STUDIES ON CHILLI (*Capsicum annuum* L.) WILT IN JAMMU

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THESIS

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Sher-e-Kashmir
University of Agricultural Sciences and Technology
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Jammu

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This is to certify that Sh. Surrender Kumar Shali Regd. No. 96A/439M of M.Sc. Agriculture (Plant Pathology) has delivered his thesis seminar on research entitled "Studies on chilli (*Capsicum annuum* L.) wilt in Jammu" on 15-12-1999 in partial fulfilment of requirements of the degree programme.

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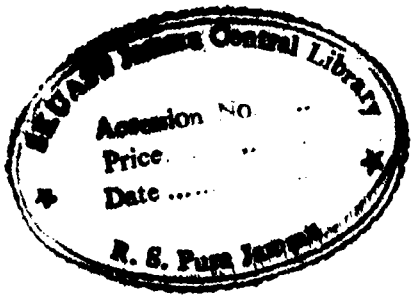

12/2
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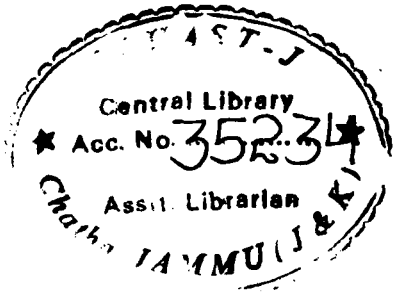

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This is to certify that the thesis entitled **"Studies on chilli (*Capsicum annuum* L.) wilt in Jammu"** submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Plant Pathology)** to the **Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu,** is a record of bonafide research, carried out by **Shri Surrender Kumar Shali,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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We, the members of Advisory Committee of **Shri Surrender Kumar Shali**, a candidate for the degree of **Master of Science in Agriculture (Plant Pathology)**, have gone through the manuscript of the thesis entitled **"Studies on chilli (*Capsicum annuum* L.) wilt in Jammu"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the degree.

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Abstract

Investigations on the wilt disease of chilli (*Capsicum annuum* L.) were undertaken during the year 1998 and 1999 at Sher-e-Kashmir University of Agricultural Sciences and Technology, R.S. Pura and Regional Horticulture Research Station, Udheywalla, Jammu. The field observations were recorded during the survey of different localities of Jammu, Udhampur, Rajouri and Kathua districts during the year 1999. Studies revealed that chilli wilt was present in all the locations surveyed. However, per cent mean wilt incidence varied from locality to locality and district to district. The maximum wilt incidence of 58.32 per cent was recorded at Nagbani in Marh block and the least one of 29.83 per cent at Dhungara in Bhilawar block. The wilt incidence of 44.21, 50.53, 33.53 and 33.15 per cent in Jammu, Udhampur, Rajouri and Kathua, respectively, while the overall status of chilli wilt was 41.47 per cent ranging from 8.33 - 80.00 per cent. Isolations made from the sample of wilted plants collected during survey indicated the association of two fungi *Phytophthora capsici* and *Fusarium solani* with the wilt of chilli. However, *P. capsici* was more predominant and was associated with 70.90 per cent of wilted samples in

comparison to *F. solani* which was found to be associated with 12.70 per cent of the disease samples. The pathogenicity test revealed that both the fungi were pathogenic. Wilt symptoms appeared in the first week of July with the onset of monsoon and continued till September. The disease appeared the most when there was maximum rainfall and was positively correlated with rainfall (r = 0.83) and relative humidity (r = 0.44). Inoculation of seeds with *P. capsici* and *F. solani* resulted into 58.4 and 23.2 per cent total mortality, respectively. Field evaluation of 9 treatments based on fungicide, antagonists, nutrients and other amendments against chilli wilt revealed that all the treatments were significantly superior to control which recorded 100 per cent mortality. Captan 50WP (0.2 %) gave the minimum mortality of 60.00 per cent followed by Carbendazim (0.1%) and K (20 kg/ha) which recorded 65.00 per cent mortality each. However during rainy season no commercial control was viable.

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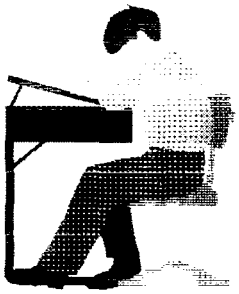


introduction

CHAPTER 1

INTRODUCTION

Chilli (*Capsicum annuum* L.) is unequivocally an important culinary condiment through out the world. It is an indispensable spice in every house in the tropical world. The edible portion of the chilli crop is fruit. Chilli fruit is used fresh, cooked, pickled, canned, in sauces and as powder for hot spice. Green chillies are rich in vitamins especially in vitamin C (upto 400 mg %) and also contain some quantities of vitamin A, B_1, B_2 (Saimbhi *et al.*, 1977; Sayed and Bagvandas, 1980) and also rich in vitamin P (rutin), which is of immense pharmaceutical importance (Purseglove, 1977).

Chilli crop is widely grown in tropics as well as temperate regions of the world covering an area of 12.52 lakh hectare with an annual production of 16.59 million tonnes (FAO, 1998). India

is the largest chilli producer and consumer in the world and its introduction in India is believed to be in 17th century through Portugese. In India,chilli covers an area of 9.565 lakh hectares spread over 23 states. During 1996-97, India produced 9.45 lakh tonnes of dry chilli and exported 2.75 per cent of its total production (Peter, 1999). Andhra Pradesh, Karnataka and Maharashtra account for 75 per cent of the country's net area under chillies and its production (Singh *et al.*, 1983). In Jammu and Kashmir, chilli is cultivated throughout the state. It occupies an area of 660 hectares in Jammu province (Directorate of Agriculture, 1997).

The active growth period of this crop coincides with the advent of monsoon period. Prevalence of warm temperature and high humidity during rainy season, which is quite congenial to the active growth of the crop, also favours the development of many diseases caused by bacteria, fungi and viruses. During field survey in the recent past (unreported) chilli wilt has been observed in an increasing proportion in all the three climatic zones of Jammu region, sometimes leading to total failure of the crop. In certain places the growers have even stopped growing chillies because of the disease psyche. The production has drastically been reduced both at commercial as well as kitchen garden level. In view of the nutritive importance, cash value of the chillies and the economic loss caused

by the outbreak of wilt disease it was thought imperative to ascertain the cause and evaluate control measures with the following objectives:

To know the incidence of chilli wilt in different locations of Jammu region.

To study the etiology of the wilt complex.

To work out the strategy of disease management.

review of literature

CHAPTER 2

REVIEW OF LITERATURE

GEOGRAPHICAL DISTRIBUTON

Wilt disease due to bacteria or fungi is common in peppers and often causes serious losses. It has been reported from various parts of the world. Chilli wilt was first observed in New Mexico in 1908. Since then it has been reported from Colorado, New Jersy, Argentina, Peru, Italy, Greece, Purtorico, California (Chupp and Sharf, 1960), Montengero (Mijuskovic and Vucinic, 1976), Turkey (Cinar and Bicici, 1977), Netherlands (Steekelenburg, 1980), Chile (Fernandez, 1983) and South Africa (Thompson *et al.*, 1994).

In India, chilli wilt has been reported from Karnataka (Khan *et al.*, 1979) Tamil Nadu (Vidhyasekaran and Thiagarajan,

1981), Haryana (Srivastava and Diwakar, 1987), Himachal Pradesh (Singh and Singh, 1995) and Kashmir (Dar and Mir, 1995a) in alarming proportions.

CAUSAL ORGANISM

Bacteria

Bacterial wilt caused by *Pseudomonas solanacearum* was common on peppers in U.S.A which also infected tomato, potato, egg-plants and a number of other cultivated as well as wild plants (Doolittle, 1953). In India, Das and Chattopadhyay (1955) and Chattopadhyay and Mukherjee (1969) reported that Chilli could be one of the hosts for the strains of *P. solanacearum* isolated from potato and egg plants. Khan *et al.* (1979) documented that the isolate infecting chilli plants was a strain of *P. solanacearum* and the isolates obtained from brinjal, potato and tomato as *P. solanacearum* var. *asiaticum*. They further mentioned that chilli isolate was genetically similar to that of tomato isolate but not that of potato and egg plants. Waller and Manser (1980) isolated *P. solanacearum* from wilted exotic capsicum cv. Asgro Long Green plants, however, they found local cultivars of capsicum and tomato resistant or tolerant to the pathogen.

Gangopadhyay (1984) reported a loss of 20-30 per cent due to bacterial wilt of chilli incited by *P. solanacearum* in chilli

growing pockets of India (Bangalore and Kolar districts) where the disease had become endemic. The occurrence of *P. solanacearum* race1 biotype III from the weeds *Spergula arvensis* and *Polygonum glabram* in high hills of U.P. (India) had been reported by Kishore *et al.* (1991). This race showed typical symptoms of bacterial wilt in potato, tomato, aubergine and chilli seedlings and was the first record of this race in India. Jyothi *et al.* (1993) reported *Ralstonia solanacearum* causing chilli wilt as one of the most important constraints to capsicum production in Kerala. Chatterjee *et al.* (1997) observed bacterial wilt disease caused by *R. solanacearum* infected tomato, potato, chilli, tobbaco, banana, brinjal, marigold, jute and ginger in West Bengal (India). They also reported *Cestrum diurnum, Datura metel, Croton sparsiflorus, Solanum indicum, S. nigram, Physalis minima* to be the wild hosts of this pathogen.

Fungi

Stem and fruit blight disease of peppers due to fungus was reported by Leonian (1922) from New Mexico and named the causal organism as *Phytophthora capsici* Leon. He described that the disease appeared on branches as blight and on fruits as dry lesions of various sizes. The seeds also became infected, turned brown, shrivelled and were killed in severe infection. Most frequently the

branches became infected directly at their bases, resulted into a ring of blighted tissue and the parts above it wilted. When the primary infection was on the main stem, the entire plant was killed. The size of sporangia was extremely variable from 35-85 μ or even 105 x 21-56 μ, averaging 60 x 36 μ. Oospores found in submerged mycelium, abundent on oatmeal and cornmeal agar, 25-35 μ with basal anthridia. Mycelium often gnarled becoming densely tuberous under certain cultural conditions. The tuberous outgrowth was spherical or ovoid, 5-8 μ, chlamydospores were not observed. In Florida, Weber (1932) observed some infection on stem, branches, fruits and leaves caused by *P. capsici*. He observed stem girdling at soil line as well as leaf infection and recorded 54 and 19 per cent, infection in green house and field respectively, by spraying the injured pepper plants with water suspension of sporangia in both the cases. The disease symptoms appeared 3 days after inoculation under laboratory conditions. The fungus did not produce sporangia abundantly in culture, but oospores were in abundance.

P. capsici caused sudden and severe wilting in the fields of San Joaquin valley in California. The disease symptoms consisted of rapid and permanent wilting of leaves without noticeable change in colour, stem girdling at collar region followed by lodging of the plant (Tomkins and Tucker, 1942). Leyendecker (1947)

recorded 85 per cent mortality due to *P. capsici* in a field of Southern New Mexico. *P. capsici* was found for the first time on *Capsicum annuum* in Montenegro attacking the roots, shoots and fruits and infected plant wilted and died (Mijuskovic and Vucinic, 1976). Steekelenburg (1980) reported *P. capsici* to be the pathogen causing root rot and crown rot of glass house *C. annuum* plants in Netherlands. The causal fungus was pathogenic on tomato and sometimes on eggplant but not on tobacco plants. Dipping the roots of tomato and sweet pepper plants, in a suspension of *P. capsici* resulted in most severe attack by pouring the suspension on the stem base. He further mentioned that *P. capsici* survived in moist soil without host for 15 months. Oospores remained infective for 6-10 months in Mexico under field conditions but the mycelium was not infective (Ramirez and Cova, 1980).

Fernandez (1983) found *P. capsici* to be the causal agent of wilt of *C. annuum* in Chile wherein 30 per cent of the plants were killed in the affected area. Jimenez *et al.* (1990) observed that crown rot caused by *P. capsici* was a limiting factor in sweet pepper production in Central America. A survey conducted in 1988 showed that the incidence of the disease varied from 40-80 per cent in Costa Rica. Jia (1992) mentioned that the capsicum plants with wilt and crown rot symptoms collected from various counties in Xinjiang

showed *P. capsici* as the main causal agent which had a wide host range including solanaceous, cucurbitaceous and leguminous crops; hyphal growth occurred at 12- 36 ^{0}C with an optimum of 24-30 ^{0}C and sporangial development at 14-33 ^{0}C with an optimum of 26-28 ^{0}C. Hartman and Huang (1993) found basal reaction of pepper plants varied from no symptom to severe crown lesions causing death, when pepper seedlings were inoculated with *P. capsici* in Taiwan. In South Africa, however, *P. capsici* causing root rot of *C. annuum* was reported for the first time in 1994 (Thompson *et al.*, 1994). Nonetheless, Hassan *et al.* (1994) pointed out that *P. capsici* though was the first to infect and cause root rot of capsicum, yet the secondary infection of *Fusarium* spp. should not be ignored. Mathew *et al.* (1995) observed leaf blight (*P. capsici*) and bacterial leaf spot (*Xanthomonas vesicatoria*) during 1989-91 in Kerala where *Alternaria* leaf blight, die back and fruit rot caused by *Colletotrichum capsici* were serious problems during rainy season.

Doolittle (1953)) observed *Fusarium annuum*, *P. capsici* and *Sclerotium rolfsii* to be the causal agents of chilli wilt. *Fusarium oxysporum* Schl. is known to cause wilting of chilli plants (Garofalo, 1957 and Grover and Singh, 1970) and its seed borne nature in chilli has also been reported by Negru and Florutium (1967) and Babayan and Shakhnubarayan (1969). Steekelenburg (1980) isolated

Fusarium solani frequently from rotten roots and stem bases of wilted sweet pepper plants but this pathogen was probably not the primary cause of plant death. *F. solani* showed brown to black discolouration of the stem base. *F. oxysporum* was reported to cause not only wilting and fruit rot but also reduced plant growth rate and yield in chilli (Vidhyasekaran and Thiagarajan, 1981). *Rhizoctonia* crown and root rot of capsicum characterized by defoliation and wilting, resulting to death of plants was reported from Central Iran (Alavi *et al.*, 1986), the symptoms being distinct from those caused by *P. capsici*. They observed that mature plants treated with mycelial culture filtrate of *Rhizoctonia solani* developed slight wilt but soon recovered. Srivastava and Diwakar (1987) observed severe stunting and wilting of *C. annuum* plants due to *Sclerotinia sclerotiourum* in Haryana. Ibrahimllari (1987) isolated *Verticillium dahliae*, *P. capsici* and *F. oxysporum* in the district of Tirane. However, Lukacs and Szarka (1988) found both *F. oxysporum* and *F. solani* causing wilt with stem browning above ground, peeling off the epidermis and vascular browning. *F. oxysporum* was found in all parts of the inoculated plants whereas *F. solani* occurred mostly in roots and lower stems. They further mentioned that *F. solani* spread in plant more slowly than *F. oxysporum*, but seedlings were mostly killed by *F. oxysporum*. Koleva and Vitanov (1990) isolated *F. oxysporum*, *F. solani* and *Fusarium equiseti* from field-grown peppers showing stunting, chlorosis and

root rot in Bulgaria.

Liang (1990) observed that capsicum seedlings were killed within two weeks by *F. equiseti*, after 30 days by *F. oxysporum* and *F. solani* and after 50 days by *Gibberella fujikuroi* in soil inoculation tests. *F. solani* causing stem and fruit rot of sweet peppers was isolated from the stem lesions and also from a short distance above and below them during 1992 in West Sussex, UK (Fletcher, 1994). Pepper wilt has been reported to be in alarming proportions in Kashmir valley and the incidence varied from 24 - 100 per cent in bell pepper and 4 - 81 per cent in chilli pepper. The pathogens involved were *Fusarium pallidoroseum*, *P. capsici* and *R. solani* (Dar and Mir, 1995a). Douira *et al.* (1995) observed *Verticillium* wilt in plants where capsicum was cultivated in rotation with tomatoes in Morocco. Singh and Singh (1995) reported the wilt of chillies caused by *F. oxysporum* as a major biotic stress in Paonta valley of Himachal Pradesh and is responsible for huge losses to the crop. The pathogens *Alternaria alternata*, *Cephalosporium acremonium*, *Fusarium anthophilum*, *F. moniliforme*, *F. oxysporum*, *F. solani*, *F. proliferatum*, *Macrophomina phaseolina*, *Pythium aphanidermatum* and *Rhizoctonia solani* have been isolated from roots, stems, leaves and seeds of infected plants of bell pepper and red pepper showing symptoms of wilting in Mirpur Khas district, (Sindh), Pakistan (Mushtaq and Hashmi, 1997).

ETIOLOGY AND EPIDEMIOLOGY

Leonian (1922) described that the disease generally appeared anytime after May when warm and rainy season started. Stem blight usually started at lower parts of the stem where zoospores were most likely to find favourable lodging. Godoy (1940) observed that in addition to varietal susceptibility, continuous cultivation and coincidance of crop timing during rainy season were the factors favouring the outbreak of *Phytophthora* blight. He further reported that the optimum temperature for the development of blight was 24-26 ^{0}C and 70 per cent relative humidity. The fungus was reported to be situated in cortical parenchyma of infected stem and branches and entered the stem base through natural injuries caused by different agencies. Abundant soil moisture, lack of drainage and high relative humidity as well as temperature were factors favouring infection and spread of root rot disease (Tompkins and Tucker, 1942). Leyendecker (1947) observed three points of pathogen entry viz, main stem at ground level, green fruits and young succulent stem tips and found that the pathogen remained active over a longer period in high productive fields.

Ele-nkov and Khrelkova (1977) found abundant rainfall and warm weather in August favoured epiphytotic outbreaks

of the disease in Bulgaria whileas splashing rain and run-off water appeared to be the main means of spread (Schlub, 1983). Casterjon and Rodriquez (1984) while describing some physiological aspects of capsicum wilt syndrome caused by *P. capsici* that cell membrane permeability was not significantly altered when one month old capsicum plants were inoculated with the fungus. On the first appearance of symptoms, respiration rose by 40 per cent and transpiration fell by 83.6 per cent. This indicated that syndrome was caused by obstruction of vascular system. Lukacs and Szarka (1988) reported *Fusarium* species causing damage on capsicum only when the plants were weakened by unfavourable growth conditions. *C. annuum* plants when transferred to a liquid medium which was subsequently inoculated with *P. capsici* and examined under light microscope revealed sporangium differentiation, zoospore release and root infection occurred within 24 - 48 h of inoculation. The primary infection caused wilt symptoms and dropped in transpiration, leading to death of the susceptible plants. Secondary infection spread and zoosopore release occurred on 3rd or 4th day killing partially resistant plants (Palloix *et al.*, 1988). *Phytophthora* blight of *C. annuum* did not occur in dry but in wet soils (Shin and Tezuka, 1992) whereas it was delayed in the treatments of low inoculum density when soil moisture levels were kept low (Shin and Nobuo, 1993). Abiotic factors such as frequent rains during crop growth, heavy soils coupled with

poor drainage and monoculture aggravated the disease (Dar and Mir, 1995a).

CHEMICAL MANAGEMENT

Mijuskovic and Vucinic (1976) found chemical control of the disease caused by *P. capsici* was complex and not completely effective but recommended seed treatment with thiram, captan, zineb or orthophaltan and soil treatments while field application of triphenyltin acetate at 3 g/m^2 a.i. at 20 day interval gave 92 per cent control against *P. capsici* (Cinar and Bicici, 1977).

Teoh and Chuo (1978) in Singapore reported that when sodium hypo-chlorite 15 - 25 ppm was added to nutrient solution and applied by flooding controlled bacterial wilt (*Pseudomonas* species). Yield and average fruit weight were highest with sodium hypochlorite at 15 ppm. Lower concentration were ineffective and concentration of 50 ppm and above were phytotoxic. Application of fungicide as a drench around the stem of pepper plants, was more effective than foliar spray (Kim *et al.*, 1982). Three soil drenches of metalaxyl suppressed final incidence of *Phytophthora* blight to below 3 per cent as compared to 21-31 per cent in foliar spray and cultural control. Sarhan and Sharief (1986) reported reduced incidence and severity of pepper (capsicum) wilt caused by *Fusarium oxysporum* f. sp.

redolens with the application of nitrogen and lime. Treatments with nutrient solution in which nitrogen was high resulted in plants with less disease than the plants those received low nitrogen. They further reported that plants growing in soils with an initial pH 7.7 - 8.3 showed lower wilt symptom than those at 6.4 - 7.0. By applying lime (2 or 4 g) in soil in conjugation with 420 - 630 ppm nitrate-nitrogen, greater disease reduction was obtained than by using the components individually. Simons *et al.* (1990) reported that spraying metalaxyl directly at the lower stem of bell pepper plants gave effective control of root rot diseases caused by *P. capsici* and *Fusarium* spp. Moens and Ben (1990) found that pepper wilt caused by a complex of fungi (*Phytophthora capsici*, *Fusarium solani* and *Rhizoctonia solani*) could be efficiently controlled by metham Na (100 ml/m^2), dazomet (70 g/m^2) or metalaxyl (0.1 g/m^2). They further mentioned that soil solarization reduced wilt incidence not significantly diffrent from that observed after the chemical treatements. Matheron and Matejka (1995) observed that sodium tetra-thio-carbonate (STTC) had potential benefit as management tool for the control of *Phytophthora* root and crown rot of *C. annuum*.

CULTURAL MANAGEMENT

Incidence of *P. capsici* was considerably reduced when

plants were transplanted on top of the furrow ridges and the depth of furrow was increased to 30 cm (Ferreyra *et al.*, 1984).

Sarhan and Hegazi (1988) found application of high level of nitrogen and potassium effective in reducing susceptibility of pepper (*C. frutescense*) plants to culture filtrate and fusaric acid, whereas phosphorus in soil had no effect. Choe (1989) conducted the experiments with varying ridge heights ranging from 0 - 45 cm and found that ridge heights of 15 - 30 cm greatly reduced the incidence of *Phytophthora* blight when compared to no ridge fields. Non-host crops such as onion (*Allium cepa* L.) Welsh onion (*Allium fistulogum* L.) ginger and green pea also had inhibitory effects on mycelial growth, sporangium formation and zoospore release of *P. capsici* (Lee *et al.*, 1990, 1991). Jyothi *et al.* (1993) mentioned cultivars manjeri of capsicum as resistant to *P. solanacearum* wilt in Kerala. Café Filho and Duniway (1995) while evaluating the effect of furrow irrigation schedules (7, 14 and 21 days) and host genotypes on *Phytophthora* root rot of pepper concluded that the frequency of irrigation was an important factor in the epidemics of *P. capsici* root rot and effective irrigation management and genetic response significantly reduced disease development.

BIOLOGICAL MANAGEMENT

The new race of *Streptomycin ochraceiscleroticus* in biological control of some soil borne plant pathogens was reported by Turhan (1981), the effectiveness of this mycoparasite in controlling Verticillium wilt and Phytophthora blight of pepper was 71.43 and 73.43 per cent, respectively. *Pseudomonas cepacia* and *Trichoderma harzianum* used for suppression of *Phytophthora* blight ranged from 0-86 per cent depending upon the application method, antagonist concentration and the amount of pathogen inoculum (Jee *et al.*, 1988). Simon *et al.* (1992) carried biological control experiments of soil borne pathogens, using several *Trichoderma* species and strains on green house crops (capsicum, lettuce, tomatoes, ornamantal plants etc) and some field crops in Hungary, found especially effective against *Fusarium* spp. but was also effective against other pathogens. Roe *et al.* (1994) investigated various organic and living mulches as alternative to polyethylene mulch. *P. capsici* infection reduced *C. annuum* plant stand number in control, polyethylene mulch plots compared with organic and living mulch plots. Despite stand reduction, total yields were highest in polyethylene mulch and organic mulch plots. Verma and Sharma (1995) found biological agents *Trichoderma harzianum* and *Gliocladium virens* effective in reduction of disease when applied to soil at the time of transplanting. Various

composts and soil amendments incorporated in the top 20 cm of bed to control Phytophthora root and crown rot of *C. annuum* caused by *P. capsici* were evaluated by Kim *et al.* (1997), and found chitosan (0.2 %, w/v) and perennial groundnuts reduced disease incidence and severity.

INTEGRATED MANAGEMENT

Jia (1992) achieved good control of the *Phytophthora* blight with metalaxyl application with cultural measures. Organic amendment (chicken manure), fungicide (Fosetyl-Aluminum as Aliette), soil solarization (with transparent and black polyethylene) and their combinations were studied by Chavez *et al.* (1995) to compare epidemiological progress of the disease and to determine economic feasibility of the treatments. The treatment with Fosetyl-Al + chicken manure + transparent polyethylene showed the best disease control, the lowest disease progress and highest yield against *P. capsici*. Dar and Mir (1995b) reported that pre-transplanting dip of chilli seedling with Bavistin (0.05 %), Benalate (0.05 %) or Captan (0.2 %) and post-transplanting drench with Bavistin (0.1 %) or Captan (0.3 %) controlled early wilt of chilli caused by *F. pallidoroseum* to a great extent. However, these chemicals failed to control the wilt at late stages. They further pointed out that the application of fungicides

and soil amendments with decomposed poultry litter failed to control the disease under wet conditions. However, transplanting of seedlings on raised bed (20 cm x 2 m) with light irrigation in mid and high altitude areas was found beneficial in managing the disease. Hwang and Kim (1995) concluded that resistant *C. annuum* cultivars with high fruit quality need to be developed and that integrated disease management could be achieved by using metalaxyl together with resistant cultivars. They suggested that cultural control method such as drainage with high ridges, crop rotation and mixed cropping should be integrated into overall disease control programme.

materials and methods

CHAPTER 3

MATERIALS AND METHODS

The present studies were carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology, R.S. Pura, J&K during the year 1998 and 1999. The laboratory work was done in the Division of Plant Pathology and Regional Horticulture Research Station, Udheywalla, Jammu and the field survey was conducted in the farmers field in chilli growing areas of Jammu region.

3.1 STATUS OF CHILLI WILT

Survey on the prevalence of chilli wilt incidence in different localities of Jammu region was conducted during the year 1999 for recording observations on chilli wilt incidence. The vegetable growing areas of Jammu, Kathua, Udhampur and Rajouri districts

were surveyed.

Five to ten chilli fields/kitchen gardens at random were surveyed in each locality for recording wilt symptoms and disease incidence. The wilt per cent was calculated as per the formula.

$$\text{Wilt per cent} = \frac{\text{Number of wilted plants}}{\text{Total number of plants examined}} \times 100$$

The data thus recorded were compiled and presented in the Appendix I.

3.2 COLLECTION OF DISEASED SAMPLES AND IDENTIFICATION OF THE PATHOGENS

During survey, samples of chilli plants were collected in alkathene bags and brought to plant pathology laboratory for conducting morphological studies as well as isolation of the causal agent (s) from the diseased plant parts.

3.2.1 Preliminary examinations

The infected portions of the diseased chilli plant viz., root, stem, leaf and fruit were scrapped with sterilized teasing needle.

The scrapping of each portion was then placed on clean glass slide in a drop of distilled water/lactophenol in cotton blue, covered with clean cover slip and examined under microscope for the presence of mycelial bits, spores or fruiting bodies if any as preliminary observations to ascertain the identity of causal agent.

3.2.2 Isolation of the pathogen(s)

For detection of microflora associated with the wilt of chilli agar plate method was used. The affected parts (root, collar, twig, leaf and fruit) of the plant were washed with tap water to remove the adhering soil particles / saprophytic infection, if any. Small bits of infected tissue (3 mm x 3 mm) were cut at the junction of diseased and healthy portion with the help of disinfected blade/ knife. The bits were then surface sterilized in 0.1 per cent mercuric chloride ($HgCl_2$) for 1-2 minutes followed by three washing with sterilized distilled water to remove the traces of mercuric chloride. These bits were subsequently placed on sterilized filter paper to remove excessive moisture and then transferred aseptically to the Petri plates containing sterile potato dextrose agar/oat meal agar medium. The inoculated plates were incubated at 25 ^{0}C±2. The culture thus obtained was subjected to purification.

3.2.3 Single spore culture

A loop full from the above obtained sporulating culture (s) was drawn aseptically with the help of sterilized inoculation needle and suspended in 1 ml sterilized water. Several dilutions were made to obtain 50 spores/ conidia/ sporangium per ml. One ml. of the spore suspension was mixed with 20 ml. of luke warm water agar (2 per cent) and poured in sterilized Petri plates. Petri plates were examined under low power microscope after its solidification for locating single conidium / sporangium. The single conidium/ sporangium was then removed with the help of 5 mm cork borer from the plate along with agar and transferred aseptically to PDA/OMA slants. The slants were incubated at 25 ^{0}C±2 in darkness.

Pure culture of the fungus thus obtained was then subjected to microscopic studies. Morphological examinations and cultural characters of the isolated fungi were recorded and observation compared with standard text for establishing their correct identification.

3.3 ISOLATION OF FUNGI FROM RHIZOSPHERE OF WILTED PLANTS

Soil dilution method was used to isolate the fungi from

rhizosphere of the wilted plants. Soil dilution were prepared by taking 10 g air dried soil in 90 ml sterilized water and it was further diluted to get final dilution of 10^{-3}. One ml. of this was spread on the sterilized culture medium Petri plates. The plates were given clockwise and anti clockwise rotations to distribute the soil suspension uniformly on the medium. The plates were incubated in BOD incubator at 25 ^{0}C±2 and the growth of the fungus was regularly observed. The culture thus obtained was subjected to purification and microscopic studies as mentioned in 3.2.3.

3.4 PATHOGENICITY TEST

For testing the pathogenicity of *Phytophthora capsici* and *Fusarium solani* in pots the soil was sterilized by 40 per cent formalin diluted with water in 1:7 ratio. The solution was mixed in soil, which was later covered with polyethylene sheets for 72 hours followed by 3 - 4 days exposure to atmosphere and frequently turning the soil for eliminating the fumes of formaldehyde. The sterilized soil was filled in sterilized polyethylene bag/pots for studying the pathogenicity of the causal agent (s) isolated from the plants as well as rhizosphere of the infected chilli plants.

Pathogenicity of the isolated *Phytophthora* sp and *Fusarium* sp. was evaluated separately on apparently healthy one

month old chilli seedlings of Pusa Jawala variety raised from seeds in earthen pots containing sterilized soil. Five seedlings of susceptible variety Pusa Jawala were transplanted in each earthen pot. Ten such pots were maintained. Cultures of *Phytophthora* sp. and *Fusarium* sp. used for pathogenicity test were grown separately on PDA/OMA. Seven-day-old cultures of the causal agent (s) were harvested separately by washing mycelial growth along with conidia/ sporangiospores and then suspended in 500 ml of tap water. In case of *Phytophthora* sp fungal suspension was chilled at 5 ^{0}C for 15 minutes to induce zoospore formation and used after storing for 30 minutes at 20 ^{0}C. The mycelia/spore suspension thus prepared was added around the stem base of the plants @10 ml per plant after the prick injury given to the plant near the soft tissue at the collar. The pots were covered with polyethylene bags to maintain high relative humidity for 48 hours and watered daily. Suitable controls with pouring only pure water around the stem base with injuries were also maintained side by side. The plants were left in open till the symptoms appeared. Attempts were made to isolate the fungus from artificially infected plants to establish Koch's postulate.

3.5 EFFECT OF METEOROLOGICAL PARAMETERS WITH THE INCIDENCE OF CHILLI WILT

With a view to ascertain the role of meteorological factors in a disease development, the chilli wilt incidence was recorded weekly in a field at Udheywalla, Jammu during the crop season of 1999. 360 plants of variety Pusa Jawala were planted 40 x 60 cm distance in a field showing high incidence of wilt disease. Simultaneously meteorological data viz., maximum and minimum temperature, per cent relative humidity and amount of rainfall was recorded daily in the chilli field. Mean temperature and relative humidity as also the cumulative rainfall received between two consecutive dates of recording wilt incidence were calculated. The correlation between wilt incidence and above three factors were worked out.

3.6 EFFECT OF CAUSAL ORGANISM (S) ON PRE- AND POST- EMERGENCE MORTALITY

To study the role of isolated pathogenic fungi in causing pre and post emergence mortality of the chilli seedlings an experiment was laid out in plastic bags in complete random design (CRD) with five replications at Regional Horticulture Research

Station, Udheywalla, Jammu.

The bags were filled with formalin sterilized soil. Fifty seeds of Pusa Jawala variety were treated with fungus culture of *Phytophthora* sp. and *Fusarium* sp. individually and in combination. The seeds sown without inoculation served as control. As soon as seeds started germinating, germination counts and post emergence mortality were recorded daily in each pot.

3.7 MANAGEMENT

For studying the effect of fungicides, bioagents, organic amendments, lime and nutrients in the management of chilli wilt, an experiment was laid out in randomized block design with four replications in a field with a previous history of wilt at Regional Horticulture Research Station, Udheywalla, Jammu during the year 1999. The detail of the fungicides, nutrients, bioagents, organic amendment and lime used and their dosages are given hereunder:

Fungicide/nutrient/antagonist/ amendments	Dosage
Captan 50 WP	15 kg ha^{-1}
(N-trichloromethyl-thio-4-cyclo-hexane-1, 2-dicarboximide)	
Bavistin 50WP	10 kg ha^{-1}
Carbendazim(2-methoxy carbamyl-benzimidazole)	

N (Urea)	138 kg ha^{-1}
K (Muriate of Potash)	20 kg ha^{-1}
Trichoderma viride	100 kg ha^{-1}
Gliocladium virens	100 kg ha^{-1}
Poultry manure	50 q ha^{-1}
Lime	36 q ha^{-1}

The sick plot 2 m x 1 m were treated with different treatments as soil mix before one week of transplanting. One month old 10 chilli plants of susceptible variety (Pusa Jawala) per plot were transplanted in the field in the middle of May. The plant to plant distance of 40 cm and row to row distance of 60 cm was maintained. A check was also maintained for comparison. Data regarding the incidence of wilt was taken after 7 days interval as soon as the disease appeared. The data thus obtained were tabulated and analysed.


experimental
results

CHAPTER 4

EXPERIMENTAL FINDINGS

4.1 STATUS OF CHILLI WILT

The observations recorded on the incidence of chilli wilt in different locations of Jammu region during 1999 (Appendix I) have been presented block (Table 1) and district wise (Table 2).

The perusal of the data (Appendix I) indicated that chilli wilt was present in all the locations surveyed. The wilt disease incidence varied from 8.33 to 80.00 per cent. The highest wilt incidence (80.00 %) was recorded in Nagbani area and the lowest (8.33 %) in Ponichak. None of the areas was found free from wilt disease.

Table 1 Incidence of wilt on chilli (*Capsicum annuum*) in different blocks of Jammu region during 1999

Block	No. of villages surveyed	Mean disease incidence (%)	Disease incidence range (%)
Marh	4	49.71	8.33 - 80.00
Akhnoor	3	47.22	22.40 - 72.40
R.S. Pura	3	42.80	10.45 - 66.80
Vijaypur	3	37.11	16.07 - 63.42
Tikri	3	47.81	21.60 - 67.92
Chenani	1	57.92	32.42 - 71.72
Reasi	4	45.87	15.44 - 72.72
Rajouri	4	35.25	10.00 - 62.84
Nowshera	2	31.81	14.66 - 48.66
Kathua	3	34.26	12.35 - 48.46
Bhilawar	3	32.05	12.77 - 45.29

Table 2 Incidence of wilt on chilli (*Capsicum annuum*) in different districts of Jammu region during 1999

District	No of blocks surveyed	No. of villages surveyed	Mean disease incidence (%)	Disease incidence range (%)
Jammu	4	13	44.21	8.33-80.00
Udhampur	3	8	50.53	15.44-72.72
Rajouri	2	6	33.53	10.00-62.84
Kathua	2	6	33.15	12.35-48.46

The incidence of wilt disease also varied from block to block (Table 1) and district to district (Table 2). The maximum wilt disease incidence of 57.92 per cent was recorded in Chenani block and a minimum of 31.81 per cent in Nowshera block. In other blocks chilli wilt ranged between 32.05 and 49.71 per cent.

The maximum wilt incidence of 50.53 per cent (Table 2) was recorded in Udhampur district and a minimum of 33.15 per cent in Kathua district. Other district viz., Jammu and Rajouri recorded a disease incidence of 44.21 and 33.53 per cent, respectively. However, the overall status of chilli wilt disease in Jammu division was found 41.47 per cent.

For knowing the frequency of different fungi, associated with chilli wilt in different chili growing areas of Jammu region during 1999, 165 samples of affected chilli plants were examined. The data (Table 3) indicate that 70.90 per cent of the samples yielded *Phytophthora* sp., 12.70 per cent *Fusarium* sp. while no pathogens could be isolated in 16.40 per cent of the samples. *Phytophthora* sp. was found present in all the locations whereas *Fusarium* sp. was absent in samples collected from R.S. Pura and Chenani blocks. The *Phytophthora* sp. was, however, more predominant in all the locations surveyed.

Table 3 Frequency of fungi associated with wilt of chilli (*Capsicum annuum*) in different chilli growing areas of Jammu region during 1999

District	Block	Number of wilt samples examined	Number/per cent incidence		
			Phytophthora sp.	*Fusarium* sp.	No pathogen
Jammu	Marh	20	16* (80.00)	3 (15.00)	1 (5.00)
	Akhnoor	15	11 (73.34)	2 (13.33)	2 (13.33)
	Vijaypur	15	13 (86.67)	2 (13.33)	-
	R.S. Pura	15	11 (73.34)	-	4 (26.66)
		65	51 (78.46)	7 (10.76)	7 (10.76)
Udhampur	Tikri	15	10 (66.69)	2 (13.33)	3 (20.00)
	Chenani	5	3 (60.00)	-	2 (40.00)
	Reasi	20	13 (65.00)	3 (15.00)	4 (20.00)
		40	26 (65.00)	5 (12.50)	9 (22.50)
Rajouri	Nowshera	10	8 (80.00)	1 (10.00)	1 (10.00)
	Rajouri	20	13 (65.00)	4 (20.00)	3 (15.00)
		30	21 (70.00)	5 (16.66)	4 (13.33)
Kathua	Bhilawar	15	10 (66.67)	2 (13.33)	3 (20.00)
	Kathua	15	9 (60.00)	2 (13.33)	4 (26.67)
		30	19 (63.63)	4 (13.33)	7 (23.34)
Total		165	117 (70.90)	21 (12.70)	27 (16.40)

* Number of samples

Figures in parentheses are per cent incidence

During the isolation of the rhizosphere of wilted chilli plants the fungi isolated were *Penicillium* spp., *Aspergillus* spp., *Fusarium* spp., *Alternaria* spp., *Phytophthora* spp., *Rhizopus* spp. and *Mucor* spp.

4.2 SYMPTOMATOLOGY

The chilli wilt appeared mainly when the plants were flowering/fruiting stage during rainy season, with warm and moist weather, being most conducive for the prevalence of the disease. Wilting of chilli plants in the field was accompanied by sudden drooping of leaves leading to death of the plant within few days.

During the present investigations chilli wilt was found occurring moslty due to two fungal pathogens viz., *Phytophthora capsici* and *Fusarium solani* as confirmed through isolation and pathogenicity.

The chilli plants infected with *P. capsici* showed sudden and severe wilting in the field. The symptoms consisted of rapid and permanent wilting of plants without noticeable change in colour of the freshly drooped leaves (Plate 1). Subsequently dark brown areas of irregular shapes and sizes were observed on leaves of chilli plants growing under moist and shady conditions (Plate 2). The

Plate 1, 2, 3 and 4 symptoms caused by

Phytophthora capsici

Plate 1 Showing healthy and wilted (with drooped leaves) plants

Plate 2 Diseased leaves showing dark brown lesions of irregular shape and size

PLATE 1

PLATE 2.

infected leaves ultimately abscissed and fell off from the plant. Girdling symptoms were also observed on some branches, which led to withering of the branch above it giving a partial blight symptom of plant (Plate 3). The stem was usually found infected near the soil line, showing dark water-soaked band leading to girdling of the stem (Plate 4). The affected plants soon wilted and died. In pathogenicity test, the one month old chilli seedlings raised in sterilized pot soil showed flaccid leaves, as the first wilt symptoms with in 5 - 8 days after inoculation of the wilt pathogen (*P. capsici*).

The symptoms of chilli wilt due to *F. solani* in the field were quite inconspicuous. The field symptoms were epinasty, foliar chlorosis, leaves turning light green to yellow accompanied by gradual wilting. However, in advanced stage, the leaves shrivelled, drooped down and dried but remained clinging to the wilted plants. The collar region of the wilted plant showed dark brown discoloration followed by rotting of the stem, peeling off the epidermis (Plate 5). The roots turned blackish, sloughing off the epidermis (Plate 7) accompanied by vascular browning (Plate 8). The first wilt symptoms on one month old potted chilli seedlings appeared as epinasty and yellowing of leaves within 10 - 15 days after inoculation. The plants succumbed to wilt within 30 - 35 days. Stunting and chlorosis (Plate 6) were also observed in chilli plants grown in sterilized water in

PLATE 3

PLATE 4

Plate 5, 6, 7 and 8 Symptoms caused by

Fusarium solani

Plate 5 Rotting of stem and peeling of epidermis

Plate 6 Stunting and chlorosis

PLATE 5

PLATE 6.

Plate 7 and 8 Symptom on roots and vascular browning

PLATE 7

PLATE 8.

conical flasks and inoculated with the wilt pathogen, *F. solani*.

4.3 CAUSAL ORGANISM(S)

Microscopic examinations of the scrapping/washing/ isolation from the diseased portion of the wilted plants and pathogenecity there of revealed the presence of two pathogenic fungi viz., *Phytophthora capcisi* and *Fusarium solani*.

4.3.1 *Phytophthora capsici*

The fungal colony gave fluffy and cottony white appearance (Plate 9) on oatmeal agar medium. Hyphae were simple, branched but often become variously swollen and tuberous. Sporangia were rarely produced in the medium but were abundantly produced in tap water. Sporangia were hyaline, ovoid to pyriforn, lemon shaped, non pedicellate with hemispherical papilla at the apex (Plate 10). The mean size of the sporangium was 36.8 - 46 μ. The pathogen did not produce chlamydospore at all. Oospores were found abundantly in aerial as well as submerged mycelium in the medium. The oospores formed thick walls and were circular to spherical measuring 18.4 - 27.6 μ, averaging 22.08 μ. The morphological features of the isolated fungus resembled that of *Phytophthora capsici* as described by Leonian (1922) and Satour and Butler (1968).

4.3.2 *Fusarium solani*

The fungus produced dense white aerial mycelium, which later turned to dirty white and developed bluish brown discoloration (Plate 11) on potato dextrose medium. Hyphal diameter ranged between 2.30 - 4.35 μ. Microconidia developed abundantly in fresh cultures and were oval shaped, range between 8.75 - 12.50 μ x 2.5 - 3.75 μ in size with 0 - 1 septum. Macroconidia of the fungus were multicelled, attenuate, fusoid, elongate with 3 - 5 septa. The size ranged from 35.0 - 47.5 μ x 5.0 - 6.25 μ borne on short branched conidiophores (Plate 12). Chlamydospores were thick walled, terminal or intercalary on short lateral branches usually in old cultures. They were globose to oval in shape. As compared with available standard literature Booth (1971), Barnett and Hunter (1972) the morphological characters described above resembled with *Fusarium solani*.

4.4 PATHOGENICITY

In order to ascertain the pathogenicity of both the fungi *Phytophthora capsici* and *Fusarium solani* one month old chilli seedlings grown in sterilized pot soil were inoculated with the isolated fungi separately. The symptoms became apparent after 5 - 8 days in case of plants inoculated with *P. capsici* and all the plants collapsed

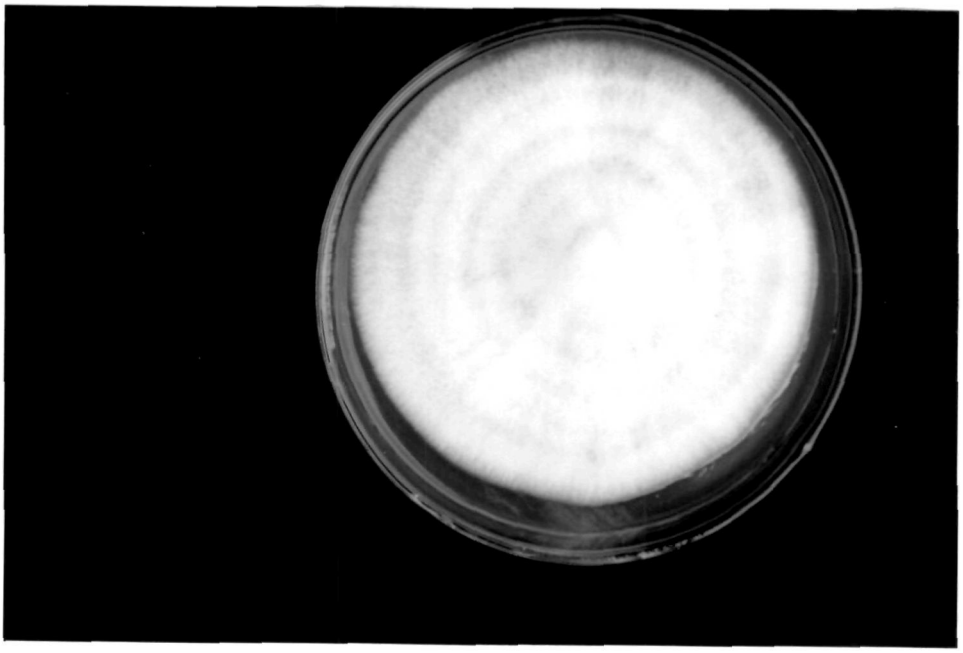


PLATE 11

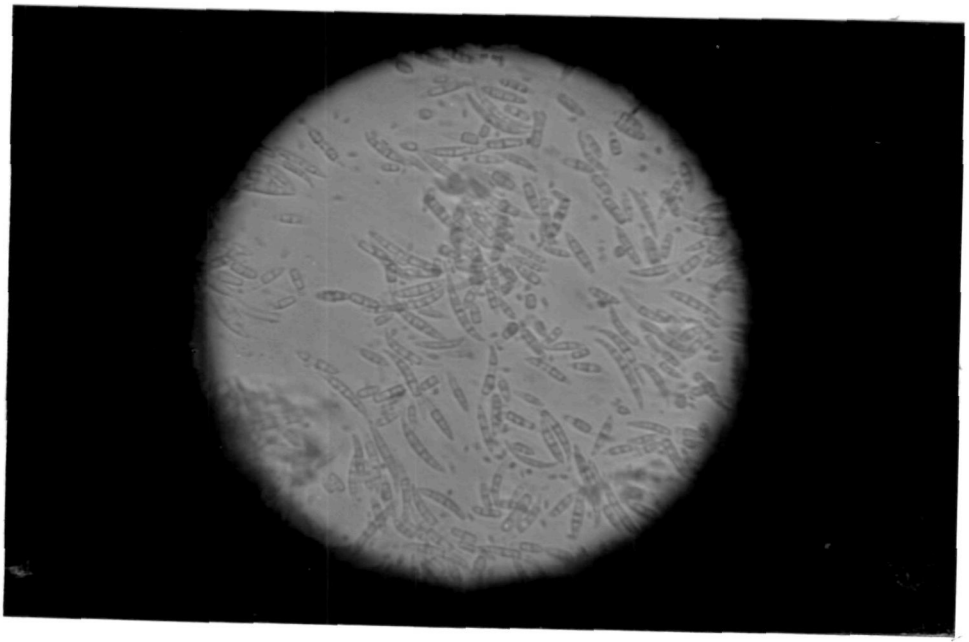


PLATE 12.

within 7 - 15 days whereas in case of *F. solani* symptoms appeared within 10 - 15 days and the plants wilted in 30 - 35 days. The symptoms thus exhibited were identical to those found occurring in the plants naturally infected in the field. No symptoms of the disease were observed on uninoculated plants. On re-isolation of the causal agent(s) from these diseased plants same two fungi were found when compared with the original culture. Hence their pathogenic behaviour was confirmed.

4.5 Effect of causal organism(s) on pre and post emergence mortality of chilli seedlings

With an object to find out the effect of *P. capsici* and *F. solani* on the pre emergence and post emergence mortality of chilli seedlings, the experiment was laid out in complete randomised design and the data thus generated was presented in Table 4.

The perusal of the data indicated that both the pathogens caused pre emergence and post emergence mortality. The maximum mortality was observed in case of *P. capsici*. The pre emergence, post emergence and total mortality of 31.6, 26.8 and 58.4 per cent respectively was recorded in *P. capsici* whereas in *F. solani* it was 14.8, 8.4 and 23.2 per cent respectively. Both the pathogens in

Table 4 Mortality due to fungi associated with wilt of chilli (*Capsicum annuum*)

Seed inoculated with	Per cent seedling emerged	Per cent seedling mortality		
		Pre emergence	Post emergence	Total
Phytophthora capsici	68.4	31.6	26.8	58.4
Fusarium solani	85.2	14.8	8.4	23.2
Phytophthora + *Fusarium* spp.	72.4	27.6	24.4	52.0
Control	90.4	9.6	-	9.6

Data based on 50 seeds

combination recorded 27.6 per cent, 24.4 per cent and 52.00 per cent as pre emergence, post emergence and total mortality respectively. There was no post emergence mortality in uninoculated treatment but pre emergence mortality was 9.6 per cent.

4.6 CORRELATION OF DISEASE INCIDENCE WITH METEOROLOGICAL CONDITIONS

The correlation of the wilt disease with the meteorological parameters viz., rainfall, humidity and temperature were worked out (Table 5).

The perusal of the data indicated that wilt incidence had a direct correlation with rainfall, relative humidity and temperature. The wilt incidence was found significant ($r = 0.83$) and positively correlated with the amount of the rainfall. Maximum relative humidity ($r = 0.44$), though positively correlated but was non significant. Minimum humidity and maximum temperature were non significant and negatively correlated.

4.7 MANAGEMENT

Fungicides viz., Captan 50 WP (15 kg ha^{-1}) and Bavistin 50 WP (10 kg ha^{-1}), nutrients viz., N (138 kg ha^{-1}) and K (20

Table 5 Effect of meteorological parameters on incidence of wilt on chilli (*Capsicum annuum*) during 1999

Date of observation	Wilt (%)	Rainfall (mm)	Relative humidity (%)		Temperature (°C)	
			Maximum	Minimum	Maximum	Minimum
2/7/99 - 8/7/99	8.33	7.70	90.14	78.14	34.10	23.00
9/7/99 - 15/7/99	14.54	22.60	89.78	55.35	34.70	21.80
16/7/99 - 22/7/99	29.43	210.40	90.78	57.00	30.50	20.90
23/7/99 - 29/7/99	25.62	28.90	90.85	61.07	31.60	20.80
30/7/99 - 5/8/99	34.45	243.20	91.28	56.92	30.70	21.60
6/8/99 - 12/8/99	29.24	143.60	92.57	58.71	30.60	21.30
13/8/99 - 19/8/99	20.58	8.70	90.57	62.01	31.50	20.60
20/8/99 - 26/8/99	9.25	2.00	88.50	56.21	31.20	21.80
27/8/99 - 2/9/99	8.16	8.50	92.00	55.50	30.80	19.60
3/9/99 - 9/9/99	4.40	18.30	90.57	56.50	31.50	20.30

Correlation coefficients between weather parameters and wilt incidence

Rainfall	0.83*
Maximum humidity	0.44
Minimum humidity	-0.18
Maximum temperature	-0.43
Minimum temperature	0.03

kg ha^{-1}), fungal antagonists, *Trichoderma viride* (100 kg ha^{-1}) and *Gliocladium virens* (100 kg ha^{-1}), soil amendments viz., Poultry manure (50 q ha^{-1}) and lime (36 q ha^{-1}) were evaluated for their efficacy in controlling the wilt disease of chilli under field conditions. The data thus generated on the wilt incidence are presented in Table 6.

The persual of the analysis of variance of the data in Table 6 (Appendix 2) revealed significant effect of all the treatments in reducing the wilt disease incidence when compared to check. However, the efficacy of the individual treatments differed significantly. Captan 50WP proved the most effective treatment in reducing the chilli wilt and showed only 60 per cent plant mortality in comparison to the check which gave 100 per cent plant mortality. The next best treatments were Bavistin 50 WP and K (potassium) both recording 65 per cent mortality each and were statistically at par with Captan 50 WP. Poultry manure, *Trichoderma viride*, *Gliocladium virens* and lime recorded 72.50, 75.00, 75.00, 77.50 per cent plant mortality respectively and were statistically at par with each. N (nitrogen) recorded 80 per cent mortality and remained least effective in curtailing the wilt incidence.

Table 6 Efficacy of different soil treatments against chilli (*Capsicum annuum*) wilt during 1999

Treatment	Dosage (ha^{-1})	Mortality (%)	Disease control (%)
Captan 50WP	15 kg	60.00	40.00
Bavistin 50WP	10 kg	65.00	35.00
N(urea)	138 kg	80.00	20.00
K (MOP)	20 kg	65.00	35.00
Trichoderma viride	100 kg	75.00	25.00
Gliocladium virens	100 kg	75.00	25.00
Poultry manure	50 q	72.50	27.50
Lime	36 q	77.50	22.50
Control	-	100.00	-
SE(d)±		3.06	
CD (p = 0.05)		6.30	

discussion

CHAPTER 5

DISCUSSION

Chilli plants are known to be suffered from many abiotic factors such as atmospheric temperature, relative humidity, rainfall etc., and biotic agents such as fungi, bacteria and viruses causing various types of diseases on foliage, twigs, stems, fruits and roots. The symptoms of the diseases are exhibited in the form of wilt blight, dieback, rots etc.

The wilt disease of chilli that has been encountering in Jammu region for the last few years had not earlier been systematically studied from Jammu province. Therefore, the present investigations were undertaken to generate a basic information about the disease in Jammu during 1998 and 1999. The findings thus achieved have been discussed in light of the literature scanned.

The survey in the chilli growing areas of Jammu, Udhampur, Rajouri and Kathua districts, covering 33 villages in 11 blocks during 1999 revealed that wilt of chilli was prevalent almost in all the areas of Jammu region. The incidence of wilt ranged between 8.33 - 80.00 per cent. None of the areas surveyed was found free from the disease. The incidence varied from block to block and district to district. The highest incidence of wilt (57.92 %) was recorded in Chenani block of Udhampur district whereas minimum incidence 31.81 per cent was monitored in Nowshera block of Rajouri district. Udhampur district recorded the maximum incidence of 50.53 per cent while the minimum incidence of 33.15 per cent was found in Kathua district. However, overall incidence of chilli wilt in Jammu region was recorded 41.47 per cent. Similarly varying levels of incidences/ losses due to chilli wilt in India and abroad have been recorded as 20 - 30 per cent in Banglore and Kolar districts (Gangopadhyay, 1984), 40 - 80 per cent in Costa Rica (Jimenez *et al.*, 1990). 100 per cent losses in Kerala (Gopal Krishnan and Peter, 1991), 60 per cent in Korea (Yang *et al.*, 1991) and 4 - 81 per cent in Kashmir (Dar and Mir, 1995a). The variation in the wilt incidence might be due to varying host genotype, pathogen, climate, soil factors and cultural practices which influenced soil borne disease manifestation thereof.

Various workers have reported different pathogens for causing wilt of chilli (Doolittle, 1953; Srivastava and Diwakar, 1987; Dar and Mir, 1995a; Douira *et al.*, 1995, Mushtaq and Hashmi, 1997). However, the present investigation revealed involvement of two fungi; namely *Phytophthora capsici* and *Fusarium solani* in the wilt of chilli. Pathogenic behaviour of these two fungi was proved through pathogenicity test and their identification was confirmed through documented literatur[illegible] given by Leonian (1922), Satour and Butler (1968) and Ho, (1981), Booth (1971), Barnett and Hunter (1972). The association of *P. capsici* and *F. solani* with wilt of chilli has also been reported by various workers (Ramirez and Cova, 1980, Steekelenburg, 1980; Fernandez, 1983; Lukacs and Szarka, 1988; Moens and Ben, 1990; Thompson *et al.*, 1994; Hassan *et al.*, 1994). As regards the prevalence of the pathogens causing wilt in chilli growing area of Jammu region, 165 samples of wilted chilli plants were examined where 70.90 per cent samples yielded *P. capsici*, 12.70 per cent *F. solani* and in 16.40 per cent samples no pathogen was isolated. Both the fungal species were encountered almost in all the blocks except R.S. Pura and Chenani where only *P. capsici* was isolated. The *P. capsici* dominated in all the locations surveyed. Moens and Ben (1990) also found pepper wilt caused by a complex of fungi (*P. capsici*, *F. solani* and *R. solani*). Steekelenburg (1980) also got

similar results but found that *F. solani* was probably not the primary cause of plant death. Lukacs and Szarka (1988) mentioned that unfavourable growth conditions make the plant susceptible to the disease. This sort of variation might be due to change in agro climatic conditions, edaphic factors, host cultivars and aggressiveness of the pathogen in different locations. The chilli plants where no pathogen was isolated might have been killed due to excessive water logging leading to necrosis at stem base, collar and roots. Similar observation have also been made by Matta and Garibaldi (1980).

The symptoms of the disease in the artificially inoculated plants became apparent within 5 - 8 days and whole plant wilted within a fortnight time in case of plants inoculated with *P. capsici*, whereas in case of *F. solani* the symptoms appeared in 10 - 15 days and the plant wilted within 30-35 days after inoculation. Almost similar results have been reported by Polach and Webster, 1972; Steekelenburg, 1980 and Liang, 1990. The present findings on pathogen behaviour indicated that *P. capsici* was more predominant and aggressive than *F. solani* in causing chilli wilt in Jammu.

The wilt disease in field did not occur prior to monsoon (July - August). However, it appeared just after few showers of monsoon when atmospheric humidity increased. The disease

incidence increased at rapid pace when there were frequent rains and the soil under plant become saturated with moisture. Maximum wilt incidence (34.45 %) was observed in Ist week of August when there was maximum rainfall (243.20 mm) and humidity of 91.28 per cent. The disease started declining after September. The correlation of wilt incidence in field with meteorological parameters indicated a positive correlation with the amount of rainfall (r = 0.83) and relative humidity (r = 0.44). Schlub (1983) had also reported that rainfall and soil moisture correlated better with disease incidence than did humidity, temperature on calendar days in *P. capsici* pathosystem. Dar and Mir (1995a) were of the same view that frequent rains during crop growth and heavy soils with poor drainage aggravated the disease.

Under laboratory conditions both the isolated pathogens caused pre and post emergence mortality when seeds were inoculated with them separately as well as in combination. The maximum mortality was due to *P. capsici* (58.4 %) followed by combination of *P. capsici* and *F. solani* (52.0 %) and *F. solani* (23.2 %). Similar observation have been made by Hashmi (1989) who found seed rot and wilting of capsicum seedlings with *Fusarium* spp. and Shyam (1969) with *P. capsici*.

Management studies though reflected significant results in the present investigation, yet these cannot be considered economical / encouraging as none of the treatments checked mortality of chilli plants below 60 per cent. Captan 50 WP (0.2 %), however, remained the most effective treatment recording 40 per cent control of wilt in chilli. The other best treatment found statistically at par with Captan 50 WP were Bavistin 50 WP (0.1 %) and K (20 kg ha^{-1}) each with a disease control of 35 per cent. The efficacy of Bavistin 50 WP and Captan 50 WP against chilli wilt has also been documented by Dar and Mir (1995b) who found pre-transplanting dip of chilli seedlings in Bavistin (0.05 %) or Captan (0.2 %) and post transplanting drench with Bavistin (0.1 %) or Captan (0.3 %) quite effective in checking early wilt of chilli caused by *Fusarium pallidoroseum* to a great extent. These chemicals however, failed to control wilt at later stage under wet conditions in Kashmir valley. Soil application of potassium (K) and nitrogen (N) significantly reduced the wilt incidence in chilli (35% and 20 %) respectively. High doses of nitrogen and potassium have been reported to be effective in reducing the susceptibility of pepper plants (Sarhan and Hegazi, 1988) and are in unanimity with the present findings.

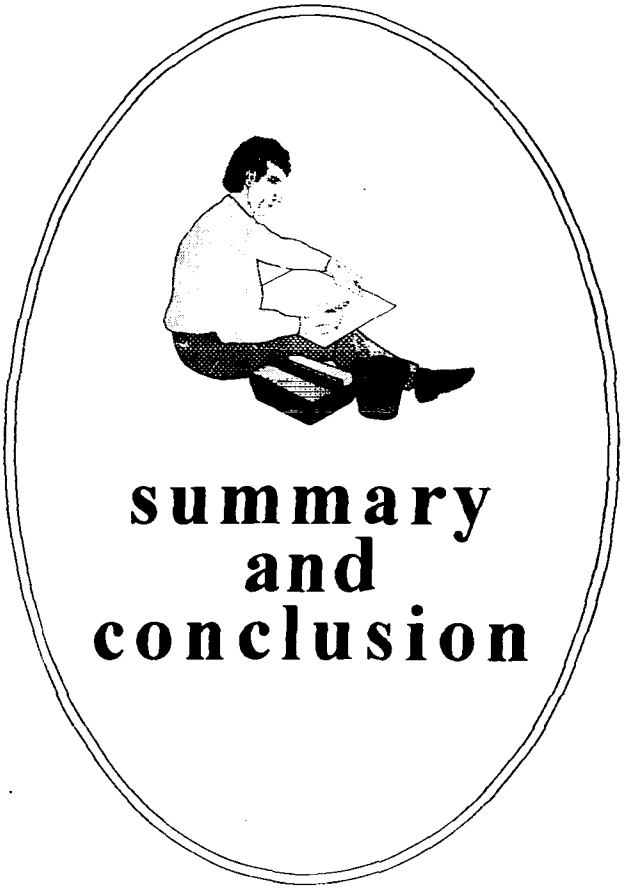
Biological control is target specific, non-hazardous to plants and human health and controls plant diseases satisfactorily.

Trichoderma and *Gliocladium* spp. which grow saprophytically in soil have proved effective bio-control agents of many plant pathogens (Singh, 2000). The fungal antagonists viz *Trichoderma viride* and *Gliocladium virens* used in the present studies were also found significantly superior in reducing chilli wilt (25 % each) in field. Simon *et al.* (1992) also found several species and strains of *Trichoderma* effective against many soil borne pathogens of vegetable crops including *Capsicum.*

Soil amendments with decomposable organic matter are an effective method of changing the soil environment. These amendments help in altering the physical, chemical and biotic conditions of the soil including increase in zymogenous population of soil microflora. Organic matter influences physical characteristic of soil such as pore size, aeration, temperature, water retention capacity etc., which helps plant to resist the attack of pathogens (Singh, 1983).

In the present studies amendments of soil with lime (36 q ha^{-1}) and poultry manure (50 q ha^{-1}) also reflected wilt control of 22.50 and 27.50 per cent, respectively. Incidence and severity of pepper (*Capsicum*) wilt caused by *Fusarium oxysporum* f sp. *redolens* have also been found reduced after application of N and lime (Sarhan

and Sharief, 1986); poultry manure (chicken manure) has also been reported to check the wilt incidence caused by *Fusarium oxysporum* f sp. *lycopersici* in tomato (Homma *et al.*, 1979) and *P. capsici* in pepper (Chavez *et al.*, 1995).



summary and conclusion

CHAPTER 6

SUMMARY AND CONCLUSION

The present investigations were undertaken to study the status of wilt disease of chilli in chilli growing areas of Jammu region and to identify the causal agents associated there of. The attempts were also made to manage the disease through different soil treatments with some fungicides, nutrients, antagonist and amendments.

The survey of different chilli growing areas made during 1999 revealed the presence of wilt in all the chilli growing areas of Jammu region. The incidence varied from location to locations. The maximum wilt incidence of 58.32 per cent was recorded at Nagbani in Marh block and the least of 29.83 per cent at Dhungara in Bhilawar block. The wilt disease incidence varied from 31.81 to

57.92 per cent within blocks and 33.15 to 50.53 per cent with in district while the overall status of chilli wilt disease was 41.47 per cent, ranging from 8.3 to 80.00 per cent.

Isolation from the diseased plants and the rhizosphere soil yielded two fungi viz.,; *Phytophthora capsici* and *Fusarium solani*. The frequency of *P. capsici* was 70.90 per cent while that of *F. solani* 12.70 per cent. Both the fungi were pathogenic when tested on potted plants.

On inoculation tests the symptoms appeared within 5 - 8 day in *P. capsici* and the whole plant wilted within a fortnight while as in *F. solani* it took 15 - 18 day for appearance of first disease symptom and the plant wilted within 30 - 35 days.

Wilt symptoms appeared in the first week of July with the onset of monsoon and continued till September. The disease appeared the most when there was maximum rainfall and was positively correlated with rainfall (r = 0.83) and relative humidity (r = 0.44).

P. capsici and *F. solani* caused pre and post emergence mortality in pot experiments, *P. capsici* was dominant in causing total mortality (58.4 %) while as *F. solani* caused the minimum mortality

(23.2 %).

Soil application with some fungicides, nutrients, antagonists and amendments made under natural conditions at Udheywalla, Jammu during rainy season, 1999 helped in checking the wilt disease significantly. Application of Captan 50 WP was found to be the best treatment in checking the disease which recorded 40 per cent disease control. Next best treatments were Bavistin 50 WP and potassium (K) which recorded 35 per cent disease control in each case. However, these treatments were not economically viable for the management of the disease as none of them could contain the plant mortality below 60 per cent.

From the present studies it is concluded that chilli wilt has emerged as major disease in all the chilli growing areas of Jammu region ranging from 8.33 to 80.00 per cent.

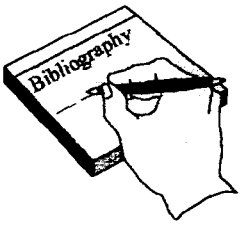
Phytophthora capsici and *Fusarium solani* have been found associated with the disease.

P. capsici was predominant in all the areas surveyed.

The chilli wilt appeared at its peak during rainy season.

Though the treatments viz., Captan 50 WP, Bavistin 50 WP, N (urea), K (MOP), fungal antagonists (*Trichoderma viride* and *Gliocladium virens*), lime and poultry manure reduced the wilt incidence significantly yet they could not contain the plant mortality below 60 per cent.

Overdependence on single method of disease control particularly on fungicides is not ecologically sound, owing to its adverse side effects on various desirable components of chilli field ecosystem. Therefore, disease incidence may however be reduced by integrating ecofriendly means such as soil amendments, nutrient application, antagonists etc. to realising full yield potential of chilli crop.



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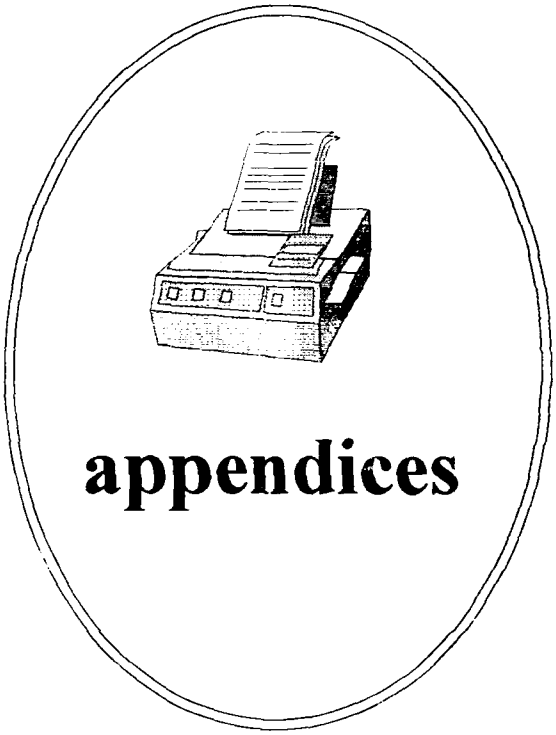
*Original not seen



appendices

Appendix I

Status of chilli wilt (*Capsicum annuum*) indifferent locations of Jammu region during 1999

District/ Blocks	Village	Locations								Mean disease incidence (%)	Disease incidence range (%)
		I	II	III	IV	V	VI	VII	VIII		
Jammu											
Marh	Pounichak	40.00	46.60	22.72	8.33	78.90	58.33	22.85	70.00	43.46	8.33 - 78.90
	Nagbani	66.66	20.66	50.00	74.28	80.00	-	-	-	58.32	20.66 - 80.00
	Halqua	64.00	42.85	62.40	20.00	54.16	-	-	-	48.68	20.00 - 62.40
	Marh	31.42	25.00	58.33	72.40	45.83	66.78	48.92	39.20	48.40	25.00 - 72.40
Akhnoor	Ghanderwan	22.40	56.45	70.40	62.40	28.30	57.20	-	-	49.52	22.40 - 70.40
	Tandikali	22.50	58.33	33.33	61.01	55.55	64.00	-	-	49.12	22.50 - 64.00
	Tanda	17.50	23.50	56.45	49.89	41.86	28.30	66.67	60.21	43.04	23.50 - 66.67
R.S. Pura	Kalyana	10.45	33.60	57.60	31.60	10.80	57.20	62.40	-	37.66	10.45 - 62.40
	Arnia	23.60	31.20	54.80	62.80	49.93	63.71	33.24	-	45.61	23.60 - 63.71
	Rathiana	22.20	46.60	66.80	58.72	31.42	-	-	-	45.14	22.20 - 66.80
Vijaypur	Sarore	16.07	32.25	33.60	46.86	43.76	32.33	17.64	53.41	34.48	16.07 - 53.41
	Yakhtarore	18.98	26.40	34.05	63.42	44.87	55.38	-	-	40.01	18.98 - 63.42
	Patelimorh	23.20	31.12	28.77	39.33	41.23	57.52	-	-	36.86	23.20 - 57.52
Udhampur											
Tikri	Tikri	26.40	34.35	42.78	55.38	67.92	49.24	-	-	46.01	26.40 - 67.92
	Sunderni	53.33	63.33	45.00	28.80	46.00	66.66	-	-	50.52	28.80 - 66.66
	Chamba	46.00	55.33	53.30	55.00	21.60	50.27	-	-	46.91	21.60 - 55.33
Chenani	Chenani	56.50	54.26	71.72	62.50	53.08	65.00	32.42	67.92	57.92	32.42 - 71.72

Appendix I (contd.)

Status of chilli wilt (*Capsicum annuum*) indifferent locations of Jammu region during 1999

District/ Blocks	Village	Locations								Mean disease incidence (%)	Disease incidence range (%)
		I	II	III	IV	V	VI	VII	VIII		
Reasi	Poni	63.50	62.50	20.80	47.50	15.44	61.37	58.29	61.78	48.89	15.44 - 63.50
	Gun	21.45	63.75	44.87	34.05	52.50	63.33	-	-	46.65	21.45 - 63.75
	Agarbhalian	17.25	65.64	3055	36.15	42.78	62.83	18.24	50.08	40.44	17.25 - 65.64
	Reasi	52.50	38.27	72.72	31.25	66.50	22.89	49.05	46.86	47.50	22.89 - 72.72
Rajouri											
Rajouri	Bathoni	62.84	62.00	50.49	11.60	24.57	47.33	36.50	32.30	40.95	11.60 - 62.84
	Muradpur	10.00	20.80	37.33	40.80	44.40	40.00	48.80	-	34.59	10.00 - 48.80
	Dhangri	38.40	37.60	45.33	37.20	13.50	22.40	33.20	-	32.51	13.50 - 45.33
	Kheroa	34.80	38.40	34.40	17.60	19.20	33.85	42.14	4342	32.97	17.60 - 43.42
Nowshera	Sunderbani	47.33	14.66	17.60	15.55	46.88	41.81	26.60	-	30.06	14.66 - 47.33
	Nowshera	48.66	24.44	16.74	41.20	19.48	44.40	40.00	-	33.56	16.74 - 48.66
Kathua											
Kathua	Chakdesa	42.80	39.71	12.73	43.60	18.38	43.11	43.60	-	34.84	12.73 - 43.60
	Jakber	18.66	23.33	40.85	46.80	38.18	30.55	48.46	-	35.97	18.66 - 48.66
	Khakyal	12.35	23.58	13.71	43.20	37.50	45.29	48.33	-	31.99	12.35 - 48.33
Bhilawar	Phinter	44.00	40.85	15.50	35.70	39.42	21.60	-	-	32.84	15.50 - 44.00
	Dungara	12.77	13.11	43.20	19.20	36.15	40.80	43.60	-	29.83	12.77 - 43.60
	Dewal	19.20	36.15	45.29	23.58	43.20	-	-	-	33.48	19.20 - 45.29
Average										**41.47**	**8.33 - 80.00**

Appendix II

Analysis of variance for wilt incidence during 1999

Sorce of variation	d.f	Sum of squares	Mean sum of squares	Fcall.
Treatment	8	4208.72	526.09	28.13**
Block	3	848.74	282.91	
Error	24	448.96	18.70	

SE(d)± 3.06
CD (p = 0 05) 6.30