). Plant ecosystem bestowed with a number of microorganisms, acts as competitors or antagonists to pathogens and act as viable and potent alternative to plant conventional chemicals for the management of plant diseases (Jeyarajan and Angappan, 1998).

In sustainable agriculture, biological control assumes major importance especially, where soil-borne diseases are serious (Ashwani *et al.*, 2004; Rudresh *et* *al.*, 2005; Shalini and Dohroo, 2005; Harman, 2006). Various biocontrol agents have been tried against different species of Fusarium wilt and got considerable success. Perveen *et al.* (1998) reported a considerable reduction in the infection of *F. solani* and *F. oxysporum* on pumpkin, watermelon, guar and chilli by soil application with *Paecilomyces lilacims* or *P. aeruginosa*. Apart from species of *Trichoderma* and *Gliocladium,* some other fungal antagonists like *Aspergillus niger* and *Paecilomyces* sp. have also been successfully used against Fusarium wilt diseases (Chattopadhyay and Sen, 1996; Munshi, 1998; Masoodi, 2000). Seedling dip treatment with biocontrol agents *Gliodadium* sp. and *Paecilomyces* sp. found more effective than seed treatment against Fusarium wilt (*F. pallidoroseum*) of chilli (Masoodi, 2000). For successful management, proper biocontrol agents need to be delivered in its active state in the right place at the right time. Better results of bioagents were observed when used with wheat bran than using mycelial or conidial cultures alone (Elad *et al.*, 1980).

Trichoderma has been observed as the most important antagonists against many soil-borne fungal pathogens (Papavizas and Lumsden, 1980; Papavizas, 1985; Rudresh *et al.*, 2005). The stimulation of enzyme production by *T. harzianum* to increase its antagonism and biocontrol potentiality against soil-borne pathogens has been reported by Jacob and Sivaprakasm (1994). Bioagents application as propagules in water suspension or dry powder to seed or rhizosphere soil drenching with that of *T. harzianum* and *T. viride* have resulted in significant management of the soil-borne pathogens particularly wilt causing diseases (Narismha *et al.*, 2004). Soil-borne diseases of potato, tomato, chilli and pea were significantly reduced by amending the soil with *Trichoderma* spp. and natural substrates (Sreenivasaprasad and Manibhushanrao, 1990). While evaluating four antagonists under field conditions as soil, seed and combined seed and soil treatments for the control of tomato wilt (*F. oxysporum* f.sp. *lycopersici*) found *T. harzianum, T. viride* and *G. virens* effective in controlling wilt and were at par with carbendazim (Singh *et al.*, 2004). Najar *et al.* (2006) evaluated different biocontrol agents under both *in vitro* and *in vivo* conditions against eggplant wilt (*F. solani* f.sp. *melongenae*) and reported that *Trichoderma* spp. were highly antagonistic to wilt pathogens followed by *Peecilomyces varioti* and *A. flavus*, whereas *Gliocladium roseum*, *Pseudomonas fluorescens* and *Trichothecium roseum* have proven less effective.

Rudresh *et al.* (2005) and Gupta *et al.* (2005) successfully managed the wilt complex of chickpea caused by *F. oxysporum* f.sp. *ciceri*, *R. solani, Sclerotium rolfsii*, under both *in-vitro* and *in-vivo* conditions by the use of *Trichoderma* spp. with corresponding increase in yield. Fusarium wilt of safflower (*F. oxysporum* f.sp. *carthami*) both *in-vitro* and pot culture studies were significantly reduced by the use of *Trichoderma* spp. (Pramella *et al.*, 2005).

2.5.1 Integrated management

Since wilt complex pathogens are mainly soil- and seed-borne, individual attempts for its control through fungicides as seed or soil application, cultural practices or bioagents have not shown promising results as its propagules are randomly distributed in soil and often are not in reach of the fungicides (Naik, 2003). Fungicidal seed treatment probably do not persist in effective concentrations for sufficiently long periods, further soil application of fungicides is expensive and also deleterious for associated soil microbiota (Bedlan, 1990). There are reports about the use of biocontrol agents alone, or in combination with fungicides and or with cultural practices for controlling wilt complex and root rot in chilli and capsicum (Chet, 1989; Bunker, 1995; Masoodi, 2000). In integrated disease management, all methods and sources available to the grower are used to suppress destructive soil-borne diseases as well as all economically important diseases (Jacob and Sivaprakasam, 1994).

Population of soil fungi responsible for causing seedling mortality and wilt in cabbage, chilli and brinjal have been reduced by the subsequent use for three years through integration of soil solarisation, bioagents, organic amendments and cultural practices (Champawat and Sharma, 2003). Similarly, in another investigation, population of soil-borne fungi viz., *R. solani*, *Fusarium* spp.., *Phythium* sp. and *Sclerotium* sp. were successfully managed by the use of integration of *T. viride,* copper hydroxide, captan and neem cake in pots and nursery beds (Pandey *et al.*, 2004). Landa *et al.* (2004) reported significant reduction in chickpea wilt (*F. oxysporum* f.sp. *ciceris*) by the successive use for three years of the integration of biological control agents, cultural practices, organic amendments and partial resistance genotypes.

In pot culture study Sclerotial wilt of bell pepper (*S. rolfsii*) was reduced by the integration of bioagent (*T. viride*) and neem cake as organic amendment (Chowdhary *et al.*, 2002). Bunker and Kusum (2001) observed reduction in seedling mortality due to dry root rot in bell pepper by integration with Bavistin (carbendazim) as seed treatment and soil application with *T. harzianum* and *T.*

aureoviride.

Integration of *T. harzianum* and *T. aureoviride* as seed and soil treatment was the most promising one in increasing the germination and suppression of chilli root rot pathogen. Damping off of tomato was managed by the integration of *T. viride* and farmyard manure (Neelamegam and Govindarajalu, 2002). Potato wilt (*S. rolfsii*) was managed successfully under pot culture as well as field conditions by the integration of farm yard manure and neem cake (Narasimha *et al*. 2004). Soil application of fungal antagonists viz., *T. hamatum, T. harzianum* and *T. viride* reduced brinjal wilt incidence (*F. solani*) as well as through rhizosphere drench with carbendazim. However, soil application with *T. hamatum* and seed treatment with carbendazim have shown more persistent effect on disease (Vimala *et al.*, 1994). Population of soil- borne pathogen responsible for causing fusarium wilt of muskmelon (*F. oxysporum*) was reduced under pot as well as field conditions by integration of bioagents. *A. niger* and *T. viride*, organic amendments and carbendazim with definite concomitant increase in yield (Chattopadhyay and Sen, 1996).

Rhizome rot of ginger caused by mainly *P. myriotylum* and *F. solani* was successfully managed by integration of soil application with *T. harzianum* and fungicidal rhizome treatment with carbendazim, metalaxyl-Mz and increased the efficiency of disease control as compared to the individual treatment (Ram *et al.*, 1999). The carnation wilt caused by *F. oxysporum* f.sp. *dianthi* was able to be managed under field conditions by the soil application with *T. harzianum* 14-16 days prior to the transplanting and cuttings were dipped in carbendazim at transplanting (Pratibha and Sharma, 2000). Wilt complex of French bean caused by *S. rolfsii*, *R. solani* and *F. oxysporum* under field conditions was managed by the integration of chemical and biological control methods (Mukherjee *et al.*, 2001). Pigeon pea wilt (*F. udum*) was reduced by the use of integration of chemical, biological and host resistance (Panday and Upadhyay, 1999; Mahalinga *et al.*, 2004). Similarly, wilt of linseed (*F. oxysporum* f.sp. *lini*) was successfully managed under both *in vitro* and *in vivo* conditions by the integration of Thiram and *Trichoderma* spp. (Sharma *et al.*, 2003).

Raju and Raoof (2003) reduced the castor wilt (*F. oxysporum* f.sp. *ricini*) under greenhouse and field conditions by the integration of seed dressing with carbendazim and *T. viride* incorporated in soil with a significant increase in yield.

Wilt disease complex in lentil (*R. solani, F. oxysporum, S. rolfsii* and *Macrophomina phaseolina*) was significantly reduced with corresponding increase in yield by the use of integration of chemicals (carbendazim and copper oxychloride), botanicals (neem leaf extract, marigold extract and garlic bulb extract) and muriate of potash (Sinha and Sinha, 2004).

Chapter – 3
MATERIALS AND METHODS

The present studies on the "Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir" were carried out during 2005-2006 in the laboratory as well as chill experimental field of Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar. The details of the methodology adopted are as under :

3.1 Symptomatology

Chilli (*Capsicum annuum* L.) cv. Kashmir Long 1 plants grown in plots and exhibiting wilt symptoms were selected for the study of symptom expression *in situ*. Besides, the plants exhibiting wilt symptoms were uprooted, bagged separately in polyethylene bags and immediately brought to laboratory for further studies.

3.2 Isolation and identification of pathogen

Isolations were made from lower, middle and upper portions of root system and also from vascular tract above collar region. About ½ to 1 cm plant bits were excised from plants showing typical wilt symptoms at flowering, fruit formation and ripening stages, surface sterilized with 0.1 per cent mercuric chloride for one minute followed by three consecutive rinses in sterilized distilled water and blotter dried. The bits were then aseptically transferred to potato dextrose agar (PDA) medium in petri plates, slants and incubated at $25 \pm 2^{o}C$ for 7 days. The cultures thus obtained were purified by single spore and hyphal tip isolation methods and their morphological cultural characteristic studies and the pathogen identified with the help of descriptions given by Booth (1977), Booth and Sutton (1984) and Brayford (1993). The cultures were maintained by periodical sub-culturing on freshly prepared PDA slants and stored at $4^{o}C$.

3.3 Isolation and identification of *Trichoderma viride*

Trichoderma viride was isolated from the experimental chilli field of Division of Plant Pathology SKUAST-K, Shalimar, Srinagar. Standard serial dilution technique was employed for the isolation of *T. viride*. PDA medium was used for the isolation of antagonist.

The culture thus obtained was purified by single spore and hyphal tip isolation method and their morphological/cultural characteristics studied and identified with the help of descriptions given by Rifai (1969) and Bissett (1991). Mass production of *T. viride* was done on wheatbran-sawdust medium (Anahosur, 1999).

3.4 Methodology

Wheatbran-sawdust medium (2:1:4) was used for multiplication of *T. viride* for soil application. 520 g of wheatbran-sawdust medium was filled in 1 kg capacity of 2 white polypropylene bags and sterilized at 15 lb pressure for 2 hours for two successive days. Bags were inoculated aseptically with 9 mm disc of ten days old culture of *T. viride.* The bags were incubated at 26±2^{o}C for 21 days, agitated thoroughly to allow the growth of *T. viride* uniformly. The formulation of *T. viride* was applied in soil 15 days prior to transplantation of crop at the rate of 0.16 t ha^{-1}. A light irrigation was given to maintain the desired humidity in soil for the development and multiplication of bioagent.

3.5 Bio-assay of the culture filtrate of the antagonist (*T. viride*) against the growth of *F. pallidoroseum*

3.5.1 Preparation of the culture filtrate of *T. viride*

The antagonist was seeded individually in 100 ml of sterilized (potato dextrose broth) contained in 250 Erlenmeyer conical flasks and incubated at $25\pm2^{o}C$ for 10 days. After incubation the culture was filtered separately through three layered Whatman No. 42 filter paper. The filterate was collected in sterile flasks as standard solution for bio-assay study.

3.5.2 Effect of culture filtrate of antagonist on the mycelial growth of *F. pallidoroseum*

The potato dextrose broth was prepared in 250 ml Erlenmeyer conical flasks. The standard culture filterate of antagonist @ 10, 20, 30 ml was added to 40, 30, 20 ml of sterilized broth, respectively in the flasks, so as to make the final concentration 20, 40 and 60 per cent of the culture filtrate in broth. The medium without culture filtrate was served as control. Each flask was inoculated with 9 mm mycelial disk from ten days old culture of pathogen and incubated at $25\pm2^{o}C$ for seven days. The resultant fungal growth was filtered through pre-weighed Whatman No. 42 filter paper, dried at $60^{o}C$ in hot air oven and weighed the actual dry weight of mycelium was obtained by subtracting the weight of the filter paper from the total filter paper mycelium weight.

3.6 Disease management

Studies on the management of the disease through carbendazim, *T. viride* formulation, cultural practices, besides use of the most effective organic amendment, decomposed farm yard manure (FYM) were conducted in the chilli field with history of wilt incidence.

3.6.1 Cultural practices

The effects of two different irrigation frequencies given after every 7 and 14 days in combination with planting in raised beds, on wilt development and fruit yield of chili cv. Kashmir Long 1 were studied during *kharif* 2005 in a field trial laid in RBD with 3 replications and plot size of 2 x 2 m.

3.6.2 Irrigation frequency

Two irrigations were evaluated, the frequent irrigation comprised of irrigating the plots after every 7 days, where as normal and delayed irrigated plots received irrigation after every 14 days interval. The irrigation was given with a fountain bucket at the rate of 20 l m^{-2} and the plots protected from rain with polythene sheets as and when required.

3.6.3 Soil amendment

The well decomposed organic manure, viz., farm yard manure (FYM) at 80 per cent moisture level was incorporated at the concentration 20 t ha^{-1} into the soil 10 days before transplanting of 45 day old seedling of chili cv. Kashmir Long 1 in 2 x 2 m plots in RBD with three replications with appropriate check. Except test amendment, all other cultural practices were followed as per recommendations (Anonymous, 2004).

3.6.4 Seedling dip

The root portion of the 45 days old disease free seedling of chili cv. Kashmir Long 1 were dipped in 0.1 per cent carbendazim 50 WP for 2 hours separately and water served as check in 2 x 2 m plot in RBD with three replications prior to transplanting.

3.6.5 Field evaluation

Seedling root dip treatment method in 0.1 per cent carbendazim 50 WP, soil amendment (well decomposed FYM) @ 20 t ha^{-1} and formulation of *T. viride* @ 0.16 t ha^{-1} incorporated in plot and delayed irrigation owing to its better performance in field experimentation was used in different combinations. 53 seedlings per replications per treatment was transplanted in a plot size of 2 x 2 m at a spacing of 30 x 25 cm during *kharif* 2005. Recommended dose of well decomposed FYM and NPK were applied as per package of practices (Anonymous, 2004). Observations on wilt incidence were recorded at three different growth stages viz., flowering, fruit formation and ripening stages of crop and other horticultural parameters were recorded at final fruit picking stage while fruit yield was recorded at all the pickings as given under :

a) Effect on wilt incidence

Total number of plants showing wilt symptoms till final fruit picking stage were counted and the per cent disease incidence calculated by using the following formula.

$$\text{Wilt Incidence (\%)} = \frac{\text{Number of wilted plants}}{\text{Number of plants examined}} \times 100$$

b) Other yield contributing factors

i) **Plant height (cm) :** The height of plants in each treatment from ground to the tip was recorded in centimeters at final fruit picking stage with the help of meter scale. Ten plants randomly selected from each replication were uprooted and their root length was recorded.

ii) **Fruit number plant^{-1} :** A record of fruits harvested per treatment was kept by counting the number of fruits picked from each treatment. The average number of fruits per treatment was obtained by dividing the total number of fruits with the number of plants in that treatment.

iii) **Fruit yield plant^{-1} (g) :** Fruits harvested per treatment were weighed at each picking and the weight pooled at the end of experiment to represent total fruit yield per treatment. The fruit weight plant^{-1} was determined by dividing total fruit yield per treatment with total number of plants in that treatment.

iv) **Fruit yield (q ha^{-1}) :** The fruit yield obtained plot^{-1} was converted to total fruit yield on ha^{-1}basis and expressed in q ha^{-1}.

3.7 Statistical analysis

The data obtained in different experiments were subjected in appropriate statistical analysis as per methods given by Panse and Sukhatme (1985).

Chapter – 4
EXPERIMENTAL FINDINGS

The results of various laboratory as well as field experiments conducted during 2005-2006 on "Integrated Management of Chilli Wilt [*Fusarium pallidoroseum* (Cooke) Sacc.] in Kashmir" at Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar are discussed as under :

4.1 Isolation and maintenance of pathogen

The associated pathogen isolated from root system and also from vascular tract above collar region was morphologically characterised and identified on the basis of authentic descriptions given by Booth (1977), Booth and Sutton (1984) and Brayford (1993). The purified pathogen was identified as *F. pallidoroseum* (Cooke) Sacc. and further its confirmation was made by Dr. G.M. Dar, Mycologist, Division of Plant Pathology, SKUAST-K, Shalimar, Srinagar. After purification, the culture was maintained by periodical sub-culturing on freshly prepared PDA slants stored at 4^{o}C.

4.2 Isolation of the antagonist

The antagonist was isolated from experimental chilli crop field by standard serial dilution method. PDA medium was used for the isolation of antagonist. The culture was purified, characterised, identified on the basis of authentic descriptions given by Rifai (1969) and Bisset (1991). The purified antagonist was identified as *T. viride*. After purification the culture was maintained by sub-culturing at periodic intervals and mass production of *T. viride* was done on wheatbran-sawdust medium (Plate 1).

4.3 Characterization of *T. viride*

Microscopic examination revealed that colonies of *T. viride* were initially white, but scattered dark green patches became visible after conidia formation (Table 1). Colonies were woolly and became compact with time, and covered 5-7 cm diameter medium surface after 4 days of incubation at 25 ± 1^{o}C on PDA (Plate 2). Hyphae were septate, hyaline, slender, branched and measured 2.5-3.5 µm in diameter. Conidiophores were septate, branched in pyramidal arrangement and measured 2.5-5.0 µm in diameter. Phialides were aseptate, slender to flask-shaped, inflated at the base, measured 2.0-6.0 x 2.0-4.5 µm in size, attached to the conidiophores at right angles and arranged in groups of 2-4. Conidia were aseptate, green, globose to ellipsoidal, roughened, grouped in sticky heads at the tips of phialides (Plate 3) and measured 2.0-4.0 µm in diameter. Chlamydospores were aseptate, hyaline terminal and spherical and measured 5.5-9.8 µm in diameter (Plate 4).

4.3 Disease management

4.3.1 *In-vitro* evaluation of antagonist

The method (Plate 5) evaluated for antagonism and the data on the influence of *T. viride* on the mycelial growth of pathogen *F. pallidoroseum* is presented in Table 2. The data indicated that with increase in concentration of culture filtrate of *T. viride,* there is a significant reduction in the mycelial growth of *F. pallidoroseum*. At 60 per cent concentration of culture filtrate, highest mycelial inhibition (87.59%) was recorded in comparison to 20 and 40 per cent concentrations. The same concentration of culture filtrate also resulted lowest (49.06 mg) mycelial dry weight of the *F. pallidoroseum* as compared to control (395.42 mg).

4.3.2 Effect on wilt incidence

The data on the effect of different management practices and their combinations on wilt incidence at different growth stages of chilli crop cv. Kashmir Long 1 viz., flowering, fruit formation and ripening stages is presented in Table 3. The data revealed that among the individual application of different treatments, carbendazim 50 WP @ 0.1% as seedling root dip treatment for two hours recorded minimum wilt incidence (2.00, 13.12 and 33.56%) at flowering, fruit formation and ripening stages, respectively, in comparison to check (10.20, 46.36 and 68.75%) wilt incidence. Among the dual application of treatments, carbendazim + decomposed FYM exhibited minimum wilt incidence of 1.08, 9.00, 27.53 per cent, respectively, over control. The combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM recorded least wilt incidence 0.62, 6.25, 18.15 per cent, respectively, over control. The combined application of two or more treatments showed a significant reduction in wilt incidence in comparison to control or carbendazim treated plants at different growth stages of chilli plants (Plate 6 and 7). An insight into the data (Fig. 1) showed clearly that chilli wilt is cumulative in nature. Among the various treatments and their different combinations, the combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM exhibited highest disease control.

4.3.3 Effect on yield contributing factors

4.3.3.1 Plant height (cm)

The height of chilli plants recorded separately for root and shoot portions at final fruiting picking stage for each treatment. The data (Table 4) indicated that carbendazim alone recorded maximum plant height (11.30 cm), root length and shoot height (98.90 cm) over control (9.70 cm), root length and shoot height (87.50 cm). Among the dual application of treatments, carbendazim +

decomposed FYM recorded maximum plant height by 12.37 and 105.22 cm shoot height and root length over control.

The combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM revealed highest root length and shoot height of plant (14.83 and 110.60 cm) over control (9.70 and 87.50 cm). However, the combined application of two or more treatments had a little effect on root shoot ratio.

4.3.3.2 Fruit number plant^{-1}

The results (Table 5) indicated that application of all treatments exhibited a significant increase in number of fruits plant^{-1}. The highest fruit number i.e. 32.70 fruits plant^{-1} was recorded by the *T. viride* + carbendazim + delayed irrigation + decomposed FYM followed by *T. viride* + carbendazim + decomposed FYM which resulted 31.60 fruits plant^{-1} compared to the average number of 26.40 fruits per plant recorded in control.

4.3.3.3 Effect on fresh fruit yield (q ha^{-1})

The data on the influence of different management practices and their combinations on yield in relation to wilt incidence of chilli crop cv.

Kashmir Long 1 is presented in Table 5. The data revealed that among the individual application of treatments, carbendazim alone provided maximum fruit yield of 73.25 q ha^{-1}. Among the dual application of treatments, carbendazim + decomposed FYM provided maximum fruit yield of 76.85 q ha^{-1}. The combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM resulted in maximum fruit yield of 84.25 q ha^{-1}, whileas, control gave only 42.50 q ha^{-1}. Other combined treatments also produced considerable yields of 79.50, 78.00, 75.90 q ha^{-1} as compared to the application of individual treatments and check.

An insight into the data (Fig. 2) propounded clearly that with increase in wilt incidence, the yield also decreases, and by the regression equation we can predict the yield. This is process of estimation of the variable (dependent variable i.e. Y) from the other (independent variable i.e. X). This process of estimation is often referred to as regression. If Y is to be estimated from X by means of some equation, we call the equation of Y on X and the corresponding curve a regression curve of Y on X. Here R^2 is coefficient of determination.

Chapter – 5

DISCUSSION

Soil-borne pathogens such as species of *Fusarium, Verticillium, Rhizoctonia, Sclerotium* and *Sclerotinia*, causing wilts and fruit- or collar-rots in vegetables are increasing dimensions in management of diseases (Najar, 2001; Khar, 2004). Among soil-borne diseases, wilt complex is a serious bottleneck in the profitable chilli cultivation, and is known to be caused by a number of fungal genera such as *Fusarium, Verticillium, Phytophthora* and *Rhizoctonia* in different parts of the world (Vidhyasekaran and Thiagarajan, 1981; Sarhan and Sharief, 1986; Moens and Benaicha, 1990). However, in Kashmir valley, *Phytophthora capsici, Rhizoctonia solani* and *Fusarium pallidoroseum* have been reported to be associated with chilli, *F. pallidoroseum* being quite predominant (Dar and Mir, 1995a; Najar, 2001). The disease occurs in mild to severe form in one or the other part of the valley causing considerable losses (Dar and Mir, 1995a; Najar, 2001). Since wilt complex pathogens are mainly soil and seed-borne, individual attempts for its control through fungicides as seed or soil application, cultural practices or bio-agents have not shown promising results as its propagules are randomly distributed in soil and often are not in reach of the fungicides (Naik, 2003).

Managing chilli wilt, which is soil- and seed-borne in nature, is a hard task. Various measures of wilt disease management in vogue in different parts of world aim at eliminating or at least reducing the primary inoculum in soil or in/on seed and propagating material. Integrated disease management involving, all methods and sources available to the grower to suppress destructive disease or all economically important diseases to provide acceptable yield and quality at the minimum cost (Jacob and Sivaprakasam, 1994). Establishing the status and the resultant yield losses of the disease are the pre-requisites for deciding at the adoption of integrated disease management practices. Keeping this in view, an effort has been made to interpret the results obtained in the light of available literature.

Identification of isolated antagonist was done on the basis of morphological and cultural characteristics and were compared with authentic descriptions given by Rifai (1969) and Bissett (1991). Under *in vitro* conditions efficacy of *T. viride* against *F. pallidoroseum* was done by culture filtrate method. The data indicated that with increase in concentration of culture filtrate of *T. viride* caused a significant reduction in the mycelial growth of *F. pallidoroseum*. At 60 per cent concentration of culture filtrate, highest (87.59%) mycelial inhibition was recorded followed by 40 and 20 per cent concentrations, respectively over control. Similar findings have been observed by Mukherjee *et al.* (2001). It has been established that *Trichoderma* spp. inhibit pathogenic invasion through phenomena of mycoparasitism, antibiosis, competition, lysis of pathogenic hyphae, production of organic metabolites – glitoxin, cellulose, β-(1-3)-glucanase, chitinase and volatile inhibitory substance like acetaldehyde (Elad *et al.*, 1980; Bell *et al.*, 1982; Stayaprasad *et al.*, 1998; Bunker and Kusum, 2001).

During the present study, it was observed that the data indicated a significant reduction in wilt incidence at flowering, fruit formation and ripening stages of crop due to individual, dual and combined application of different treatments over control. The combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM depicted highest reduction in wilt incidence 0.62, 6.25 and 27.53 per cent followed by *T. viride* + carbendazim + decomposed FYM at different stages of crop respectively over control. Similar results have been reported by other researchers in chilli and other Solanaceous crops (Bunker, 1995; Bunker and Kusum, 2001; Najar, 2006). Augmentation of soil organic matter elucidate mechanism of biocontrol, enhance efficacy of antagonists serve as substrate for antibiotic or toxic products and also produce inhibitory volatile substances, improving nutrient status and soil tilth (Papavizas and

Lumsden, 1980; Lewis and Papavizas, 1985). Carbendazim inhibiting mycelial growth and sporulation of *Fusarium* spp. (Singh and Singh, 1988 and Dwivedi, 1995). Restricted irrigation and planting on raised beds or ridges have been tried and found a significant reduction in inoculum build in soil and disease severity (Bowers and Mitchell, 1990; Ristaino, 1991; Najar, 2001).

Plant height is an important growth characteristic as it determines the vigour of the plant. The data on the plant height viz., root length and shoot height clearly indicated that there was a significant increase in root length and shoot height over control due to application of different treatments. Among the various treatments, combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM recorded highest increase of 14.83 and 110.60 cm root length and shoot height of plant, respectively over control. The results corroborate with the findings of several other researchers (Masoodi, 2000; Khar, 2004; Najar, 2006). Increased growth of plants by bioagent treatments in combination with soil amendments have been reported as an added advantage, while pathogenic infection leads to the production of toxic metabolites which adversely affect plant growth (Mongia, 1996; Khar, 2004).

The results indicated that application of different treatments did exhibit a significant effect on the number of fruits plant^{-1} as compared to average number of 26.40 fruits plant^{-1} recorded in control. The number from treated plants ranged between 26.90-32.70 fruits plant^{-1}. The results are in consonance with that of findings of Khar (2004) and Najar (2006).

Application of different treatments revealed reduction in wilt incidence with corresponding increase in growth and fruit yield in comparison to control. The data revealed that among the individual application of treatments, carbendazim proved the best in providing maximum fruit yield of 73.25 q ha^{-1}. Among the combined application of two or more treatments, *T. viride* + carbendazim + delayed irrigation + decomposed FYM provided maximum fruit yield of 84.25 q ha^{-1} in comparison to control (42.50 q ha^{-1}). The above findings are confirmatory with the findings of other researchers (Vimla *et al.*, 1994; Bunker and Kusum, 2001; Khar, 2004; Najar, 2006).

Field trials conducted earlier by other workers (Ramanathan and Sivaprakasham, 1994; Kaur, 1999; Najar, 2001; Khar, 2004) using various bioagent in combination with different amendments have also mentioned advantageous effects on yield, biomass and management of pathogen(s). Integration of chemicals, cultural practices and soil application of antagonists was found compatible and synergistic (Patibanda *et al.*, 2002).

A meaningful, realistic and integrated combination of different prophylactic, cultural and protective measures for managing chilli wilt incidence with corresponding yield gains can be adopted in an eco- and economic-friendly manner, as brought out in the course of present investigations, for successful management of the disease.

Chapter – 6
SUMMARY AND CONCLUSION

The investigation entitled "Integrated Management of Chilli Wilt [*Fuarium pallidroseum* (Cooke) Sacc] in Kashmir", was carried out during 2005-2006 in the laboratory and experimental chilli field of Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar.

Under *in vitro* conditions, efficacy of *T. viride* against *F. pallidoroseum* was performed by culture filtrate method. Different concentrations of culture filtrate were used, of which 60 percent concentration showed highest mycelial inhibition of 87.59 per cent over control. Field experiments were conducted under Randomised Block Design with sixteen treatments and three replications. The combined treatments were found superior over individual treatments. The combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM recorded least wilt incidence of 0.62, 6.25, 27.53 per cent at flowering, fruit formation and ripening stages of chilli crop, respectively, over control. Among the individual application of different treatments, carbendazim recorded least wilt incidence of 2.00, 13.12 and 33.56 per cent at flowering, fruit formation and ripening stages, respectively, over control. However, individual application of *T. viride* followed by delayed irrigation were found least effective in controlling wilt incidence.

Combined application of *T. viride* + carbendazim + delayed irrigation and decomposed FYM exhibited highest root length and shoot height of 14.83 and 110.60 cm over control, whileas, *T. viride* and delayed irrigation treatments exhibited least affect on root and shoot length of plant.

Application of different treatments exhibited a significant increase of 26.90-32.70 fruits plant^{-1} as compared to the average number of 26.40 fruits recorded in control.

Moreover, fruit yield was significantly varying among different treatments. Application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM showed highest fruit yield of 84.25 q ha^{-1} followed by *T. viride* + carbendazim + decomposed FYM (79.50 q ha^{-1}). Among the individual application of treatments, carbendazim exhibited maximum fruit yield of 73.25 q ha^{-1} followed by decomposed FYM (61.31 q ha^{-1}) in comparison to control (42.50 q ha^{-1}).

Thus from the present findings it can be concluded that combined application of *T. viride* + carbendazim + delayed irrigation + decomposed FYM reduced the wilt incidence and increased yield of chilli crop significantly. Among the dual application of treatments, carbendazim + decomposed FYM and individual application of carbendazim significantly reduced wilt incidence with corresponding increase in fruit yield. Therefore, integrated disease management practices like cultural, biological and chemical can be considered efficacious in sustainability of chilli crop in the valley and may be recommended to the farmer for keeping the socio-economic and ecological balance into consideration.

Table 3. Effect of different management practices and their combinations on wilt incidence (%)of chilli crop cv. Kashmir Long 1

Treatment No.	Treatments	Wilt incidence (%)		
		Flowering	**Fruit formation**	**Ripening**
1.	***TRICHODERMA VIRIDE SOIL APPLICATION @ 0.16 T HA^{-1}***	5.35 (2.31)+	28.43 (32.2)**	50.00 (44.98)**
2.	Carbendazim 50 WP seedling root dip for 2 hours @ 0.1%	2.00 (1.41)	13.12 (21.22)	33.56 (35.37)
3.	Irrigation after 14 days	6.20 (2.48)	30.82 (33.70)	52.20 (46.25)
4.	Decomposed FYM soil amendment @ 20 t ha^{-1}	3.75 (1.93)	24.76 (29.82)	48.25 (43.98)
5.	*T. viride* + Carbendazim 50 WP	1.43 (1.19)	11.25 (19.57)	31.90 (34.37)
6.	*T. viride* + Irrigation	4.20 (2.04)	26.80 (31.15)	49.50 (44.69)
7.	*T. viride* + Decomposed FYM	3.10 (1.76)	22.16 (28.06)	40.20 (39.33)
8.	Carbendazim 50 WP + Irrigation	1.75 (1.32)	12.50 (20.70)	32.10 (34.49)
9.	Carbendazim 50 WP + Decomposed FYM	1.08 (1.03)	9.00 (17.44)	27.53 (31.63)
10.	Irrigation + Decomposed FYM	3.49 (1.86)	23.50 (28.97)	45.12 (42.18)
11.	*T. viride* + Carbendazim 50 WP + Irrigation	1.20 (1.09)	10.95 (19.30)	29.50 (32.88)
12.	*T. viride* + Carbendazim 50 WP + Decomposed FYM	0.93 (0.96)	7.25 (15.60)	21.63 (27.48)
13.	Carbendazim 50 WP + Irrigation + Decomposed FYM	1.02 (1.00)	8.92 (17.36)	24.25 (29.48)
14.	Irrigation + Decomposed FYM + *T. viride*	2.95 (1.71)	20.39 (26.82)	36.75 (37.30)
15.	*T. viride* + Carbendazim 50 WP + Irrigation + Decomposed FYM	0.62 (0.78)	6.25 (14.46)	18.15 (25.20)
16.	Control	10.20 (3.19)	46.36 (42.89)	68.75 (56.07)
	CD (p=0.05)	**(0.10)**	**(1.57)**	**(2.96)**

+ Figures in parenthesis are square root transformed values

** Figures in parenthesis are arc sine transformed values

Table 5. Effect of different management practices and their combinations on yield in relation to wilt incidence of chilli crop cv. Kashmir Long 1

Treatment No.	Treatments	No. of fruits/ plant	Fruit weight		Yield (q ha^{-1})
			Per plant (g)	Per plot (2 x 2 m) (kg)	
1.	**TRICHODERMA VIRIDE *SOIL APPLICATION @ 0.16 T HA^{-1}***	26.90*	43.20*	2.29*	57.25*
2.	Carbendazim 50 WP seedling root dip for 2 hours @ 0.1%	29.70	55.28	2.93	73.25
3.	Irrigation after 14 days	26.10	42.26	2.24	56.00
4.	Decomposed FYM soil amendment @ 20 t ha^{-1}	29.40	26.22	2.45	61.31
5.	*T. viride* + Carbendazim 50 WP	27.80	56.41	2.99	74.75
6.	*T. viride* + Irrigation	27.20	44.53	2.36	59.00
7.	*T. viride* + Decomposed FYM	29.70	47.35	2.51	62.75
8.	Carbendazim 50 WP + Irrigation	28.20	55.66	2.95	73.75
9.	Carbendazim 50 WP + Decomposed FYM	30.33	57.92	3.07	76.85
10.	Irrigation + Decomposed FYM	29.70	47.17	2.50	62.50
11.	*T. viride* + Carbendazim 50 WP + Irrigation	30.20	57.28	3.036	75.90
12.	*T. viride* + Carbendazim 50 WP + Decomposed FYM	31.60	60.00	3.18	79.50
13.	Carbendazim 50 WP + Irrigation + Decomposed FYM	29.90	58.86	3.12	78.00
14.	Irrigation + Decomposed FYM + *T. viride*	29.89	48.67	2.58	64.50
15.	*T. viride* + Carbendazim 50 WP + Irrigation + Decomposed FYM	32.70	63.58	3.37	84.25
16.	Control	26.40	32.07	1.70	42.50

CD (p=0.05)	0.51	2.59	0.13	0.79

* Means of three replications

Table 4. Effect of different management practices and their combinations on root and shoot length of chilli crop cv. Kashmir Long 1

Treatment No.	Treatments	*Root length (cm)	*Shoot height (cm)	Root/Shoot ratio
1.	***TRICHODERMA VIRIDE SOIL APPLICATION @ 0.16 T HA^{-1}***	10.20	91.46	0.11
2.	Carbendazim 50 WP seedling root dip for 2 hours @ 0.1 %	11.30	98.90	0.114
3.	Irrigation after 14 days	9.98	84.20	0.118
4.	Decomposed FYM soil amendment @ 20 t ha^{-1}	10.48	94.72	0.110
5.	*T. viride* + Carbendazim 50 WP	11.84	100.90	0.117
6.	*T. viride* + Irrigation	10.85	91.77	0.118
7.	*T. viride* + Decomposed FYM	10.35	93.55	0.110
8.	Carbendazim 50 WP + Irrigation	11.45	100.40	0.114
9.	Carbendazim 50 WP + Decomposed FYM	12.37	105.22	0.117
10.	Irrigation + Decomposed FYM	10.59	94.10	0.112
11.	*T. viride* + Carbendazim 50 WP + Irrigation	11.98	104.16	0.115
12.	*T. viride* + Carbendazim 50 WP + Decomposed FYM	13.50	108.56	0.124
13.	Carbendazim 50 WP + Irrigation + Decomposed FYM	12.86	106.18	0.121
14.	Irrigation + Decomposed FYM + *T. viride*	10.88	96.20	0.113
15.	*T. viride* + Carbendazim 50 WP + Irrigation + Decomposed FYM	14.83	110.60	0.134
16.	Control	9.70	87.50	0.110

CD (p=0.05)	**0.62**	**4.75**	**-**

* Means of three replications

Table 2. Effect of culture filtrate of *Trichoderma viride* on the mycelial growth of *Fusarium pallidoroseum*

Treatment No.	**Concentration of the culture filtrate (%)**	***Mycelial dry weight (mg)**	**Inhibition over control (%)**
1.	***20***	145.57	63.18
2.	***40***	113.47	71.30
3.	***60***	49.06	87.59
4.	***Control***	395.42	-
	CD (p=0.05)	**103.19**	**-**

*Means of five replications

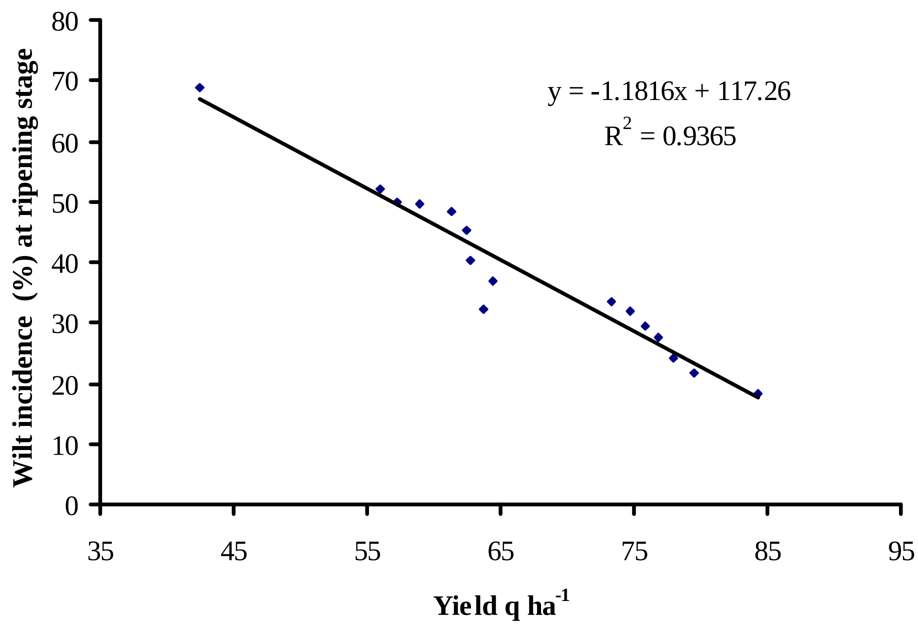
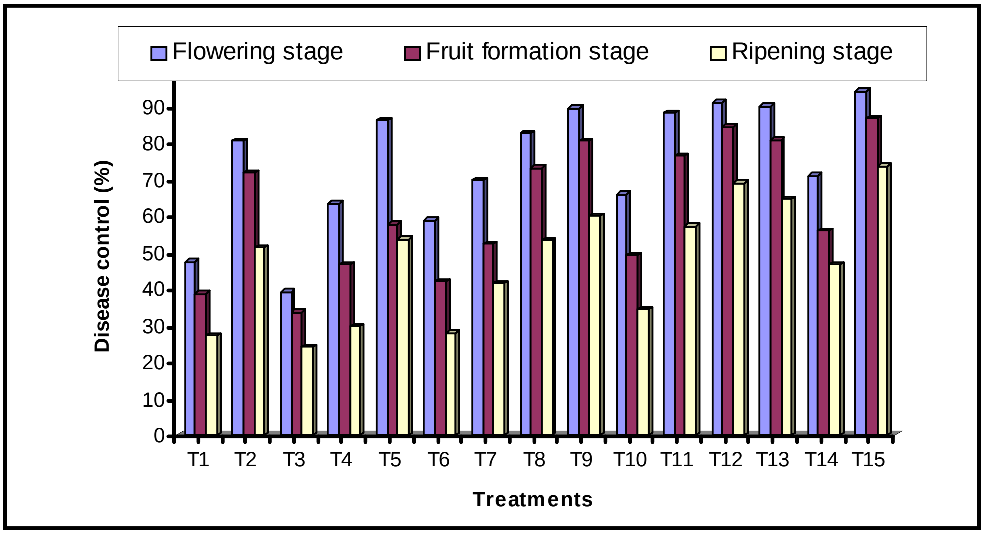


Fig. 2. Yield in relationship with per cent wilt incidence

Table 1. Morphological characteristics of *Trichoderma viride* Pers. Ex Gray

Fungal propagule	**Colour**	**Shape**	**Size**	**Septation**
Colonies	Initially white; but, scattered dark green patches became visible after conidial formation	Grows rapidly, colonies are woolly and become compact with time	5-7 cm dia. after 4 days at 25 °C on PDA	-
Hyphae	Hyaline	Slender, branched	2.5-3.5 µm (wide)	Septate
Conidiophores	Hyaline	Branched in pyramidal arrangement	2.5-5.0 µm (wide)	Septate
Phialides	Hyaline	Slender or flask shaped, inflated at the base; attached to the conidiophores at right angles; arranged in groups of 2-4.	2.0-6.0 x 2.0-4.5 µm	Aseptate
Conidia	Green	Globose to ellipsoidal, roughened, grouped in sticky heads at the tips of phialides	2.0-4.0 µm in diameter	Aseptate
Chlamydospores	Hyaline	Terminal, spherical	5.5-9.8 µm in diameter	Aseptate



T_1 = *T. viride;* T_2 = Carbendazim 50 WP; T_3 = Irrigation after 14 days; T_4 = Decomposed FYM

Fig. 1. Effect of different management practices and their combinations on the control of chilli wilt at different growth stages of chilli crop cv. Kashmir Long 1.

Plate 1. Mass production of *T. viride* on wheatbran-sawdust medium

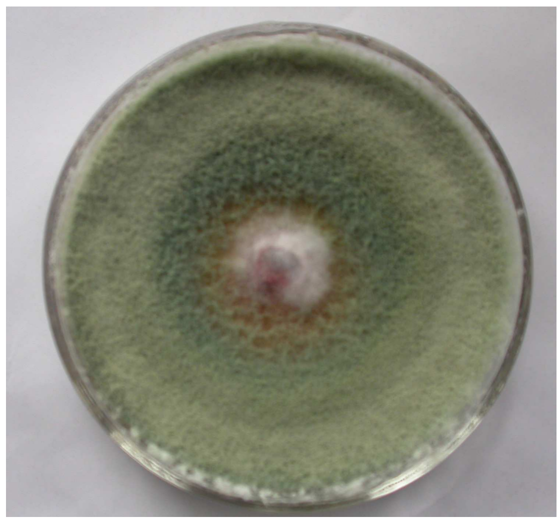


Plate 2. Mycelial growth of *T. viride* on PDA

Plate 3. Conidiophores alongwith conidia at 450x

Plate 4. Chlamydospores at

Plate 5. Effect of culture filtrate of *T. viride* on the mycelial growth of *F. pallidoroseum*

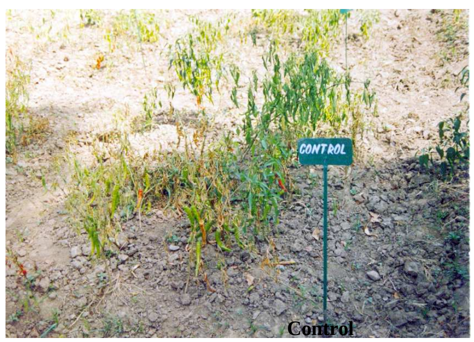
Plate 6. An overview of the field trial showing effect of different disease management practices and their combinations on growth of chilli crop and suppression of Fusarial wilt

***T. viride*+ carbendazim+irrigation+ decomposed FYM**

***T. viride*+ carbendazim+ decomposed FYM**

Carbendazim+ decomposed FYM

Carbendazim



Control

Plate 7. **Effect of some disease management practices and their combinations on wilt incidence and fruit yield of chilli**

LITERATURE CITED

Ahmed, S., Hamid, K., Tariq, A.H. and Jamil, F.F. 2000. Chemical control of root and collar rot of chillies. *Pakistan Journal of Phytopathology* **12** : 1-5.

Anahosur, K.H. 1999. Management of plant disease through antagonist, pp 38-56. **In** : *Recent Advances in Plant Pathology* (Eds. J.G. Vaidya and S.Y. Kamble). Department of Botany, University of Pune.

Anonymous, 1993. *Annual Progress Report – 1993*. Division of Plant Pathology, SKUAST-K, Shalimar, Srinagar, p. 44.

Anonymous, 2004. *Information on Vegetables, Spices and Tubers of Kashmir Division*. Directorate of Agriculture, Kashmir, J&K Government.

Anonymous, 2004. *Production Recommendations for Vegetables (Kashmir Division)*. Directorate of Extension Education, SKUAST-K, Shalimar, Srinagar, p. 95.

Anonymous, 2005. *Agricultural Research Data Book*. Indian Agricultural Statistics Research Institute, New Delhi. p. 154.

Ashraf, M., Bhat, Z.A., Hussain, B., Bhat, M.A., Ahmed, M. and Khan, F.U. 2005. Influence of organic amendments and *Trichoderma viride* on root rot incidence, growth and flowering parameters in African Marigold. *Progressive Horticulture* **37** : 434-436.

Ashwani, T., Sharma, Y.P. and Lakhanpal, T.N. 2004. Effect of volatile compounds released by *Gliocladium virens* and *Trichoderma* spp of the growth of *Dematophora necatrix. Journal of Mycology and Plant Pathology* **34** : 37-40.

*Babay, D.N. and Shakhnubaryan, S.T. 1969. Presence of infection by fungal wilt in the seeds of tomato, pepper and eggplant under conditions of the Ararat Plain. *Uchen-Zap, Erevan, University* **1** : 136-147 [cf : *Review of Plant Pathology* **49** : 355].

Basak, A.B., Fabir, G.A. and Maridha, M.A.U. 1998. Relation of seed-borne infection to different infection grades in fruit rot disease of chilli. *Seed Research* **24** : 30-69.

Beckman, C.H. 1987. Nature of wilt disease. *American Phytopatho-logical Society*, St. Paul, Minnesota, USA, p. 174.

*Bedlan, G. 1990. Soil-borne diseases of capsicum and their control. *Pflanzennschuts* (Wein) **5** : 4-5 [cf : *Review of Plant Pathology* **70** : 661].

Bell, D.K., Wells, H.D. and Markhan, C.R. 1982. *In vitro* antagonism of *Trichoderma* spp against six fungal pathogens. *Phytopathology* **72** : 379-382.

Biehn, W.L. and Diamond, A.E. 1970. Reduction of tomato Fusarium wilt symptoms by benomyl and correlation with bioassay of fungitoxicant in benomyl-treated plants. *Plant Disease Reporter* **54** : 12-14.

Bissett, J. 1991. A revision of the genus *Trichoderma*. *Canadian Journal of Botany* **69** : 2373-2417.

Black, L.L. 2003. Fusarium wilt. pp 14-18. **In** : *Compendium of Pepper Diseases*. American Phytopathological Society Press, St. Paul, Minnesota, USA.

Booth, C. 1977. *Fusarium - Laboratory Guide to Identification of Major Species.* Commonwealth Mycological Institute, Kew, Surrey, UK, p. 58.

Booth, C. and Sutton, B.C. 1984. *Fusarium pallidoroseum*, the correct name for *Fusarium semitectum*. *Transactions of the British Mycological Society* **83** : 702-704.

Bowers, J.H. and Mitchell, D.J. 1990. Effect of soil water matric potential and periodic flooding on mortality of pepper caused by *Phytophthora capsici*. *Phytopathology* **80** : 1447-1450.

Brayford, D. 1993. *The Identification of Fusarium Species*. International Mycological Institute, Kew, Surrey, UK. p. 27.

Bunker, R.N. 1995. *Integrated Management of Root-rot of Chilli caused by Rhizoctonia solani* Kühn. M.Sc thesis, submitted to Rajasthan Agricultural University, Bikaner Campus, Udaipur. p. 98.

Bunker, R.N. and Kusum, M. 2001. Integration of biocontrol agents and fungicides for suppression of dry root rot of *Capsicum frutescens. Journal of Mycology and Plant Pathology* **31** : 330-334.

Café-Filho, A.C. and Duniway, J.M. 1995. Effect of furrow irrigation schedules and host genotypes on Phytophthora root rot of pepper. *Plant Disease* **79** : 39-43.

Camino, V., Despestre, T. and Espinosa, J. 1987. Search for *Capsicum annuum* susceptibility to *Fusarium*. *Capsicum Newsletter* **6** : 70.

Champawat, R.S. and Sharma, R.S. 2003. Integrated management of nursery disease in brinjal, chilli, cabbage and onion. *Journal of Mycology and Plant Pathology* **2** : 290-291.

Chattopadhyay, C. and Sen, B. 1996. Integrated management of Fusarium wilt of muskmelon caused by *F. oxysporum*. *Indian Journal of Mycology and Plant Pathology* **26** : 162-170.

Chattopadhyay, S.B. and Mustafee, T.P. 1978. Influence of organic amendments on the growth of soil inhibiting fungal pathogens. *Indian Journal of Microbiology* **18** : 69-70.

*Chaves, B.A. 1947. Principais doencas das plants en nordeste. Brazil. *Bollettino Agriculture Pernambuco* **14** : 5-46 [cf : *Review of Applied Mycology* **26** : 481].

Chet, I. 1989. *Innovative Approaches to Plant Disease Control*. John Willey and Sons, New York, USA. p. 250.

Chowdhary, K.A., Reddy, D.R., Reddy, T.B. and Reddy, I.P. 2002. Integrated management of Sclerotial wilt of bell pepper. *Indian Journal of Plant Protection* **28** : 115-118.

Chupp, C. and Sherf, A.F. 1960. *Vegetable Diseases and their Control*. John Wiley and Sons, New York, USA. p. 693.

*Cifferi, R. 1926. Primer informe, annual de la estacion Agron. U. col. De. Agric. *Dettaina. Republica Dominicana* **1** : 27-36 [cf : *Review of Applied Mycology* **6** : 600].

Dar, G.M. and Mir, N.A. 1995a. Pepper wilt, causes and prevalence in Kashmir. (Abstract). p. 43. **In** : *National Symposium on Recent Trends in the Management of Biotic and Abiotic Stresses in Plants* held at HPKVV, Palampur (H.P.).

Dar, G.M. and Mir, N.A. 1995b. Studies in the management of chilli wilt in Kashmir (Abstract). p. 43. **In** : *National Symposium on Recent Trends in the Management of Biotic and Abiotic Stresses in Plants* held at HPKVV, Palampur (H.P).

Doolittle, S.P. 2005. Diseases of peppers, pp 131-136. **In** : *Diseases of Vegetable Crops* (Ed. Alfred Steferud). Biotech Books, New Delhi, India.

Dwivedi, R.S. and Pathak, S.P. 1981. Effect of certain chemicals on population dynamics of *Fusarium oxysporum* f.sp. *lycopersici* in tomato field soil. *Proceedings of Indian National Science Academy* **47** : 751-755.

Dwivedi, S.K. 1995. Effect of fungicides on wilt guava seedlings. *National Academy Science Letters* **12** : 129-130.

Elad, Y., Chet, I. and Kattan, J. 1980. *Trichoderma harzianum* – a biocontrol agent effective against *Sclerotium rolfsii* and *Rhizoctonia solani*. *Phytopathology* **70** : 119.

Fernadez, M.C. 1983. *Phytophthora capsici*, causal agent of wilt of *Capsicum annuum*. *Agricultura Technica* **43** : 91-93.

Gupta, S.B., Thakur, K.S., Anup, S., Thamarakar, D.K. and Thakur, M.P. 2005. Efficacy of *Trichoderma viride* and *Rhizobium* against wilt complex of chickpea in field. *Journal of Mycology and Plant Pathology* **35** : 89-92.

Harman, G.E. 2006. Overview of mechanisms and uses of *Trichoderma* spp. *Phytopathology* **96** : 190-194.

Hashmi, M.H. 1989. Seed-borne mycoflora of *Capsicum annuum* L. *Pakistan Journal of Botany* **21** : 302-308.

Jacob, C.K. and Sivaprakasam, K. 1994. Evaluation of some plant extracts and antagonists for the control of emergence damping off of brinjal. pp 289-294. **In** : *Crop Diseases, Innovative Techniques and Management* (Eds. K. Sivaprakasam and K. Seetharaman). Kalyani Publishers, New Delhi, India.

Jeyarajan, R. and Angappan, K. 1998. Mass production technology for fungal antagonists and field evaluation. pp 48-58. **In** : *Biological Control of Plant Diseases, Phytoparasitic Nematodes and Weeds* (Eds. S.P. Singh and S.S. Hussaini). Project Directorate of Biological Control, Bangalore, Karnataka, India.

Jones, J.P. and Overman, A.J. 1978. Evaluation of chemicals for the control of Verticillium and Fusarium wilt of tomato. *Plant Disease Reporter* **62** : 451-455.

Kannaiyan, J. and Nene, Y.L. 1979. Effect of crop rotation and planting time on the incidence of wilt in Lentil. *Indian Journal of Plant Protection* **7** : 114-118.

Kapoor, K.S. and Sharma, S.R. 1988. Soil application of fungicides against wilt of eggplant. *Capsicum Newsletter* **7** : 90-91.

Kaur, P. 1999. Non-chemical management of pea wilt/root rot complex – A case study, pp 112-118. **In** : *National Symposium on 'Plant Disease Scenario under Changing Agro-ecosystems'* 29-30 Oct, HPKVV, Palampur, India.

Kaur, S. 1993. Fusarium wilt a cause of chilli crop failure in Punjab. *Plant Disease Research* **8** : 181-183.

Khar, M.S. 2004. *Biological Control of Fusarium solani* f.sp. *melongenae Incitant of Brinjal Wilt in Kashmir*. M.Sc thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. p. 60.

Kim, K.Y., Park, S.K., Shin, Y.A. and Lee, E.J. 1990. Survey on the actual condition of cultural methods and continuous cultivation injury of red pepper in field. *Acta Horticulturae* **32** : 1-10.

Landa, B.B., Navas, Cortes, J.A. and Jimenez-Diaz, R.M. 2004. Integrated management of Fusarium wilt of chickpea with sowing date, host resistance and biological control. *Phytopathology* **94** : 946-960.

Lewis, J.A. and Papavizas, G.C. 1985. Effects of mycelial preparations of *Trichoderma* and *Gliocladium* on population of *Rhizoctonia solani* and the incidence of damping off. *Phytopathology* **75** : 812-817.

Liping, Ma., Xiong Wu-Qiao., Fen-Goa., Biang-Qing, Hao., Qiao-XU., Gao, F. and Hao, B.Q. 2002. Control of sweet pepper Fusarium wilt with compost extracts and its mechanisms. *Chinese Journal of Applied and Environmental Biology* **7** : 84-87.

Lolpuri, Z.A. 2002. *Management of Fungal Wilt Complex of Brinjal* (*Solanum melongena* L.). M.Sc thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. p. 63.

Mahalinga, D.M., Jayalaksmi, S.K. and Gangadhara, G.C. 2004. Management of pigeonpea wilt through integration of bioagents and resistant sources. *Plant Disease Research* **19** : 181-182.

Masoodi, M.A. 2000. *Biological Management of Chilli Wilt* [*Fusarium pallidoroseum* (Cooke) Sacc.] *in Kashmir*. M.Sc thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. p. 49.

McRae, N. 1932. *Science Report for 1930-31*. Imperial Institution of Agriculture, Research, Pusa, India. p. 84.

Moens, M. and Benicha, B. 1990. Control of pepper wilt in Tunisia. *Parasitica* **46** : 103-109.

Mongia, K. 1996. *Studies on Wilt Disease of Chillies (Capsicum annuum* L.). Ph.D thesis, submitted to the Faculty of Postgraduate Studies, Haryana Agricultural University, Hissar. p. 100.

Mukherjee, S., Tripathi, H.S. and Rathi, Y.P.S. 2001. Integrated management of wilt complex in French bean (*Phaseolus vulgaris* L.). *Journal of Mycology and Plant Pathology* **31** : 213-215.

Munshi, N.A. 1998. *Studies on the Fusarial Blight of Mulberry*. Ph.D thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, pp 45-50.

Muthukrishnan, C.R., Thangaraj, T., Chatterjee, R. and Maity, T.K. 2002. Capsicum and chilli, pp 204-261. **In** : *Vegetable Crops* volume 1 (Eds. T.K. Bose, J., Kabir, T.K. Maity, V.A. Parthasarathy and M.G. Som). Naya Porkash, Kolkata, India.

Naik, M.K. 2003. Challenges and opportunities for research in soil-borne plant pathogens with special reference to Fusarium species. *Journal of Mycology and Plant Pathology* **33** : 1-14.

Naik, M.K. and Sen, B. 1994. Effectiveness of different soil amendments against a spectrum of Fusarium isolates causing wilt of watermelon. *Indian Journal of Plant Protection* **21** : 19-22.

Najar, A.G. 2001. *Cause and Management of Chilli Wilt in Kashmir*. Ph.D thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar. p. 159.

Najar, A.G., Mushtaq Ahmad, Shafi, M.B. and Bhat, Z.A. 2006. Effect of various soil amendments on chilli wilt. *SKUAST Journal of Research* **8** : 236-239.

Najar, A.G., Shafi, M., Mushtaq Ahmad, Shafi, M.B. and Bhat, Z.A. 2006. Comparative efficacy of different biocontrol agents for control of Fusarium wilt of brinjal. *SKUAST Journal of Research* **8** : 33-37.

Narasimha Rao, S., Anahosur, K.H. and Kulluarni, S. 2004. Eco-friendly approaches to management of wilt of potato. *Journal of Mycology and Plant Pathology* **34** : 327-329.

Nash, S.M., Christou, T. and Synder, W.C. 1961. Existence of *Fusarium solani* f.sp. *phaseoli* as chlamydospores in soil. *Phytopathology* **51** : 303-312.

*Nasreen, S., Khan, S.A.J. and Khanzada, A.K. 1988. A new fusarium wilt of okra in Pakistan. *Pakistan Journal of Scientific and Industrial Research* **31** : 577-578 [cf : *Review of Plant Pathology* **70** : 131].

Nedumaran, S. and Vidhyasekaran, P. 1982. Damage caused by *Fusarium semitectum* in tomato. *Indian Phytopathology* **35**:322-323.

Neelamegam, R. and Govindarajalu, T. 2002. Integrated application of *Trichoderma viride* and farmyard manure to control damping off of tomato. *Journal of Biological Control* **16** : 65-69.

*Nikolaeva, V. 1978. Results of trials of chemical preparations in the control of the pathogen of Fusarium wilt of tomato in the glasshouse. *Lozarska Nauka* **15** : 66-71 [cf : *Review of Plant Pathology* **58** : 5020].

Ooijkaas, L.P., Thamper, J. and Buitelaar, R.M. 1988. Biomass estimation of *Coniothyrium minitaus* in solid state fermentation. *Enzyme Microbiological Technology* **26** : 355-361.

Padmodaya, B. 2003. Effect of soil amendments at different concentrations and incubation periods of decomposition against Fusarium wilt of tomato. *Journal of Mycology and Plant Pathology* **33** : 317-319.

Pandey, K.K. and Upadhyay, J.P. 1999. Comparative study of chemical, biological and integrated approach for management of Fusarium wilt of pigeonpea. *Journal of Plant Pathology* **29** : 214-216.

Pandey, K.K., Pandey, P.K. and Mishra, K.K. 2004. Integrated disease management of vegetable nursery. *Vegetable Science* **31** : 45-50.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, India. p. 347.

Papavizas, G.C. 1985. *Trichoderma* and *Gliocladium* their biology, ecology and potential of biocontrol. *Annual Review of Phytopathology* **23** : 23-47.

Papavizas, G.C. and Lumsden, R.D. 1980. Biological control of soil-borne fungal propagules. *Annual Review of Phytopathology* **18** : 389-413.

Patibanda, A.K., Upadhyay, J.P. and Mukhopadhyay, A.A. 2002. Efficacy of *Trichoderma harzianum* alone or in combination with fungicides against Sclerotium wilt of groundnut. *Journal of Biological Control* **16** : 57-63.

Perveen, S., Ehteshamul Haque, S., Ghaffar, A. 1998. Efficacy of *Pseudomonas aeruginosa* and *Paecilomyces lilancinus* in the control of root rot, root knot disease complex on some vegetables. *Nematologia Mediterranea* **26** : 209-212.

Prameela, M., Rajeswari, B., Prasad, D.R. and Reddy, D.R.R. 2005. Bioefficacy of antagonists against *Fusarium oxysporum* f.sp. *carthami* isolates inciting safflower wilt. *Journal of Mycology and Plant Pathology* **35** : 272-274.

Pratibha, S. and Sharma, P. 2000. An integrated approach for the management of carnation wilt caused by *Fusarium oxysporum* f.sp. *dianthi*. *New Botanist* **27** : 1-4.

Raju, M.R.B. and Raoof, M.A. 2003. Integrated approach for the management of castor wilt (*Fusarium oxysporum* f.sp. *ricini*). *Indian Journal of Plant Protection* **31** : 64-67.

Ram, P., Mathur, K. and Lodha, B.C. 1999. Integrated management of Rhizome rot of ginger involving biocontrol agents and fungicides. *Journal of Mycology and Plant Pathology* **29** : 416-420.

Ramnathan, A. and Sivaprakasam, K. 1994. Effect of seed treatment with antagonists and fungicides on seed viability and seedling vigour of chilli. pp 251-254. **In** : *Crop Diseases Innovative Techniques and Management* (Eds. Sivaprakasam, K. and Seethdraman, K.). Kalyani Publishers, New Delhi, India.

Rifai, M.A. 1969. A revision of the genus *Trichoderma. Mycological Papers* **116** : 1-56.

Ristaino, J.B. 1991. Influence of rainfall, drip irrigation and inoculum density on development of Phytophthora rot and crown rot epidemics and yield in bell pepper. *Phytopathology* **81** : 922-929.

Ristaino, J.B., Duniway, J.M. and Marois, J.J. 1988. Influence of frequency and duration of furrow irrigation on the development of Phytophthora root rot and yield in processing tomatoes. *Phytopathology* **78** : 1701-1706.

Rudresh, D.K., Sivaprakash, M.K. and Prasad, R.D. 2005. Potential of *Trichoderma* spp as biocontrol agents of pathogens involved in wilt complex of chickpea (*Cicer arietinum* L.). *Journal of Biological Control* **19** : 157-166.

Sango, S. 2003. Chilli peper and the threat of wilt diseases. *Plant Health Progress* **18** : 1-5.

*Sarhan, A.R.T. and F.M. Sharif. 1986. Integrated control of Fusarium wilt of pepper. *Acta Phytopathologica et Entomologica Hungarica* **21** : 123-126 [cf : *Review of Plant Pathology* **67** : 230].

Satyaprasad, K., Kunwar, I.K. and Ramarao, P. 1998. Biological control of fusarial diseases, pp 563-579. **In** : *Integrated Pest and Disease Management* (Eds. R.K. Upadhyay, K.C. Mukherji, B.P. Chamola and O.P. Dubey). A.P.H. Publishing Corporation, New Delhi, India.

Sen, B. 1986. Cultural management of soil borne diseases. pp 367-381. **In** : *Vistas in Plant Pathology* (Eds. A. Verma and J.P. Verma). Malhotra Publishing House, New Delhi, India.

Sen, B. and Kapoor, J. 1974. Chemical control of wilt of tomato. *Pesticides* **8** : 40-42.

Shalini, V. and Dohroo, N.P. 2005. Novel approach for screening different antagonists against *Fusarium oxysporum* f.sp. *pisi* causing Fusarium wilt of autumn pea. *Plant Disease Research* **20** : 58-61.

Sharma, R.L., Singh, B.P., Thakur, M.P. and Trimurthy, V.S. 2003. Antagonistic effect of *Trichoderma* against *Fusarium oxysporum* f.sp. *lini* causing wilt of linseed (*Linum usitalissimum* L.). *Journal of Mycology and Plant Pathology* **33** : 411-414.

Sharma, R.L., Singh, B.P., Thakur, M.P. and Verma, K.P. 2002. Chemical management of linseed wilt caused by *Fusarium oxysporum* f.sp. *lini*. *Annals of Plant Protection Sciences* **4** : 390-391.

Shugha, S.K., Kapoor, S.K. and Singh, B.M. 1995. Management of chickpea wilt with fungicides. *Indian Phytopathology* **12** : 27-31.

Singh, D. and Singh, A. 2004. Fusarial wilt – a new disease of chilli in Himachal Pradesh. *Journal of Mycology and Plant Pathology* **34** : 885-886.

Singh, D. and Singh, D. 1988. Management of Fusarium wilt through fungicides in Kagzi lime. *Progressive Horticulture* **4** : 285-286.

Singh, F., Indra, H. and Sindhan, G.S. 2004. Biological control of tomato wilt caused *Fusarium oxysporum* f.sp. *lycopersici*. *Journal of Mycology and Plant Pathology* **34** : 568-570.

Singh, R.N., Upadhyay, J.P. and Ojha, K.L. 1993. Management of chickpea wilt by fungicides and Gliocladium. *Journal of Applied Biology* **12** : 46-51.

Sinha, R.K.P. and Sinha, B.B.P. 2004. Effect of potash, botanicals and fungicides against wilt disease complex in lentil. *Annals of Plant Protection Sciences* **12** : 454-455.

Sivaprakasham, K. 1991. Soil amendments for crop disease management, pp 382-404. **In** : *Basic Research for Crop Disease Management* (Ed. P. Vidhyasekharan). Day Publishing House, New Delhi, India.

Sreenivasaprasad, S. and Manibhushanrao, K. 1990. Biocontrol potential of fungal antagonists (*Gliocladium virens* and *Trichoderma longibrachiatum*). *Journal of Plant Disease Protection* **97** : 570-579.

Thind, T.S. and Jhooty, J.S. 1985. Relative prevalence of fungal diseases of chilli fruits in Punjab. *Indian Journal of Mycology and Plant Pathology* **15** : 305-307.

Thurston, H.D. 1990. Plant disease management practices of traditional farmers. *Plant Disease* **74** : 96-102.

Utkhande, R.S. and Rahe, J.E. 1983. Interaction of antagonist and pathogens in biological control of onion white rot. *Phytopathology* **73** : 890-893.

Vidhyasekaran, P. and Thiagarajan, C.P. 1981. Seed-borne transmission of *Fusarium oxysporum* in chilli. *Indian Phytopathology* **35** : 624-627.

Vijaylakshmi, M. and Umamahesawara Rao, V. 2003. Fungi associated with chilli fruits during development. *Journal of Mycology and Plant Pathology* **33** : 451-452.

Vimala, R., Sivaprakasam, K. and Seetharaman, K. 1994. Management of brinjal wilt caused by *Fusarium solani*. pp 575-586. **In** : *Crop Diseases, Innovative Techniques and Management* (Eds. Sivaprakasam and Seetharamank). Kalyani Publishers, New Delhi, India.

*Vitanov, M. 1989. Movement of *Phytophthora capsici* in soil and infection of pepper. *Rasteniev' dni Nauki* **26** : 60-66 [cf : *Review of Plant Pathology* **65** : 6816].

Wani, M.A. 1994. *Studies on Fungal Wilt of Chilli* (*Capsicum annuum* L.). M.Sc thesis, submitted to Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, p. 74.

Wensley, R.N. 1953. Microbiological studies of the action of some selected soil fumigants. *Canadian Journal of Botany* **31** : 277-308.

Xie, J., Cardenas, E.S. and Sammis, T.W., Wall, M.M., Lindsey, D.L. and Murray, L.W. 1999. Effect of different irrigation regimes on the soil-borne pathogens. *Agricultural Water Management* **42** : 127-142.

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* Original not seen.